

On-Farm Management of *Persea Americana* (Avocado) and its Influence on Some Soil Physicochemical Properties and Maize Yield: A Case of Damot Gale, South Ethiopia

MESFIN KASSA, Zebene Asfaw (Ph D), Sheleme Beyene (Ph D),
Hawassa University, College of Agriculture, P.O. Box 5, Hawassa, Ethiopia

ABSTRACT

On-farm trees are known to contribute to biophysical and economical sustainability at farm and landscape levels. This study assessed the contribution of on-farm avocado tree on some selected soil fertility parameters and maize yield, and explored farmers' local knowledge, the influence of avocado on maize production and soil fertility at Aro-Wagera, Damot Gale, Southern Ethiopia. Soil samples were collected from under the canopies of four avocado trees at four radial distances (0.5-1, 2-2.5, 4.5-5 and 16m) away from the trunk and at two depths (0 – 15cm and 15 – 40cm) 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 both depths and all radial distances. There was no significant difference in the textural classes between samples taken from open field and under the canopy. The bulk density showed increasing trend with increasing depths and positively and significantly correlated with distances from the tree trunk to open area. Chemical properties including, available P, total N, organic carbon, soil pH, and CEC had decreasing tendency with increasing depths and four radial distances from the tree trunk. The local knowledge was gathered by involving seven KI, 35% of HHs from the total of 206 HHs over the studied area. Random sampling technique was used to selected the HHs from each of the three wealth categories. Both informal and formal surveys were employed. Households with different wealth categories have different strategies in managing avocado tree grown at different niches. The interviewed farmers indicated that avocado tree have negative influence on maize production. The farmers view is supported by quantitative analysis. Tree-maize interaction showed reduction of maize yield under the tree canopy compared with open area. On the hand, the farmers' perception that avocado tree depletes soil nutrient was not supported by soil analyzed. In conclusion, on-farm avocado tree influence soil nutrients grown on ic Nitosols (which is equivalent to Ultisols) in research site do not influence fertility of soil under their canopy. Indeed, the tree can be regarded as parkland agroforestry trees to integrate them with maize production to enhance the sustainability of soil fertility.

Key words: Local knowledge, Income, Parkland , Soil fertility

1. INTRODUCTION

Agriculture is the mainstay of Ethiopian economy and the performance of the sector is directly correlated with overall economic development of the country. The sector accounts for more than half of the gross domestic product, 90 percent of the export earnings and 80 percent of employment (ESRDF, 2005). In addition, Ethiopia has adapted a long-term development strategy of Agricultural Development-Led Industrialization, more specifically, the smallholders' agriculture is the primary stimulus to generate employment and income, reduce poverty, promote industrialization and ensure a dynamic and self-sustaining growth (ESRDF, 2005). High population pressure and scarcity of arable land compelled farmers to grow two or more crops on the same pieces of land. In southern Ethiopian, the population pressure is high (> 400 persons/km²), with average land holding of less than 0.5 hectares (Tilahun et al., 2001). On-farm tree cultivation (agroforestry practice) is one of such a type of land use. Use of agroforestry practice in the Southern Region is thus, attributed to high density of population and managed both for productive and protective purposes.

One of the predominant forms of agroforestry practice is the scattered tree system commonly known as parkland agroforestry practice (Rao et al., 1998). The best known practices are those involving *Faidherbia albida*, prevalent throughout the sub-Saharan Africa (Poschen, 1986; Kamara and Haque, 1992; Laike, 1992), *Croton macrostachyus* (Jiregna et al., 2005), *Milletia ferruginea* and *Cordia africana* (Tadesse et al., 2000; Zebene, 2003). Scattered trees have been recognized to represent islands of improved soil conditions within landscapes. These trees also provide products that can be marketed for cash and offer several services that assist farm households to diversify their productions (Rocheleau et al., 1988; Kessler, 1992). Parkland agroforestry practices are the most conspicuous traditional practices in low and high lands of Ethiopia, in which farmers deliberately preserve several native tree species for a variety of uses (Zebene, 2003; Tesfaye, 2005). In this research, contribution to income and influences on soil fertility of avocado parkland agroforestry trees managed by local knowledge is considered. In the absence scientifically based research information, understanding the available farmers' knowledge is important for future improvement of the traditional agroforestry practices (Zebene, 2003). Understanding the influence of the trees on soil fertility and crop yield will also help to focus

