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Effect of farmland trees *Terminalia brownie* and *Vitex doniana* on soil physicochemical properties and maize yield

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This study was focused on evaluating maize yield and soil fertility improvement under the canopy of retained farmland tree species, particularly *Terminalia brownie* and *Vitex doniana* in parkland Agroforestry. The study area was suitable for maize cropping and mature tree species exist in the area. The result showed that Maize yield decreased the understory of studied tee species compared with open field due to the shading effect on crop performance. On the other hand, soil fertility parameters near tree trunk/under canopy cover showed improvement in terms of soil pH level, total nitrogen, phosphorus, and organic carbon obtained except available potassium. *Terminalia brownie* and *Vitex doniana* farmland trees supply quantified amounts of important nutrients through the addition of organic biomass and modifying microclimate for ease of decomposition, so resource poor farmers had shortage to replenishing the soils with mineral fertilizer application. The present study concluded that multipurpose agroforestry trees have the potential to improved soil fertility in farming system and these could be promoted in smallholder farms by using appropriate above ground management options.

Key words: *agroforestry, canopy cover, farmland trees, maize, soil fertility*

INTRODUCTION

Low soil productivity is the foremost challenge for agricultural production that affects smallholder farmers the tropical conditions (Young, 1997). Farmland trees have the potential to improve soil fertility (Zebene & Agren, 2007). Soil fertility improvement by trees is due to the increase of organic inputs and fixing nitrogen by legume tree species. The research carried out on farmland tree species show that there is declining of fertility status from a tree trunk to the edge of its crown and/ open field (Gole et al., 2008; Jiregna et al., 2005; Zebene, 2008). Land productivity and soil fertility decreasing are increasingly being observed as serious problems hindering agricultural production and livelihood of the communities in tropical Africa. The decline of soil fertility is the most common, and main issue on yields of maize (*Zea mays* L.), and sustainable production of maize-based farming systems in southern and eastern Africa. Conventional agriculture without using organic amendments and nutrients resulted in the degradation of cultivated soils that bear a series challenge for crop production in farming systems (Scherr, 1991).

Parkland Agroforestry trees grown on farmlands describes a large part of the Ethiopian agricultural landscape and it is the widespread land use system in the semi-arid and sub-humid zones the country (Kindeya, 2004). Trees enhance nutrient balance of soils by reducing nutrient losses from erosion and leaching and by increasing nutrient inputs through fixing nitrogen and increasing biological activities by providing decomposable biomass, and a suitable microclimate (Aweto & Dikinya, 2003). Microclimate modifications and changes in floral and faunal populations (Shukla, 2009). Yield enhancement and soil fertility improvement were obtained under scattered tree canopies. The grain yields of sorghum understory of *Cordia africana* tree increased by 14% more than those grown on farmlands without trees in Burkina Faso (Boffa, 2000).

Agroforestry practices promote the efficient use of resources and other production and protection services. This land use system aims to reduce risks and diversify productivity by providing socioeconomic and ecological services to individual farmers and their communities. The practice of integrating desirable multifunctional tree species into the agricultural landscape play important role in reducing environmental degradation, and soil erosion, improving water infiltration through SOM, and restoring soil fertility (biological, physical, and chemical property). This boosts agricultural production through soil fertility improvement. Despite their direct and indirect benefit, the increasing human population and conventional agriculture expansion adversely affect the diversity of multipurpose tree species on the farms aggravating land degradation and loss of soil nutrients. Therefore, to promote multipurpose agroforestry trees' importance on farmland, their suitability with field managed crops on specific site conditions needs to be considered and careful integration of such species is important for sustainable production, maintaining ecological stability, and reducing wood products shortage. Detail investigation is vital to reveal the annual crop yield and soil physicochemical properties in farmland trees and in order to encourage landowners toward retaining and integrating of trees in farming systems. The objectives of this study mainly focused on evaluating the yielding potential of maize crop under the canopy of on-farm trees with radial projection from tree trunk to open field, and to know on-farm trees' effect on soil physicochemical properties under the zonal compartment of canopy cover in comparison with open field.

MATERIALS AND METHODS

Description of study Area

The present study was conducted from March 2019 to August 2021 in Alega and Kure kebele in Debub Ari district, Southern Ethiopia. The selected study sites receive bi-modal rainfall with the shorter rainy season from March-May, which is important for crop production, and the longest rainy period starts from August- November. Geographically the study area located in 36041' E and 05050' N. Biophysically, the study site described with altitudinal range of 1435m–2400 m above sea level; annual rainfall is 1304.4 ± 250.7 mm. The annual mean maximum and minimum temperatures are 27.7± 1.4°C and16.3 ± 0.9°C from Jinka station. The communities practiced both crop cultivation and animal raring to sustain their livelihood.

