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Fodder quality of *Ziziphus spina-christi* tree leaves and its effect on soil physicochemical properties and household income in the dry lands of Tigray, Ethiopia

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Abstract
Ziziphus spina-christi is a multipurpose drought tolerant tree or shrub and is commonly used in the parkland agroforestry system in Sub-Saharan Africa. The study determined the effect of *Ziziphus spina-christi* on soil physicochemical properties, its foliar nutrient content as animal fodder and its contribution to household income. Soil physical and chemical properties declined with depth and increasing distance from the tree trunk. The soil silt and clay content was significantly decreased with increasing depth (P<0.05). The silt and clay content was significantly higher in the cultivated land while the sand content was significantly higher in the grazing land. The soil organic carbon, available phosphorous and available potassium significantly decreased with increasing depth and distance from the tree crown (P<0.05). Leaves were good source of proteins (18-20%), fats and carbohydrates and were within the recommended range for ruminant livestock growth and development. The mean income of *Ziziphus spina-christi* growers was significantly higher than that of non-growers. Thus *Ziziphus spina-christi* is a multipurpose tree that improves soil nutrient, feed resource and income generation to households.

Keywords: Diameter classes, Income, Nutritional evaluation, Tree fodder

Introduction

In Ethiopia agriculture is the mainstay of the national economy and agricultural production has been highly dependent on natural resources for centuries (Amsalu *et al*., 2007). The increase in human population has degraded natural resources in the country and became a serious threat to sustainable agriculture. Degradation of soil resources as a result of natural and anthropogenic factors such as soil erosion, nutrient mining, inappropriate land use systems and inadequate supply of nutrients was very common in the country (Zeleke and Hurni, 2001). Soil fertility depletion and low crop yields are widespread in the Tigray region (EARO, 2002). The use of supplementary inorganic fertilizers has become less affordable for many Ethiopian farmers, following the removal of fertilizer subsidies. Consequently, fallows are cultivated with *Sesbania sesban,* to address low fertility problems of small holder fields in the region (EARO, 2002).

The presence of indigenous tree species in the region creates great untapped potential for growing with agricultural crops (Teklay and Malmer, 2004; Kindeya, 2004). There are many indigenous forage plants that can produce high yield of biomass for improvement of livestock production (Kumar *et al*., 2017; Roy, 2016; Ogunbosoye and Babayemi, 2010), but they are not utilized because the information on their nutrient composition is not known. Mekonnen *et al.* (2009) pointed out that very little research has been done on the nutritional value of indigenous tree and shrub species in Ethiopia, which means indigenous knowledge of fodder tree and shrub species is not strongly supported by scientific bases. Against this background, to gain benefits like fuel wood, food, shade, fodder, medicine, ecological services including soil fertility and microclimate amelioration from trees, farmers in Alamata district of Tigray region maintain and plant different indigenous and exotic trees and shrubs.

Ziziphus spina-christi is a multipurpose indigenous tree that is easily propagated and has edible fruits. The leaves are used as fodder, branches for fencing, wood as fuel and construction and furniture making (Sudhersan and Hussain, 2003). It is adapted to dry and hot climates which make it suitable for cultivation in an environment characterized by increasing degradation of land and water resources (Gebauer *et al*., 2007). There are many indigenous tree species including *Ziziphus spina-christi* that have a potential of maintaining the ecology and economic development (Kindeya, 2004). Dispersed trees on farms, that is parkland agroforestry systems, are typical in Tigray region of Ethiopia (Teklay, 2004) covering large tract of agricultural land. However, despite their significance in contributing to the livelihood of rural people, they have been largely ignored in the research domain. Rather, the impacts of trees like *Faidherbia albida*, *Cordia africana* and *Crotton macrostachyus* on soil properties and yields have been studied extensively. The objective of this paper was to determine the effect of *Ziziphus spina-christi* on soil physico-chemical properties, its foliar nutrient content as animal fodder and its impact in household income.

Materials and Methods

Study site: The study was conducted in Alamata district, southern zone of Tigray regional state, Ethiopia (Fig 1). The district has a geographical location of 12° 15' N and 39° 35' E. It is situated at 600 km north of the capital Addis Ababa and 180 km south of Mekelle town, the regional capital. The district has a flat topography with altitude ranging from 1478 to 3148 m (BoARD, 2012). The rainfall distribution of the study area is bimodal, mostly falling within the months of June to September, exhibiting high temporal and spatial variability. The annual rainfall ranges from 615 to 927 mm with average annual temperature range of 14.6 to 27 °C (Fig 2). The dominant soil types are Eutric, Vertisols, Lithic Leptosols (Cambic) and Lithic Leptosols (Orthic) (IPMS, 2005).