efforts in developing suitable management and future research direction. From the Southern Ethiopia, Tadesse et al (2000) and Zebene (2003) reported improved soil properties under the canopies of Cordial africana and Milleitia ferrugenia trees as compared to adjacent open plots. With regard to our understanding of avocado based parkland practice, under different ecological and cultural settings in Ethiopia is very much limited. This is also true for avocado parkland trees are managed in maize fields in Aro-Wagera, in Damot Gale. Hence, there is a need to improve our understanding on the influence scattered avocado trees on soil physicochemical properties and crop yield in Damot Gale.

In Damot Gale, avocado trees are managed as one of the components of parkland agroforestry, boundry, homegarden, and live fence type of agroforestry practices. Although avocado trees have been, and are currently, dominantly used at the study site, there is no study to date that has investigated and documented how farmers manage them and view them. Furthermore, there is no scientific information on its influence on physicochemical propertes of soils and socio-economic contributions. In order to enhance our understanding, the study was initiated with the following objectives

- ❖ To assess the influence of avocado tree on the selected physicochemical properties of the soil
- ❖ To identify farmers' perception on soil fertility and management practice of the avocado tree
- ❖ To assess the influence of avocado tree on maize yield and its contribution to income

2. MATERIALS AND METHODS

2.1. Description of the Study Site

This study was carried out at Aro-Wogera peasant association (PA) in Damot Gale district, in the Wolaita zone of the Southern Nations Nationalities and Peoples Regional State. It is located at 372 km South of Addis Ababa, 134 km northwest of Hawassa and 5 km from Bodditi town. Aro-Wogera (PA) is geographically found between $6^{\circ} 89' -7^{\circ} 12' N$ and $37^{\circ} 75' -38^{\circ} 0' E$. The nearest meteorology station is located at five km from study site. The long-term weather information shows average annual rainfall of 952-1589 mm with bimodal distribution pattern giving rise to two distinct seasons. The short rains (belg season) is between March to May, whereas the heavy summer rains (meher season) is between June to October, with a peak in August. The mean annual temperature is 19 °C.

2.2 Sampling Methods

2.1.1. Informal survey

Informal interview were carried out at PA level using Rapid Rural appaisal (RRA) techniques. To explore local knowledge on crop production, avocado management and soil fertility, key informant (KI) were interviewed. In this study, KI defined as persons who have lived in the village for more than 35 years and are knowledgeable about local community, agrofoerstry and soil fertility management. They were selected by farmers who were choosen by snowball. The most frequently appeared seven KIs were selected to involve in two activities of the research. Firstly, they were asked to catagorize local farmers into three wealth classes. Secondly, they were used to generate information related to mangement of soil fertility, avocado tree and impact of trees on crops and soil fertility.

2.1.2. Formal survey

Formal survey was administered to a sample of 71 (34% of the total HHs) HHs from the 206 HHs presented in the PA. The aim of HHs interview was to generate and verify qualitative data collected through KI interview.

Table 6. Wealth categories of households in the Aro-Wogera, Damot Gale during 2009

<i>Socio-economic group</i>	<i>No of HHs Per PA</i>	<i>Sample size</i>	Percent
Poor	90	31	44
Medium	78	27	38
Rich	38	13	18
Total	206	71	100

2.2. Tree sampling and data collection

From the selected 71 HHs, farms having relatively similar avocado trees from maize fields were identified. Farmers having avocado trees of the same age were identified and four sample trees selected. Field was defined as a unit of land with distinct management, for maize cultivation. Sample trees were selected based on their similarity in terms of age, diameter at breast height (DBH), height, and crown diameter (CD) (Table 2). Tree height was defined as the vertical distance from the base of the tree to the upper most tips, DBH was measured at 1.3m height by caliper and/or diameter tape. Crown diameter was measured by projecting the edge of the crown

to the ground. The vertical projections were measured in four directions (roughly South–North, East–West) by clinometers and each spot was pegged. Then two distance South–North, East–West were measured on the ground by meter tape. The diameter of two measurements was average to representative CD.