Treatment and Experimental design

The study was conducted in farmers' fields in the Debub Ari district. The experiment followed horizontal zonation based on canopy cover distances from tree trunk of *Terminalia brownie* and *Vitex doniana* in isolated stands of those selected species. The tree stands selected from farmers' field were not interfered with other tree species. Farmland (scattered) tree species selected for present study were four to each species and used as a replication. Trees with uniform agro ecological location were selected based on similar DBH and canopy covering status. The field experiment was done in three distances from tree trunk to outside canopy cover in four directions to estimate tree-crop interference. The distances used as a treatment for the selected tree species were tree trunk to half of the canopy radius, at the edge of the canopy and away from tree interference. These described as Radial 1 projected from tree trunk to half of the canopy, Radial 2- projected from half of the canopy cover to edge of the canopy and Radial 3 it projected from the edge to double of canopy radius. Soil samples collected from each designed distances with depths of 0-20cm and 20-40cm.

Tree selection criteria used in parkland agroforestry for soil fertility and crop production

Four tree stands belong to each species, having uniform canopy cover and DBH size, and grown on similar site conditions were selected and the canopy coverage of each tree was divided into three canopy distances described by Hailu et al., (2001). The tree species selection based on tree diameter at breast height, canopy coverage and grown in similar agro ecological condition. These parameters are used as primary criteria for retained tree species on agricultural landscape. The canopy of *Terminalia brownii* characterized as densely shady, somewhat layered, foliage drooping (12m canopy cover) and with 130.2cm of DBH(diameter breast height) size. Whereas *Vitex doniana* described as heavy rounded crown with an average canopy diameter of 12m and DBH(diameter breast height) size of 125.6cm. These tree species dominantly retained/ managed on farmland and limited management options exercised to reduce the tree interference on cultivated annual crops.

Planting of maize

After selecting the experimental tree species, land preparation and field layout was done for planting maize (BH140) in field level under designed experimental tree plots. Maize is widely cultivated cereal crop in the study area in the farming system. Planting space for maize crop was 75cm*30cm between row and plant, respectively. All the required management and agronomic practices carried out uniformly in each experimental plot.

Data collection

Composite soil sample was collected from each tree species following the designed distances with respecting to soil depths (0–20 cm and 20-40cm). Retained *Terminalia brownie* and *Vitex doniana* trees scattered on farmland having uniform canopy and similar DBH size selected and these parameters were collected accordingly. Maize crop agronomic parameters were collected to support growth performance and yielding potential under canopy and outside tree interference.

Data analysis

The analysis of variance (ANOVA) compared using the least significant difference (LSD) at 5% significance level by means of SAS statistical software (version 9.0) and for data organization Microsoft excel sheet was used.

RESULTS AND DISCUSSION

Maize Crop performance under *Terminalia brownie* and *Vitex doniana* farmland trees

The current study was conducted in Debub Ari district, Southern Ethiopia, on retained farmland trees in Parkland agroforestry practice to evaluate crop yield and soil fertility status under tree canopy interference in comparison with open field. The experimentation was carried out from 2019 to 2021 on dominant farmland trees, namely *Terminalia brownie* and *Vitex doniana* species. Insuring sustainable farming is important through retention of desirable farmland tree species in the form of agroforestry practice, ecologically promoted methods and practices that are economically viable, environmentally sound and protect community well-being. Maize crop yield presented on table (1, 2,3,4,5 and 6) for each tree species in each growing year under the canopy projection. From the result, maize yield showed increasing trend from tree trunk to outside canopies of both tree species; this might be due to shade effect and type the crop grown under canopy cover. This result disagree with the findings reported by ICRAF (2009) showed that maize yields higher under the canopy of *Faidherbia albida (*4.1 ton ha^{-1}) than outside (1.3 ton ha$^{-1)}$ in Zambia. According to the findings of Kater et al., (1992) and Kessler (1992), who reported that shading of *Parkia biglobossa* and *Vitellaria paradoxa* trees reduced yield of sorghum and millet in the Sahel region. The effect observed on crop yield reduction directly associated with the heavy canopy cover characteristics of the studied tree species in the area. This revealed that each tree species has its own physiological and genetic variability difference on the performance of cultivated crops under canopy cover.