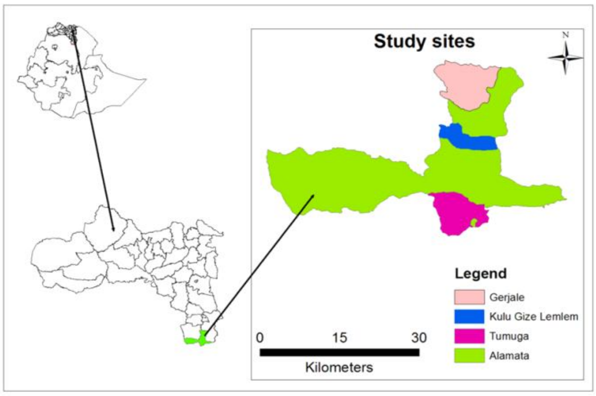

Fig 1. Study area in southern zone of Tigray regional state, Ethiopia

***Experimental design*:** Six trees were randomly selected based on DBH (diameter at breast height), crown diameter and height. There were three factors involved in the experiment, viz. distance from the tree trunk, soil depth and land uses. The distance factor had three different treatment levels; half of the canopy radius (under the tree), canopy edge (radius of the canopy) and at four times canopy radius away from the tree trunk (outside the canopy) as control following the procedure by Jiregna *et al*. (2005) and Pandey *et al*. (2000). The depth of the soil had two levels: surface soil layer (0-15 cm) depth representing the top soil and the lower layer (30-45 cm) depth to represent the subsurface soil layer. Sample trees were distributed in farm land and grazing land. The design employed had a 3×2×2×3 factorial arrangement in randomized complete block design (RCBD) replicated three times. There were a total of 36 experimental units or samples.

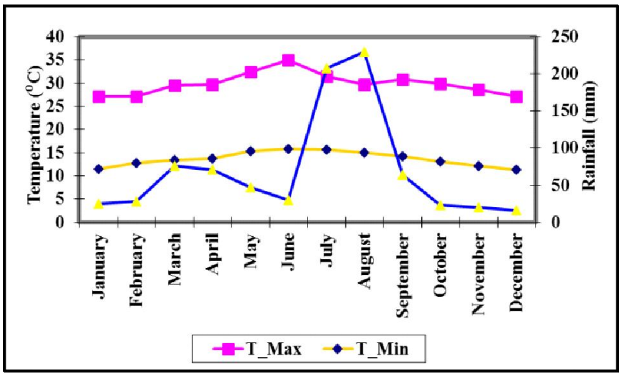

Fig 2. Rainfall and temperature pattern of the study district during 2002-2012

***Soil sampling*:** Four transects extending from the base of the tree trunk were laid out in east, west, north and south direction. From the four transects, soil samples were taken at three distances (at half of the canopy radius under the tree, canopy edge and at four times canopy radius away from the trunk outside the canopy) from the tree base and from two different depths (0-15 and 30-45 cm) of each respective distances with three replications. Overall there were 144 soil samples (72 for the surface soil and 72 for the subsurface soil). Samples within same radial distance and same depth were pooled to form a single composite sample. Contamination between the layers while taking the soil samples was avoided by digging a pit measuring 0.5 × 0.5 m and soil samples were taken by scratching the wall of the soil profile for the respective depth. First, a soil sub sample was taken for the 0-15 cm then for the 30-45 cm layer. By bulking the four sub samples and quartering a composite sample of 1 kg was prepared for the chemical and physical analysis of the soil properties. A separate soil sample was collected with a core sampler for the analysis of bulk density.

***Soil analysis and laboratory methods*:** Before chemical analysis, the collected samples were first air dried, then ground and sieved to separate <2 mm fraction at Mekelle Soil Laboratory. The soil samples were analyzed for organic carbon content by wet oxidation method of Walkley and Black (Schnitzer, 1982) and total nitrogen by the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was determined by Olsen method (Olsen *et al*., 1954), available K by neutral ammonium acetate extraction (Merwin and Peach, 1951); soil pH and EC in a 1: 2.5 soil to water suspension (Jackson, 1973); texture by hydrometer (Bouyoucos) and soil bulk density by weighing oven dried (105°C) soil samples with known volume (Brady and Weil, 2002).

***Leaf sampling and chemical analysis*:** For determination of foliar proximate chemical composition, five diameter classes (11–20, 21–30, 31–40, 41–50 and 51–60 cm at breast height) of *Ziziphus spina-christi* trees replicated four times. From each diameter class, fully matured and expanded green leaves with petiole from the middle section of the current year grown branches in all compass directions and from different crown positions were collected and evenly mixed to form 1 kg of fresh leaves per sample tree. The samples were pooled from 20 experimental units representing 5 diameter classes as treatments and replicated four times. The collected leaf samples were washed with distilled water to remove dust particles, air dried and then oven dried at 65°C until constant weight was achieved. Sampled leaves were then ground and analyzed for the leaf dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and ash contents according to AOAC (1990). The procedure used by El-Beheiry (2009) was employed for calculation of digestible crude protein (DCP) on DM basis as: %DCP = 0.929CP (%DM) - 3.52.