Table 7. Description of the avocado trees sample

No of trees	Age(years)	Height (m)	DBH (cm)	CD (m) Remark
1	23	11.2	42.3	10.80
2	21	10.9	38.7	10.05
3	25	13.2	40.8	13.0
4	22	11.8	31.2	11.50

2.3. Crop yields

Maize yield was harvested from 1m² area from compass directions (South–North, East–West) and distances 0.5-1 (near to trunk), 2-2.5 (mid), 4.5-5 (edge) and 16m from the base of the tree trunk. From each distance, yield was collected and mixed from four compass directions. The mixed samples were used as composite sample. The biomass of maize was taken from the same direction and plot size and air-dried and their dry matter was recorded.

2.4. Soil sampling and analysis

Soil samples were collected from under the canopies of four avocado trees at four radial distances (0.5-1, 2-2.5, 4.5-5 and 16m) away from the trunk and two depths (0 – 15cm and 15 – 40cm) from the surface. The 16m distance represented sampling point, which was assumed to be free from tree influence, and thus used as control. The soil samples at each sampling spots at the two depths were collected from the four compass directions. Soil samples taken from the same spot distances in the four radial directions were combined to make composite samples. Thus, a total of 32 (4 distance x 4 trees x 2 depths) 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 and Taye, 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). Cation exchange capacity (CEC) was determined following 1N ammonium acetate method at pH 7 (Chapman, 1965), and exchangeable Ca and Mg were determined using EDTA titration, whereas exchangeable K and Na were determined from the same extraction with flame photometry. Soil texture was determined by using Bouyoucos Hydrometer method. Bulk density was determined by core method (Blake, 1965).

2.5 Statistical Analysis

The significant different among of selected physicochemical properties for distance from the base were analyzed of variance (ANOVA) using SAS 1997 software and descriptive statistical analyzed by SPSS 12 Windows 2001.

3. RESULTS AND DISCUSSION

3.1. Farmers' Perception on Avocado Tree

In this study, all interviewed HHs have avocado trees at different niche. They know when and why the avocado trees were introduced to their farm and the Aro-Wogera, Damot Gale (Table 3). The interviewed HHs identified three periods of historical events. Relatively high number of avocado trees were introduced during the period of 1981-1992, the second and 1992-2009, third phase. The reasons mentioned for the increase in number include increased availability of seedling, efficient distribution and supply of seedling in adequate quantities and timely and increased access of marketing. During these periods, second and third phase, highest number of avocado trees were assigned in the order of homegardens > parkland > life fences > boundaries > front yard agroforestry practices (Table 3). These findings are in agreement with the results obtained at Wondo Genet by (Abebe, 2000), whereas the households in the area planted more trees in the homegardens followed by parkland. According to the HHs respondents (83%), household consumption is the major reasons for avocado introduction in the farms include fruit selling, firewood, lumber, shade, constructions, amenity, fodder and

others. HHs also mentioned that that avocado trees managed in homegardens are more productive than parkland field due to intensive soil management and use of organic input. They regard parkland as the most reliable site for food production.

Table 8. Period of introduction avocado tree at different niches at Aro-Wogera, Damot Gale during 2009

phase	Years of introduction	No of tree/h ^a	No of respondent and niche					Socio- economic group			Total HHs
			HG	PK	LF	B	FY	Rich (n=13)	Medium (n=27)	Poor (n=31)	
1	1972-1981	5	32	8	-	-	-	13	20	7	40
2	1982-1992	8	33	13	11	8	6	13	27	31	71
3	1993-2009	10	16	45	3	4	3	13	27	31	71

HG = homegarden, PK = parkland, LF = live fence, B = boundary, FY = front yard

3.2 Soil fertility management

The interviewed HHs have a considerable knowledge on soil fertility management. They select trees that maintain soil fertility. The farmers' view on soil fertility maintenance capability of *Cordia africana* is in line with the work of Zebene (2003) and Tesfaye (2005). Local soil fertility management practices include use of compost, leaf litter from trees, crop residues, and household refuse. The use of leaf litter of trees for soil management at the study site is in line with the work of Eyasu (2002) at Kindo Koysh, in Southern Ethiopia. Soil management strategies of farmers with different social classes were variable. The respondents mentioned that rich farmers have significantly large number of animals and have a continuous supply of organic matter to maintain soil fertility. On the contrary, poor farmers have limited number livestock and their soil is less fertile. These results are in agreement with the observation of Prudence (1993 in Burkino Faso and Machakos of Kenya (Tiffin and Mortimore, 1992).