Table 1. Analyzed maize yield and yield components data (first year) under the canopy of *Terminalia brownie* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	2.16^{b}	31.85	2.2^{b}	16.83	17.50
At the edge of the canopy cover (R2)	2.28^{b}	33.18	3.11^{b}	16.00	17.91
Outside the canopy cover (R3)	2.56^{a}	33.64	4.66^{a}	16.42	17.92
LSD	0.27	NS	1.42	NS	NS
CV(%)	5.61	8.79	19.57	7.08	7.08

Where:- CV(coefficient of variation), GY(grain yield), HSW(hundred seed weight), LSD(least significant difference), Ph (plant height)

Table 2. Analyzed maize yield and yield component data (second year) under the canopy of *Terminalia brownie* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	2.63	31.86	5.4	16.83	17.50
At the edge of the canopy cover (R2)	2.66^{b}	33.13	5.87	16.00	17.91
Outside the canopy cover (R3)	2.58	33.74	6.75	16.42	17.92

LSD	NS	NS	NS	NS	NS
CV (%)	8.26	8.79	22.46	7.08	7.08

Where: - CV (coefficient of variation), GY (grain yield), HSW(hundred seed weight), LSD(least significant difference), Ph (plant height)

Table 3. Analyzed maize yield and yield component data (3rd year) under the canopy of *Terminalia brownie* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	1.83^{b}	33.13^{ab}	3.34^{b}	16.83	17.50
At the edge of the canopy cover (R2)	1.95^{b}	32.58^{b}	4.79^{a}	16.00	17.91
Outside the canopy cover (R3)	2.25^{a}	35.29^{a}	5.34^{a}	16.42	17.92
LSD	0.36	2.52	0.70	NS	NS
CV	5.61	8.79	18.84	7.08	7.08

Where: - CV (coefficient of variation), GY (grain yield), HSW (hundred seed weight), LSD (least significant difference), Ph (plant height)

Table 4. Combined analyses of maize yield under canopy of *Terminalia brownie* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	2.04	33.36	3.58^{c}	16.83	17.50
At the edge of the canopy (R2)	2.15	33.13	4.65^{b}	16.00	17.91
Outside the canopy radius(R3)	2.32	44.57	5.42^{a}	16.42	17.92
LSD	NS	NS	0.54	NS	NS
CV	12.37	41.57	11.30	7.08	7.08

Where:- CV(coefficient of variation), GY(grain yield), HSW(hundred seed weight), LSD(least significant difference), Ph (plant height)

Table 5. Analyzed maize yield and yield component data (1st year) under the canopy of *Vitex doniana* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	2.00	31.36	1.74^{b}	14.42^{b}	16.83^{b}
At the edge of the canopy (R2)	2.19	33.4	3.51^{a}	16.00^{a}	18.50^{a}
Outside the canopy radius(R3)	2.26	33.74	4.32^{a}	15.83^{a}	17.25^{ab}
LSD	NS	NS	1.48	1.02	1.38
CV(%)	8.67	8.79	21.28	7.91	9.46

Where:- CV(coefficient of variation), GY(grain yield), HSW(hundred seed weight), LSD(least significant difference), Ph (plant height)

Table 6. Analyzed maize yield and yield component data (2 year) under the canopy of *Vitex doniana* in comparison with open field

Tree canopy cover with three distances	Measured parameters				
	Ph(m)	HSW(g)	GYtha^{-1}	Cd(cm)	L(cm)
Tree trunk to half of canopy radius(R1)	1.57^{b}	31.89	3.48^{c}	14.42^{b}	16.83^{b}
At the edge of the canopy (R2)	1.90^{a}	34.32	5.10^{b}	16.00^{a}	18.50^{a}
Outside the canopy radius(R3)	1.86^{a}	59.19	6.09^{a}	15.83^{a}	17.25^{ab}
LSD	0.17	NS	0.64	1.02	1.38
CV (%)	11.63	11.96	15.75	7.91	9.46

Where: - CV (coefficient of variation), GY (grain yield), HSW (hundred seed weight), LSD (least significant difference), Ph (plant height)

Soil fertility status under *Terminalia brownie* and *Vitex doniana* farmland trees

The result obtained in soil fertility parameters showed decreasing trend from tree trunk to the edge/outside canopy cover. Retention of important trees on farmland increases the potential of storing carbon and other beneficial nutrients to improve soil productivity. The result revealed that most of the soil parameters showed a decreasing trend from tree trunk to open field/ out of canopy cover except available potassium. The same result was obtained from the studies done on farmland tree species indicating that there is declining of soil fertility status from a tree trunk to the edge of its crown or beyond (Gole et al., 2008; Jiregna et al., 2005; Zebene , 2008). This indicates that the soil under the canopy is more fertile than open field, due to the addition of organic biomass/litter fall and root decay. Abundance of multipurpose trees on farms increase soil organic carbon (SOC) which is an important description of soil fertility (Konare *et al*., 2010). Better decomposition and nutrient releasing have been examined near to the canopy of tree cover; this is due to improved rate of carbon to nitrogen ratio and the microclimate suitability for decomposing agents. Trees on agricultural landscape are important for farmers because they contribute in livelihood improvement (Bayala et al., 2002). The findings of this study in line with the results of Bridget et al., (2012), who reported the effects of *F. albida* showed differences in the soil fertility parameters like pH, total nitrogen, organic carbon, phosphorus, and potassium at increasing radial distance from the tree trunk in Zambia.