***Socioeconomic sampling and analysis*:** Out of the 14 rural villages in the district, three *Ziziphus spina-christi* tree growers and non-grower villages with similar demographic, socioeconomic and geographic characteristics were purposively selected. A total of 150 households (86 from the *Ziziphus spina-christi* growers and 64 from the non-growers) were randomly selected based on probability proportion to sample size. Propensity score matching (PSM) developed by Rosenbaum and Rubin (1983) was used to assess the impact of *Ziziphus spina-christi* on the income of the households. PSM uses a statistical model to calculate propensity of impact on the basis of the set of observable characteristics. Grower and non-grower households were then matched on the basis of similar propensity scores. The idea behind the PSM approach was to find control observations (non-growers households) having initial observable characteristics similar to the grower households, to serve as valid surrogates for the missing counterfactuals. A Logit model was used to predict the probability that each household is a function of observed household using a sample of grower and non-grower households.

***Statistical analysis*:** Data from the experiments on soil analysis and foliar nutrients were subjected to three way ANOVA and one-way ANOVA, respectively which were analyzed using the general linear model (GLM) procedure of (SAS, 2002). Treatment means were separated by Duncan's multiple range test. Comparison of treatment means was performed using Tukey HSD test at $P<0.05$ probability level. For socio economic analysis, the data collected were analyzed using PSM logit models using The Stata version10 software. Normality and equality of variance (homogeneity) at $P>0.05$ were conducted for all data test.

Results and Discussion

***Soil physical properties*:** Sand and silt fractions were significantly different between the two land uses. Similarly the clay fraction was significantly affected by distance, soil depth and land use (Table 1). There were no significant differences in sand and silt fractions under the canopies and outside the canopy. However, the clay content was higher under the canopy than outside the canopy. This agrees with the study of Pandey *et al.* (2000) under *Acacia nilotica* canopy where the sand particles declined by 10 and 9% whereas clay particles increased by 14 and 10%, under the canopy than outside the canopy, respectively. Similarly the soil clay content under the canopy was higher under the canopy of *B. aegyptiaca* tree on farm fields than soils outside the canopy (Hailemariam *et al.,* 2010). There was no significant difference in bulk density with regards to distance from the tree trunk, soil depths as well as land uses. The lower mean values of bulk density were observed in soils under grazing land than cultivated land (Table 1).

***Soil chemical properties*:** Soil pH was significantly affected by soil depth and land uses (Table 2). The pH was not significantly affected by distance from the tree trunk. There was lower pH value under canopy (7.96) than beyond canopy (8.22) showing a decrease of 3.10% under *Balanites aegyptiaca* trees (Hailemariam *et al.,* 2010). Lower soil pH values under canopy of *Ziziphus spina-christi* as compared to outside canopy might be due to several mechanisms that release H^+ ions, such as soil base cation uptake (or depletion) by the tree, decomposition of organic matter to organic acids and

Table 1. Soil physical parameters as influenced by radial distance, depth and land uses

Soil	Depth (cm)				Distance					Land use			
	0-15	30-45	F	P	Under	Edge	Far	F	P	Culti-vated	Graz-ing	F	P
Sand (%)	39.5^a	41.4^a	3.01	0.15	39.3^a	40.8^a	41.3	1.22	0.38	33.6^b	47.3^a	15.7	0.00
Silt (%)	33.4^a	29.3^b	13.62	0.02	31.8^a	31.8^a	30.5^a	0.64	0.57	33.3^a	29.4^b	12.1	0.02
Clay (%)	29^b	27.2^a	15.69	0.01	28.8^a	26.8^{ab}	24.8^b	5.22	0.07	33^a	23.2^b	30.3	0.00
BD (gm cm^{-3})	1.29^a	1.31^a	0.29	0.61	1.29^a	1.31^a	1.32^a	0.55	0.61	1.32^a	1.30^a	0.42	0.55

BD: Bulk density; Means along the same row (soil depth) and (radial distance) with different superscripts are significantly different (P<0.05); Soil refers to the soil physical property parameters

Table 2. Soil chemical properties under *Ziziphus spina-christi* tree as influenced by distance, depth and land uses

Soil	Depth (cm)				Distance					Land use			
	0-15	30-45	F	P	Under	Edge	Far	F	P	Culti-vated	Graz-ing	F	P
pH	7.4^b	7.7^a	9.31	0.03	7.58^a	7.54^a	7.70^a	1.61	0.30	7.7^a	7.4^b	23.4	0.00
EC(dSm^{-1})	0.26^a	0.30^a	2.03	0.23	0.27^a	0.28^a	0.30^a	0.56	0.61	0.22^b	0.34^a	20.1	0.01
OC (%)	1.64^a	1.42^b	55.8	0.00	1.61^a	1.49^b	1.48^b	13.7	0.01	1.42^b	1.64^a	88.5	0.00
OM (%)	2.78^a	2.49^b	56.0	0.00	2.78^a	2.57^b	2.55^b	13.8	0.01	2.45^b	2.82^a	89.0	0.00
AVP (ppm)	17.2^a	7.79^b	26.9	0.00	17.8^a	9.72^b	9.95^b	8.65	0.03	13.7^a	11.2^a	1.89	0.24
AVK (ppm)	6.92^a	4.27^b	103	0.00	6.4^a	5.65^a	4.70^b	14.8	0.01	5.19^b	6.00^a	9.58	0.03
TN (%)	0.15^a	0.13^b	33.5	0.00	0.12^a	0.11^a	0.10^a	2.15	0.23	0.12^a	0.10^b	33.9	0.00
C/N	13.9^a	13.9^a	0.01	0.91	13.2^a	13.5^a	14.9^a	1.7	0.29	13.3^b	14.4^a	15.1	0.01
CEC (meq /100g)	27.1^a	23.8^b	3.35	0.14	27.5^a	24.3^a	24.5^a	1.35	0.35	28.4^a	22.5^a	11.1	0.02