This result is in agreement with the work of Eyasu (2002) who indicated the use of some of these plants as indicators for soil fertility at Kindo Koysh, Southern Ethiopia. Vigour and colour of crops were mentioned to be used by farmers as indicators of soil fertility. Plants that grow on Arada (fertile) produce vigorous plants, grow fast and early maturing, whereas plants that grow on Lada (infertile) soils are stunted, grow very slowly and late maturing.

3.3 Tree management practices

According to KI and HHS opinion, coppicing, pollarding, pruning and thinning are among the most important tree management practices in use at the study site. Farmers not only have profound knowledge on tree selection that is capable of coppicing and pruning, but also the timing when these activities accomplished. The suitable time for cutting coppice tree is the beginning of May and the end of October. The harvest from coppicing trees is used for firewood, charcoal and other tree product. These findings are in agreement with the work of (Rocheleau et al. 1998; Abebe, 2000; Zebene, 2003). Farmers' technical knowledge of farm trees at the study area is in line with FAO report (FAO, 1985), the work of Poschen (1986) in Hararge, Eastern Ethiopia mentioned.

3.4 Contribution of Tree for Income Generation

The agricultural land use practices in the study area involve a mixed farming system, which includes crop production, animal, and tree planting. Farmers generate income from both agricultural production and off-farm activities. The amount of income generated by avocado trees for three wealth categories is indicated in (Table 4). Rich farmers gain relatively high amount of income. The levels of dependence on tree resources for cash generation tend to be more noticeable for poor HHs than the medium and the rich.

Table 9. Wealth categories as influenced income contribution from tree at Aro-Wogera, Damot Gale.

Socio-economic group	Land hold (ha)	No of trees/ha	Niche					Yield qt/year	Annual income (Birr)
			HG	PK	LF	B	FY		
Rich	0.75	10	2	3	2	1	2	18	2563
Medium	0.25	8	2	3	1	1	1	12	1708
Poor	0.12	4	1	2	0	0	1	7	998

Avocado	pH		OC %		TN %		Avail. P mg kg ⁻¹	
	depth(cm)		depth(cm)		depth(cm)		depth(cm)	
DTB (m)	0-15	15-40	0-15	15-40	0-15	15-40	0-15	15-40
0.5-1	7.00	6.87	2.6	1.4	0.18	0.13	18.90	6.6
2-2.5	7.05	6.92	2.3	1.3	0.16	0.12	16.90	6.5
4.5-5	6.93	6.92	1.8	1.2	0.16	0.12	15.60	6.5
16.0	6.90	6.87	1.6	1.1	0.12	0.11	9.25	6.05
CV (%)	0.79		26.23		12.8		30.62	
LSD _{0.05}	0.18		1.13		0.039		9.25	

3.5 Physicochemical Properties of Soil as Influence by Tree Canopy

The present study revealed that the textural class of the soil was sandy loam at both 0-15 and 15-40 cm depths and there was no significant difference between samples taken from open field and under the canopy (Table 5). The lack of textural class difference between surface and sub surface soils under avocado trees might be attributed to the similarity in parent material from which the soils had originated. The BD of the soil showed increasing tendency from surface to sub surface and for increasing radial distances from avocado trunk (Table 5). The increasing trend of bulk density with soil depth might be attributed to low compaction, and high soil organic inputs including from vesicular-arbuscular mycorrhizal fungi that can bind soil particles into aggregates under the tree than outside resulting in structural stability and desirable pore size distribution (Whiley et al., 2002). The BD was negatively and highly significantly correlated with OC ($r = -0.78^{**}$). Besides, higher amount of OC content under the canopy resulted in lower BD. The organic matter makes soils loose, porous, and well aggregated. The finding was in line with the work of Kamara and Haque (1992) under *Faidherbia albida* and Jiregna et al. (2005) under *Cordia africana* and *Croton macrostachyus*.