Table 7. Analyzed soil nutrient status under *Terminalia* with respect to canopy projection distance and sampling depths before maize planting

Soil parameters	Soil depth(0-20cm) under each radial distance			Soil depth(21-40cm) under each radial distance		
	Radial one	Radial two	Radial three	Radial one	Radial two	Radial three
pH	6.63	6.57	6.50	6.63	6.57	6.49
%OC	3.01	2.84	2.54	2.46	2.39	1.82
%OM	5.18	4.90	4.37	4.23	4.12	3.14
%TN	0.27	0.25	0.29	0.26	0.28	0.23
C:N	13.33	11.25	9.16	10.33	8.78	8.063
av. Pppm	5.10	3.49	4.03	4.10	2.47	2.005
av. Kppm	29.83	58.34	80.87	52.43	44.37	32.93

Table 8. Pearson Correlation result of soil parameters, canopy distance and grain yield under *Terminalia*

	Canopy cover	pH	%OC	% OM	%TN	C:N	Pppm	Kppm	GY
canopy cover	1								
pH	-0.225	1							
OC	-0.350	-0.203	1						
OM	-0.349	-0.201	1.000	1					
TN	-0.049	0.211	-0.027	-0.026	1				
C:N	-0.335	-0.230	0.713	0.712	-0.655	1			
Pppm	-0.233	-0.223	0.393	0.395	-0.005	0.282	1		
Kppm	0.210	-0.425	0.067	0.065	-0.037	0.044	0.103	1	
GY	0.826	-0.193	-0.372	-0.372	0.024	-0.351	-0.080	0.132	1

Table 9. Analyzed soil nutrient status under *Vitex doniana* with respect to canopy projection distance and sampling depths before maize planting

Soil parameters	Soil depth(0-20cm) under each radial distance			Soil depth(21-40cm) under each radial distance		
	Radial one	Radial two	Radial three	Radial one	Radial two	Radial three
pH	6.82	6.64	6.49	6.77	6.63	6.40
%OC	3.77	3.71	3.53	2.65	3.09	2.81
%OM	6.50	6.39	6.08	4.56	5.32	4.84
%TN	0.30	0.28	0.26	0.23	0.22	0.217
C:N	12.738	13.193	14.38	11.80	14.46	13.348
av. Pppm	23.06	22.58	18.91	22.79	22.80	28.36
av. Kppm	42.33	52.09	38.12	60.68	55.62	40.43

Table 10. Pearson Correlation result of soil parameters, canopy distance and grain yield under *Vitex doniana*

	Canopy cover	pH	OC	OM	TN	C:N	Pppm	Kppm	GY
Canopy cover	1								
pH	-0.415	1							
OC	-0.026	-0.089	1						
OM	-0.025	-0.090	1.000	1					
TN	-0.227	-0.324	0.549	0.550	1				
C:N	0.238	0.298	0.364	0.363	-0.568	1			
Pppm	0.030	-0.510	0.149	0.149	0.207	-0.086	1		
Kppm	-0.206	0.422	-0.273	-0.273	-0.505	0.321	-0.454	1	
GY	0.816	0.029	-0.157	-0.157	-0.554	0.475	-0.237	0.121	1

The correlation result of soil parameters, canopy diameter and grain yield in both tree species showed the same trend. With grain yield increases from tree trunk to outside the canopy cover, while soil parameters were showed decreasing trend. However, the tree component interferes with annual crops for resource competition. Soil parameters negatively correlated with the tree canopy distance increase from trunk to outside the canopy cover. This showed that near to tree trunk or under canopy cover, soil fertility status improved through addition of organic biomass in terms of litter fall and enhanced rate of decomposition. The result in agreement with the findings reported (Sanchez, 2001; Su et al., 2004). Farmland tree species contribute high level of benefits in protection and production functions.

CONCLUSION

Retained farmland trees play significant role in improving production and productivity by diversifying agricultural products. Particularly, both selected tree species in the study area are dominant on farmlands and it requires desirable management options specifically above ground tree silvicultural practice to enhance the land use system. From the results of the study, it is important to recognize that the soil nutrient status showed a decreasing trend as the distance increase from tree trunk to outside canopy cover, while in maize yield the reverse trend was observed. Further research is required in the area of tree canopy management to reduce aboveground tree-crop interference and enhancing the production potential of integrated crop and selection of appropriate crop type should be important.

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AUTHOR CONTRIBUTIONS

Belayneh Lemage set-up the experiments; Belayneh Lemage carried out the experiments in their respective locations. Belayneh Lemage and Yenesew Anmaw analyzed the data and developed the manuscript. Belayneh Lemage contributed in data analysis and manuscript review.

COMPETING INTERESTS

The authors have declared that no conflict of interest exists.

ETHICS APPROVAL

Not applicable

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