Means along the same rows (soil depth) and (radial distance) with different superscripts are significantly different (P<0.05). pH: Soil pH; EC; Soil electrical conductivity; OC: Soil organic carbon; OM: Soil organic matter; AVP: Available phosphorus; AVK: Available potassium; TN: Total Nitrogen; C/N: Carbon to Nitrogen ratio; CEC: Cation exchange capacity

CO_2, root respiration and nitrification. These high soil pH values were observed mainly due to low precipitation and high evaporation that reduces the loss of the base forming cations from the soil profile.

Electrical conductivity (EC) was significantly affected between the two land uses. The lowest EC value under the cultivated land could be associated with the loss of base forming cations (Ca+ and Mg+) after deforestation and intensive cultivation. The findings of the current study seem to disagree with Hailemariam *et al*.(2010) where higher soil EC was observed under the canopy of *B. aegyptiaca* as compared to the open field. Generally the observed EC value in the present study were high (EC>0.05dSm^{-1}) despite the aridity of climate and limited rain fall to leach away base forming cations from the surface soils (Landon, 1991) in the area in general and the study site in particular.

Soil organic matter content was significantly affected by land use, soil depth and distance from trunk (Table 2). Soil OM content was highest (2.82%) under the grazing land and lowest (2.45%) on the cultivated land (Table 2). The lowest organic matter in cultivated land might be due to frequent cutting and pruning of tree for fuel wood and feed. Soil organic carbon as well as soil organic matter clearly diminished with distance from the tree trunk (Table 2) indicating marked effect of tree organic matter contribution to the soil system through litter fall and fine root decay. The decrease of SOM with distance showed that the influence of the tree disappears from only a few meters beyond the canopy zone. Soil organic matter (SOM) improves water holding capacity, increases plant nutrient and moisture availability and reduces soil erosion. The increase in soil organic matter under the canopy of different tree species was also reported by Abebe *et al.* (2001) with an average increase of about 13% organic matter under canopy of *Cordia africana* trees. Correspondingly, Tadesse (1997) and Zebene (2003) reported significantly higher organic carbon under canopies of different trees than the corresponding open area, which agrees with the result of our current study.

Soil N concentration also showed significant variation between soil depths and land use (Table 2). There was no significant difference in soil N between the distances from the tree trunk. However, soil N was higher under the canopy by 20% as compared to the open canopy (Table

2). Litter production and the rate of litter decomposition are the most important factors by which tree species regulate the size and distribution of soil C and N pools (Wang *et al*., 2010). Since the microclimate under the canopy changes with increased soil moisture status that can increase the moisture content of the surface litter to easily break the organic matter which facilitates its mineralization (Meenakshi and Kailash, 2002). The increase of nutrient accumulation under canopy might be due to the nutrient input by tree litter. Aweto and Dikinya (2003) studied the effects of *Combretum apiculatum* and *P. africanum* on the soil under their canopies in semi-arid traditional grazing land in south eastern Botswana and found that the mean N levels under the canopy were higher than in the open grassland. In on-farm field experiment in Niger under the *F. albida* canopy, nitrogen availability under trees was estimated to be more than 200% higher than in the open field causing a 26% production increase (Elseed, 2002). The C: N ratio under canopy ranged from 13.22 to 14.96, but it was lower than that of open canopies, indicating that organic materials under the canopy were of higher quality than in the open canopy. High C: N ratio of 10 or above indicates that there is N mineralization occurring in the soil (Agbenin and Goladi, 1997) which is typical in arid and semi-arid regions.

The concentration of available phosphorus decreased with increasing distance from the canopy (Table 2). Hadgu *et al*. (2009) found clear differences in SOM and available phosphorus under and away from the canopy in *F. albida* based land use systems of northern Ethiopia. The highest concentration of available phosphorus under the canopy of *Ziziphus spina-christi* might be due to the release of available organic P during the decomposition of litter fall in addition to high organic matter. *Ziziphus spina-christi* intercropped with millet improved soil fertility by increasing available phosphorous in West Africa (Verinumbe, 1993). Available potassium (K) level under the canopies was higher than outside the canopies by 36.8% (Table 2). The higher soil K accumulation under canopy zone as compared to outside canopy zone of the present study could be due to high accumulation of organic matter under the canopy. In both land uses, the value of available K was rated as very high. This high value of available K could be attributed to minimum soil leaching due to aridity of the study area. In support of this study *Tadesse et al*. (2000) reported a significantly higher soil K concentration under the *Millettia* tree canopy than in the open fields. In an on-farm field experiment in Niger, potassium level in the soils under the canopies was higher than those outside the canopies by 25% (Kho *et al*., 2001).