The pH (H₂O) values of the samples taken from both layers were neutral according to (Herrera, 2005) there was no significant difference between the depths. Similarly, Dunham (1991) has also showed that neutral pH values under the canopies of *Faidherbia albida* and *Kigelia africana* in Zimbabwe. The Organic carbon (OC) contents of the soil showed increasing tendency from surface to sub surface and radial distances from avocado trunk. The OC values were within the range of moderate to high according to (Herrera, 2005). The values of OC were highly positively correlated with TN, Av.P, CEC and soil pH, ($r=0.99^{***}$, $r=0.97^{**}$, $r=0.63^{**}$) and ($r=0.89^{**}$), respectively. The decrease in OC content in maize field without tree might be due to intensive cultivation of annual crops. This is in agreement with the observation of Solomon et al. (2002) who indicated intensive cultivation of maize the depletions of OC concentration of soil, from Southern Ethiopia, to traditional ox plowing for 25 years. The Total nitrogen content of the soils ranged from 0.12 to 0.18% and 0.11 to 0.13% for depths 0-15cm and 15-40cm, respectively. The finding is in line with the work of Tadesse et al. (2000) and Zebene (2003) who reported higher TN content under *Milletia ferruginea* and *Cordia africana* trees canopies than open field in Southern Ethiopia

Table 10. Soil pH, OC, total N, Available P as influenced by tree canopy and distance from tree trunk at Aro-Wogera, Damot Gale.

The available phosphorous (Av.P) contents ranged from 9.25 to 18.9 mg kg⁻¹ and 6.05 to 6.5 mg kg⁻¹ in the 0-15cm and 15-40cm soil depths, respectively. According to (Herrera, 2005) categorized available P as very low. The Av.P content decreased with depth and radial distance from tree trunk. The highest content of Av.P under canopy is attributed to accumulation of organic matter. This result was in agreement with that of Kessler (1992) who reported higher available P under *Parkia biglobosa* tree canopies than the control plots. Belsky et al. (1993) has also reported significantly higher available P in soils under tree than away from tree canopy. Similarly, Kamara and Haque (1992) reported higher level of available P under *Faidherbia albida* canopy. The Cation exchange capacity (CEC) values of soils ranged 27.40 to 29.1 cmol/kg and 25.35 to 28.95 cmol/kg the depths 0-15cm and 15-40cm, respectively. The CEC values could be classified as high according to Landon (1991). This is in agreement with Sharma and Gupta (1989) who reported higher CEC values under *Acacia tortilis* tree than open areas.

Table 11. Cation exchange capacity and percent base saturation as influenced by tree canopy and distance from trunk at Aro-Wogera, Damot Gale.

Avocado	CEC (cmol/kg)		PBS%	
	Soil depth(cm)		Soil depth(cm)	
DTB (m)	0-15	15-40	0-15	15-40
0.5-1	29.10	28.95	44.13	38.94
2-2.5	27.50	26.35	41.09	37.34
4.5-5	27.41	25.40	41.08	34.63
16.0	27.40	25.35	40.26	32.90
CV (%)	4.12		4.03	
LSD _{0.05}	1.29		3.52	

Exchangeable cations showed decreasing trend with increasing depth and distance from tree trunk which might be due to organic matter deposition under canopy of tree and increasing biological activity that enhance organic matter decomposition and subsequent mineralization. The exchangeable cations (Ca, Mg, Na) were no significant difference under the tree canopy than open areas. This is contrast with that of Buderson et al. (1995) who reported higher exchangeable K, Ca and Mg beneath tree crowns at several sites in Malawi. Similarly, Drjkstra and Smits (2002) higher exchangeable cations *Dipterocarpus obtusifolius* and *Samanea saman* trees canopies as compared to the open areas. The percent base saturation (PBS) values of soil showed decreasing trend with increasing depth and radical distance from tree trunk. This was in agreement with Ischei and Muoghalu (1992) who reported medium value PBS of under the canopy of *Parkia biglobosa* tree in Nigeria.

3.6 Effect of Avocado on Maize Yields

Avocado and maize are the major component in parkland agroforestry practices at the study area. Avocado interacts or competes when it grows in close proximity to maize. In avocado and maize interaction, both maize yield and biomass showed increasing trends with increasing radial distance from trunk. The interaction effects considered which was partitioned influence of soil chemical and physical changes and competition. In avocado and maize interaction light affect maize yield under the tree canopy. Similarly, Rocheleau et al. (1988) reported higher maize yield improvement under the canopies of *Acacia senegal* in the Senegal.