***Chemical composition of Ziziphus spina-christi leaves*:** The proximate chemical composition of the different diameter classes of *Ziziphus spina-christi* showed significant variation in ash, ether extract (EE) and nitrogen free extract (NFE) (Table 3). According to El-Beheiry (2009) nutrient contents (protein, carbohydrates, minerals and vitamins) and metabolisable energy (ME) change in relation to season, stage of growth, time of day, soil fertility or fertilizer application rates particularly nitrogen and probably soil moisture. Thus, an awareness of the factors influencing nutrient content of leaves is required to allow more efficient feed supplementation for animals.

The ash content results of the current study agree with Malik and Chughtai (1979) where the ash content of young and mature tree leaves of *Melia azedarach* were 7.90% and 12.8% and *Mulberry* tree had 12.2% and 23.1% ash contents at young and mature stages of growth, respectively. The ash content was comparable with *A. tortilis* (11.85%) and *A. ehrenbergiana* (12.78%) and had higher ash content than *Ziziphus spina-christi* (El-Beheiry, 2009). The mean ash values recorded in this study were within the range reported for most of the tropical fodder trees. *Ziziphus spina-christi* leaves were rich in ash. Ether extract (EE) or fat, a measure of energy levels of feedstuffs, was significantly affected by the different diameter classes (Table 3). The overall mean EE composition for the diameter classes was 3.03 %. The EE composition of *Ziziphus spina-christi* leaves were higher than the leaves of *A. tortilis* (2.98%), *A. ehrenbergiana* (2.26%), *P. distichum* (2.31%), *S. erectum* (2.32%) and *A. tortilis* (2.40%) (El-Beheiry, 2009; Heydari *et al.,* 2006). The EE of the present study indicated that *Ziziphus spina-christi* leaves could be good source of energy that can be utilized by ruminants for body maintenance and production.

The variation in NFE composition might be due to their significance in trees' metabolism which could be involved in protoplasmic structure constructions and act as sources of energy supply compounds. The NFE composition in the present study was consistent with the findings of El-Beheiry (2009) for two *Acacia* species [*A. tortilis* (41.37%) and *A. ehrenbergiana* (41.29%)]. The dry matter (DM) in the present study was not significantly affected by different diameter classes (P>0.05). DM showed an increasing trend with increasing diameter. High DM content could be obtained due to the time of sampling which was done between January and February. The lower dry matter (DM) value was obtained

Table 3. Proximate composition of *Ziziphus spina-christi* leaves as influenced by different diameter classes

Diameter	Proximate chemical composition (%)						
Class(cm)	DM	ASH	CP	CF	EE	NFE	DCP
11-20	41.01[a]	8.5[b]	19.06[a]	7.65[a]	3.01[ab]	62.93[a]	14.19[a]
20-30	42.23[a]	10.31[ab]	18.34[a]	7.88[a]	2.70[c]	59.25[ab]	14.10[a]
30-40	43.33[a]	10.31[ab]	18.97[a]	8.30[a]	2.68[b]	60.05[ab]	14.03[a]
40-50	43.9[a]	10.43[ab]	18.89[a]	8.04[a]	3.13[ab]	59.41[ab]	13.52[a]
50-60	45.36[a]	12.31[a]	17.9[a]	8.44[a]	3.63[a]	57.29[b]	13.11[a]

DM: Dry matter; CP: Crude protein; CF: Crude fibre; EE: Ether extract; NFE: Nitrogen free extract: DCP: Digestible crude protein. Mean values with different superscripts in the same column are significantly different (P<0.05). Value expressed as: Mean ± SD

in diameter class 11-20 cm, since the leaves were harvested at a relatively younger age and at higher moisture contents. The interspecies variation in DM composition of different browse species might be due to the generic differences, while intra-species variation could be attributed to effects of climate or season, geographical location or agroecology, time of day, aspect of the tree, tree age, position of leaves in the crown, age of foliage, internal nutrient balance, effects of diseases, soil type, soil age etc (Azim *et al.,* 2011). Crude protein is an important requirement to support optimum microbial growth of rumen (Table 3). There was no significant difference in crude protein contents among the diameter classes (Table 3). Average CP for all diameter classes was 18.63% and it ranged from 17.90% to 19.06%. Crude protein (CP) revealed a decreasing trend with increasing diameter. The mean CP of the present study far exceeds the minimum protein requirements of ruminants. If the mean CP is below 7% the feed intake might be depressed as it is not sufficient to meet the needs of the rumen bacteria (NRC, 1980). Comparing the CP of the current study (18.63%) with other studies done on *Ziziphus spina-christi* indicated that CP content in the present study was higher than those reported earlier (Le Houerou, 1980; Teferi, 2006; Bruh, 2008). Besides, Azim *et al.* (2011) reported that the crude protein values for top fodder tree species were lower than the current study. The fodder tree leaves were highly valued by the farmers for their palatability and performance of the animal. This result indicated that crude protein of *Ziziphus spina-christi* could be adequate to meet the requirement of the ruminants in the dry season. Generally, as plants mature the cell wall constituent increase and therefore, the structural carbohydrates (cellulose and hemicelluloses) along with lignin increase and the protein normally decrease (Mc Donald *et al.,* 2002). Digestible crude protein (DCP) was not significantly affected by the different diameter classes. Average DCP composition of the present study was higher than that of *A. tortilis* (3.4%) and *A. ehrenbergiana* (4.6%) (El-Beheiry, 2009). *Ziziphus spina - christi* leaves could be good source of DCP, even better than some nitrogen fixing *Acacia* species. Crude fibre (CF) composition of leaves showed an increasing trend with increasing diameter (Table 3). The overall mean value of CF of leaves was 8.06%. Kitalyi *et al.* (2005) suggested 18 to 20% of CF as the minimum requirement of ruminants for their rumen to function properly. Singh *et al.* (1972) reported the chemical composition of different tree leaves found in India and observed that the leaves at younger stage had low fiber but with advancement of age fibre content increased. The low CF composition in *Ziziphus spina-christi* leaves could make the species a good candidate as a supplement and improve the roughage degradability and intake to the ruminant microbes.

***Impact of Ziziphus spina-christi for household income*:** The household characteristics used to assess the impact of the species for household income were sex, age, education level, family size and land holding size. Mean age of household head was 40 and 56 years for grower and non-grower households, respectively. The education level for both growers and non-growers was generally fair, averaging at elementary school. The household size for growers and non-growers was 6 and 4 members, respectively. Larger family sizes had more demand for tree products due to high consumption and high labour force. Larger households had higher chance of *Ziziphus spina-christi* growing (Table 4). The size of household proxies for household labour endowment. Thus, larger households had labour time to devote growing of *Ziziphus spina-christi*. Moreover, such households would be better placed in terms of labour for extraction of *Ziziphus spina-christi* products. Larger households might also be viewed as having greater demand for *Ziziphus spina-christi* products which they may not satisfy on own farm production. Thus, growing *Ziziphus spina-christi* and benefiting from tree products could be viewed as a viable livelihood alternative for the larger households. Household age had a negative effect on growing *Ziziphus spina-christi*. Increase of age household heads reduced the probability of growing *Ziziphus spina - christi* as households with older age might not able to extract products easily from *Ziziphus spina-christi;* such households would not be motivated to maintain and manage the species.

Table 4. Logit model of *Ziziphus spina-christi* growers

Variables	Coefficient	Standard Error	Z
Sex of household	-0.36	2.12	-0.17
Age of household	-0.42	0.13	-3.16***
Education level of household	.048	0.56	0.09
Family size of household	1.53	0.71	2.16**
Land holding size (ha)	-2.67	2.20	-1.21
Off-farm participation	0.98	1.12	0.37
No. of observation	150		
Pseudo R-Squared	0.91		

Statistical significance at the 99% (***), 95% (**) and 90% (*) confidence levels. T-test and chi-square were used for continuous and categorical variables, respectively

The alternative matching methods adopted for assessing the robustness of the estimated results showed that the overall average income gain due to *Ziziphus spina-christi* growers ranged from 80 to 81.2 USD and was significant at 1% level based on the radius, kernel, stratification and nearest neighbour matching methods (Table 5). This robust result indicated that the mean income of households was significantly increased due to *Ziziphus spina-christi* tree growing.

Table 5. Matching methods and household income

Matching Methods	ATT (Birr)	Standard Error	t-stat
Nearest neighbor matching	80	2.51	32.25***
Radius matching	80	2.85	28.42***
Kernel matching	80	2.88	28.04***
Stratification matching	81.2	12.91	6.28***

Statistical significance difference at the 1% (***); Standard errors are bootstrapped; ATT: Average treatment effect on the treated

Conclusion

Ziziphus spina-christi trees improved the levels of OC, P and K of the soils under their canopies which indicated that the tree can improve the soil fertility through accumulation of litter under their canopies. Hence, retention of *Ziziphus spina-christi* in the farmland and grazing fields as well as its planting in degraded areas within its agro-ecological zone should be widely considered. Tree diameters significantly affected ash, EE and NFE composition of the leaf. *Ziziphus spina-christi* leaves could be important source of nutrients to supplement other low nutrient source of feeds in the study area. This tree was source of higher carbohydrates, protein and fat. *Ziziphus spina-christi* grower households earned 80 to 81.21 USD greater than non-growers. Therefore, the tree had a positive contribution on improving household income. The positive effects of trees on soils, nutrition composition of leaves as a supplemental feed for animal and an economic role is important towards increasing tree cover on farms.

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References

Abebe, Y., I. Fisseha and M. Olson. 2001. Contribution of Indigenous tree to soil Properties: The case of scattered trees of *Cordia-africana* Lam. in crop land of western Oromia. *Ethiopian Journal of Natural Resource* 3: 245-270.