Table 12. Total biomass and grain yield (ton ha⁻¹) of maize as influence by tree canopy and distance from trunk at Aro-Wogera, Damot Gale.

DTB	Total biomass	Grain yield
0.5-1	0.68	0.08
2-2.5	1.74	0.42
4.5-5	4.56	1.51
16.0	6.69	2.30
CV (%)	21	33
LSD _(0.05)	3.34	1.4

4. SUMMARY AND CONCLUSIONS

Agroforestry tree mixed with crop could increase agricultural production and productivity in area like Damot Gale district where high population pressure and low soil fertility. At the study site, avocado and maize mixed planting is managed in the form of parkland agroforestry practices. However, tree management practice and influence on soil and maize yield was not studied in the area. Thus, the research evaluated the influence of avocado tree on some selected physicochemical properties of the soil and maize yield at Aro-Wogera, Damot Gale district, Wolita Zone, Southern Ethiopia. Soil samples were collected from two depths and four radial distances away from the base of the tree. The soil samples were analysis for physical properties (texture class and BD). The study revealed that the textural class of the soil was sandy loam at both depths and there was no significant difference between samples taken from open field and under the canopy. The bulk densities of the soil were increasing tendency with increasing depth and radial distance from the avocado truck to the open area. The overall results of chemical properties (pH, OC, TN, Av.P, CEC, Exchangeable bases and PBS) in this study, demonstrated that were no significant difference under the canopy of avocado 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. Generally, soil fertility management practices should be taken into consideration local knowledge on tree management practices using locally available resources. Therefore, Avocado–maize mixed farming is crucial in giving conclusion soil management for sustainable production and productivity of the under tree canopy.

ACKNOWLEDGEMENTS

I would like to offer my genuine thanks to the School of Graduate Studies of Hawassa University for sponsoring the research work. Special thanks are also extended to Mebrat Gebre and Samuel Lencha for her/his encouragement and technical support at the time of write up.

REFERENCES

- Abebe Seifu. 2000. Farmers tree planting and management tradition at Wondo Genet Ethiopia MSc. Tropical forestry Wageningen University, The Netherlands.13 p.
- Belsky,A.J.,S.M.M Wonga, R.G.Amundson, J.M. Duxbury and A.R.Ali. 1993. Comparative effects of isolated trees on their under canopy environments in high and low rainfall savannas. *Journal of Applied Ecology* 30:143-155.
- Blake, G.R. 1965. Bulk density. In: C.A. Black (ed.), *Methods of soil analysis*. Argon. Port I, No. 9, America society. Agronomist. Madison, Wisconsin, USA. pp.374-379.
- Bunderson, W.T., A.R Sara, O.A. Itimu, Y. Mbekeani and H.K.S. Phambeya. 1995. Biomass and litter under managed and natural tropical fallows. *Forest ecology and management* 67: 177-190.
- Chapman, H.D. 1965. Cation Exchange Capacity by ammonium saturation. In: C.A. Black(ed.), *Methods of soil analysis*. Agronomist. Part II, No. 9. America society. Agronomist. Madison, Wisconsin, USA.p 12.p.
- Drjkstra, F.A and M.M. Smiths. 2002. Tree species effects on calcium cycling: The role of calcium up take in deep soils. *Ecosystems*. pp385-398.
- ESRDF (Ethiopian Social Rehabilitation and Development Fund). Aseffa Abera, Tesfaye Desta, Afework G. Eyesus and Mekonnen Kassa . 2005. Working with Communities for a Better future. The Performances and Lessens of the ESRDF. 3 p.