Agbenin, J. and J. Goladi. 1997. Carbon, nitrogen and phosphorous dynamics under continuous cultivation as influenced by farmyard manure and inorganic fertilizers in the savanna of northern Nigeria. *Agriculture, Ecosystem and Environment* 63: 17-24.

Amsalu, A. L. Stroosnijder and J. de Graaff. 2007. Long term dynamics in land resource use and the driving forces in the Beressa watershed, high lands of Ethiopia. *Journal of Environment Management* 83: 448-459.

AOAC. 1990. *Official Methods of Analysis*. 15th ed. Association of Analytical Chemists, Washington DC., USA.

Aweto, A.O. and O. Dikinya. 2003. The beneficial effects of two tree species on soil properties in a semi-arid savanna rangeland in Botswana. *Land Contamination and Reclamation* 11: 339-334.

Azim, A. S. Ghazanfar., A. Latif. and M. A. Nadeem. 2011. Nutritional evaluation of some top fodder tree leaves and shrubs of district Chakwal, Pakistan in relation to ruminants requirements. *Pakistan Journal of Nutrition*10: 54-59.

BoARD. 2012. *Bureau of Agriculture and Rural Development. Annual Reports*, Alamata District, Southern Tigray, Ethiopia.

Brady, N.C. and R. R. Weil. 2002. *Nature and Properties of Soils*. 13th ed. New York, USA.

Bremner, J.M. and C. S. Mulvaney. 1982. Nitrogen-Total. In: A. L. Page, R. H. Miller, D. R. Keeney (eds). *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties.* Agronomy Monograph No. 9. American Society of Agronomy, Madison, WI. pp. 595-622.

Bruh, W. 2008. Supplementation with dried foliages of selected indigenous browses: effects on feed intake, digestibility, and body weight gain and carcass characteristics of Abergelle goats in Tigray. Mekelle, Ethiopia.

El-Beheiry, M. A. H. 2009. Nutritive evaluation of two acacia populations in south western Saudi Arabia. *Journal of Applied Sciences Research* 5: 1030-1039.

Elseed, A. M. 2002. Nutritive evaluation of some fodder tree species during the dry season in central Sudan. *Asian-Australasian Journal of Animal Science* 15: 844-850.

EARO. 2002. An Assessment of the agricultural production base, technological packages and innovation strategies for commercial farmers in Kafta Humera wereda of Tigray Regional State Ethiopia. Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia.

Gebauer, J., A. Patzelt, K. Hammer and A. Buerkert. 2007. First record of *Grewia tenax* (Forssk.) Fiori in northern Oman, a valuable fruit producing shrub. *Genet Resource Crop Evolvement* 54: 1153–1158.

Hadgu. K. M., L. Kooistra., W. A. H. Rossing and A. H. C. vanBruggen. 2009. Assessing the effect of *Faidherbia albida* based land use systems on barley yield at field and regional scale in the highlands of Tigray, Northern Ethiopia. *Food Security* 1: 337-350.

Hailemariam, K., K. Gebrehiwot and C. Yamoah. 2010. *Balanites aegyptiaca*, a potential tree for parkland agroforestry systems with sorghum in northern Ethiopia. *Journal of Soil Science and Environmental Management* 1: 107-114.

Heydari, G., A. T. Yansari and H. Zali. 2006. Inspection on three plant spices as an animal forage source in Mazandran wetland. *Pakistan Journal of Nutrition* 5: 382-386.

IPMS. 2005. Metema Pilot Learning Site diagnosis, program design and atlas. International Livestock Research Institute, Nairobi, Kenya.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi. India.

Jiregna, G., A. Rozanov and N. Legesse. 2005. Trees on farms and their contribution to soil fertility parameters in Badessa, eastern Ethiopia. *Biology Fertility Soils* 42: 66-71. DOI 10.1007/s00374-005-0859-2.

Kindeya, G. 2004. Dryland agroforestry strategy for ethiopia. In: *Proceedings of Drylands Agroforestry Workshop* (September 1-3, 2004). ICRAF Headquarters, Nairobi-Kenya.

Kitalyi, A., D.M. Maino, S. Mwebaze and C. Wambugo. 2005. More forage, more milk: forage production for small scale zero grazing system. *Regional Land Management Unit (RELMA in ICRAF)/World Agroforestry Centre*. Technical Hand Book N. 33. Nairobi, Kenya.

Kumar, R. V., H. V. Singh, S. Kumar, A. K. Roy, and K. A. Singh. 2017. Growth and biomass production of fodder trees and grasses in a silvipasture system on non-arable land of semi-arid India. *Range Management and Agroforestry* 38: 43-47.

Landon, J. R. 1991. *Book on Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Long man Scientific and Technical, Essex, New York. pp. 1-474.

Le Houerou, H.N. 1980. Chemical composition and nutritive value of browse in tropical west Africa. In: H.N.Le Houerou (ed). *Browse in Africa: The Current State of Knowledge.* International Livestock Center for Africa (ILCA), Addis Ababa, Ethiopia. pp. 261-297.

Malik, M.Y. and M. I. Chughtai. 1979. Chemical composition and nutritive value of indigenous feedstuffs. Pakistan Association for the Advancement of Science, Lahore. Pakistan.

Mc Donald, P., R. A. Edwards, J. F. D. Greenhalgh, C. A. Morgan, L. A. Sinclair and R. G. Wilkinson. 2002. *Animal Nutrition*. 6th Edition, Pearson Educational Limited. Edinbugh, Great Britian. Pp. 1-693.

Meenakshi, K. and L. Kailash. 2002. Effect of *Albizzia lebbeck* plantation on the nutrient cycling in a semi-arid grazing land. *Tropical Ecology* 43: 305- 314.

Mekonnen, K., G. Glatzel and M. Sieghardt. 2009. Assessments of fodder values of three indigenous and exotic woody plant species in the highlands of central Ethiopia. *Mountain Research and Development* 29: 135-142. http://dx.doi.org/10.1659/mrd.1098.

Merwin, H.D. and M. Peech. 1951. Exchangeability of soil potassium in sand, silt and clay fraction as influenced by the nature of complementary exchangeable cations. *Soil Science Society of America* 15: 125-128.

NRC. 1980. *Nutrient Requirements of Dairy Cattle*. National Research Council. National Academy press, Washington, DC.

Ogunbosoye, D. O. and O. J. Babayemi. 2010. Potential values of some non-leguminous browse plants as dry season feed for ruminants in Nigeria. *African Journal of Biotechnology* 9: 2720-2726.

Olsen, S. R., C. V. Cole., F. S. Watanabe and L. A. Dean. 1954. *Estimation of Available Phosphorus in Soil by Extraction with NaHCO3*; U.S. Department of Agriculture Circular, U.S. Government Printing Office, Washington, D.C. PP. 1-939.

Pandey, C. B., A. K. Singh and D.K. Sharma. 2000. Soil properties under *Acacia nilotica* trees in a traditional agroforestry system in central India. *Agroforestry Systems* 49: 53-61.

Rosenbaum, P.R. and D.B. Rubin.1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70: 41-55.

Roy, M. M. 2016. Agroforestry on dry and degraded lands: present status and future prospects. *Range Management and Agroforestry* 37: 1-11

SAS. 2002. User's Guide: Statistics Version 9.00. SAS Institute, Inc., Cary, North Carolina.

Schnitzer, M. 1982. Organic matter characterization. In: A. L. Page., R. H. Miller and D. R. Keeney (eds) *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*. Agronomy No. 9. pp. 581-94. ASA, SSSA: Madison, Wisconsin, USA.

Singh, K., M. L. Punj, A. S. Kochar and I. S. Bhatia 1972. In vitro studies on the utilization of the carbohydrate polymers of the cell wall of tree leaves by rumen microorganisms. *Indian Dairy Science* 25: 142-152.

Sudhersan, C. and J. Hussain. 2003. In vitro propagation of a multipurpose tree, *Ziziphus spina-christi* (L.) Desf. *Turkey Journal of Botany* 27: 167-171.

Tadesse, H.1997. Effect of Melletia ferruginea on soil fertility and growth performance of maize. M Sc Thesis, SLU, Sweden.

Tadesse, H., N. Legesse and M. Olsson. 2000. *Millettia ferruginea* from southern Ethiopia: impacts on soil fertility and growth of maize. *Agroforestry Systems* 48: 9-24.

Teferi, A. 2006. Identification and Nutritional Characterization of Major Browse Species as Livestock Feed in Abergelle Wereda of Tigray. Ethiopia. pp. 1-58.

Teklay, T. and A. Malmer. 2004. Decomposition of leaves from two indigenous trees of contrasting qualities under shaded-coffee and agricultural land-uses during the dry season at wondo genet. *Soil Biology and Biochemistry* 36: 777-786.

Teklay, T. 2004. Seasonal dynamics in the concentrations of macronutrients and organic constituents in green and senesced leaves of three agroforestry species in southern Ethiopia. *Plant and Soil* 267: 297-307.

Verinumbe, I. 1993. Soil and *Leucaena leucocephala L.* growth variability under *Faidherbia albida* Del. and *Ziziphus spina-christi* (L.) Desf. *Agroforestry system* 21: 287–292.

Wang, F., Z. Li, H. Xia, B. Zou, N. Li, J. Liu and W. Zhu. 2010. Effects of nitrogen-fixing and non-nitrogen-fixing tree species on soil properties and nitrogen transformation during forest restoration in southern China. *Soil Science and Plant Nutrient* 56: 297-306.

Zebene, A. 2003. Tree species diversity, topsoil conditions and arbuscular mycorrhizae association in the sidama traditional agroforestry land use, southern Ethiopia. Department of Forest Management and Products. SLU, Uppsala, Sweden.

Zeleke, G. and H. Hurni. 2001. Implication of land uses and land cover dynamics for mountain resource degradation in the north western Ethiopia high lands. *Mountain Research and Development* 21: 184-191.