- Eyasu Elias. 2002. Farmers Perception of Soil Fertility Change and Management, SOS Sahel, Institute for Sustainable Development. Addis Ababa.117-123.
- FAO (Food and Agriculture Organization).1985. Tree growing by rural people food and agriculture of the United Nations No.64.
- Havlin J. L. Tisdale, J. C. Beaton, and W.L Nelson. 2005. Soil fertility and fertilizers: An introduction to nutrient management 7th edition. Pearson prentice Hall upper Saddle River New Jersey. 515 p.
- Herrera, E. 2005. Soil Test Interpretation. Guide A-122.Collage of Agriculture and Home Economic New Mexico State University.p. 234.
- Isichei, A.O. and J. I. Muoghalu. 1992. The effects of tree cover on soil fertility in a Nigerian savanna. Journal of Tropical Ecology 8: 329-338.
- Jiregna,G., A. Rozanov and N. Negash. 2005. Trees on farms and their contribution to soil fertility parameters in Badessa, eastern Ethiopia. pp 66-71.
- Kamara, C.S. and I. Haque. 1992. Faidherbia albida and its effects on Ethiopian highland Vertisols. Agroforestry systems 18:17-29.
- Kessler,J.J.1992. The influence of Vitellaria paradosea and parkiabioglosa on Sorghum production in Burkina Faso. Agroforestry Systems.453 p.
- Laike.A. 1992. Faidherbia albida in the traditional farming system of central Ethiopia. In: Vandenbeldt RJ(ed.), Faidherbia albida in the West African Semi- arid Tropics.39 p.
- Landon, J. R. 1991. Booker tropical Soil manual: A hand book of soil survey and Agricultural land evaluation in the tropics and subtropics. Longman Scientific and Technical. Booker Tate Ltd.12.P.
- Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available Phosphorus in soils by extraction with sodium bicarbonate. USDA circular 939.11
- Poschen, P. 1986. An evaluation of the Acacia albida based agroforestry practices in the Hararghe highlands of Eastern Ethiopia. Agroforestry Systems 4:129-143.
- Prudenico, C. Y, 1993. Ring management of Soil and Crop in the West African Semi- arid Tropic: The Case of the Mossi Farming System in Burkina Faso, Agriculture, Ecosystem and Environment 47: 237-264.
- Rao MR, Nair P.K.R.,Ong CK. 1998. Biophysical interaction in tropical Agroforestry system. Agroforestry System 38:3-50
- Rocheleau, D.,F. Weber, and Field-Juma, A. 1988. Agroforestry in dryland Africa: Science and practice of agroforestry. ICRAF, Nairobi, Kenya .311 p.
- Sahlemedhin and Taye Bekele. 2002. Procedures for soil and plant analysis. National Soil Research Center, EARO, technical paper No 74, Addis Ababa, Ethiopia. 89.P.
- SAS, 1997. SAS Institute Inc., Cary, NC, USA. SAS Proprietary Software Release 6.12.
- Sharma, B.D and I.C. Gupta. 1989. Effects of tree cover on soil fertility in Western Rajasthan. Indian Forester 115: 348-354.
- Solomon, D.F. Fritzehe, M. Tekalign, J. Kehmann, and W. Zech. 2002. Soil organic matter composition in the sub humid Ethiopian highlands as influenced by deforestation and agricultural management. Soil Science Society Americans Journal 66:78-82.
- SPPS Institute Inc. 2001. For Windows has system users guide release version 12.
- Tadesse Hailu, Legessa Negash,and M. Olson. 2000. Effects of Millettia ferrugenia on soil fertility and growth performance of maize. Ethiopian M.Sc. in Forestry program.
- Tesfaye Abebe. 2005. Diversity in homegarden agroforestry system of Sourhern Ethiopia Ph D thesis. Wagening University . The Netherlands.pp 25-43.
- Thomas G.W. 1996. Soil pH and soil acidity.In: D.L. Sparks (ed.), Methods of soil analysis: Part 3 chemical methods. SSA., ASA., Madison, WI. Cited in Fikre 2003.69.p.
- Tiffin.M, and Mortimore,M. 1992. Environment, Population and Productivity in Kenya : A case study of Machakos, District Development Policy Review, 10: 359-387.
- Tilahun Amede, Takele Belachew and Endrias Geta. 2001. Reversing the Degradation of Arable Land in Ethiopian Highlands. Managing African Soils No. 23. London. 5.p.
- Van, R. 1992. Procedures for soil Analysis. 3rd Edition. Technical paper No.9. International Soil Reference and Information Centre Wageningen, The Netherlands.
- Whliley, A.,W, B., Schaffer and B.N. Wolstenhome. 2002. The avocado, botany, production and uses tropic research and education center, university of Florida, USA. .Newyork. 431 p.
- Zebene Asfaw. 2003. Tree diversity management in the traditional agroforestry land use of Sidama, Southern Ethiopia. PhD thesis. Sweden University of Agricultural Sciences. Department of forest management and Products. Uppsala. P.30.

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