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Original Research

Moringa stenopetala Tree Species Improved Selected Soil Properties and Socio-economic Benefits in Tigray, Northern Ethiopia

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Abstract

Moringa stenopetala has gained attention recently in Ethiopia due to its multiple uses. It is a drought tolerant fast growing indigenous tree mainly planted and maintained for its nutritional value. This study was conducted to evaluate the effect of *M. stenopetala* tree species planted on homestead agroforestry system on selected soil properties and socio-economic benefits. A total of 54 composite soil samples from nine trees randomly selected at the distance of 1m, 3m and 10m away from the trunk and two soil depth of 0 – 20cm, and 20 – 50cm were taken from under and outside the canopy of *M. stenopetala* that were grown on marginal area near the homestead. The socioeconomic contribution of the tree was done through interview using a questionnaire from 100 randomly selected respondents. Soil pH was significantly higher outside the canopy than under the canopy ($P<0.001$). Organic matter (OM), total nitrogen (TN), cation exchange capacity (CEC) and exchangeable calcium (Ca), magnesium (Mg) and potassium (K) were significantly higher under the canopy of *M. stenopetala* compared to the adjacent open areas. OM, TN and available P were significantly higher on the upper soil layer ($P<0.05$). The respondents income estimated per year reached USD 3675, translating to an average value of 211 USD/household/year which is 18.9% share of total gross income. 98% of respondents had positive perception towards economic uses and environmental effects of Moringa. *M. stenopetala* could be maintained and introduced to overcome low soil fertility of near homestead marginal areas and used as agroforestry tree with the exceptions of combining it with highly P demanding crops in dryland areas. *M. stenopetala* has brought fair shares on total incomes, contributes to different income components and perceived by communities as having multipurpose roles.

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INTRODUCTION

Design and management of sustainable agroecosystems has important foundations in our understanding of how individual plants grow, develop, and eventually become the plant matter we use, consume and feed to animals as well as capability of the plant sustainable productivity as agroforestry system (Gliessman, 2007). Moringa species is one of the world's most useful plants; it is a fast-growing, much more drought-tolerant and multi-purpose tree that it has been described as a 'miracle tree' (Fuglie, 2003; Amaglo, 2006; Yisehak *et al.,* 2011; Ashfaq *et al.,* 2012). Among the wide range of uses it provides are human food, fuel wood, livestock forage, medicine, dye, water purification, soil and water conservation, quality of cooking oil, green manure and the tree is used as source of income for Moringa growers (Demeulenaere, 2001; Palada and Chang, 2003; Jiru et *al.,* 2006; ECHO, 2009; Morey, 2010; Melesse *et al.,* 2011). *M. stenopetala* is a tropical plant that belongs to family Moringaceae. The family is represented by a single genus called Moringa. The genus Moringa consists of 14 species to which *M. stenopetala* belongs (Beyene, 2005; Jiru *et al.,* 2006; Aynalem, 2008; Gebregiorgis *et al.,* 2011). Its English names are Africa Moringa tree, Ben-oil tree, Cabbage tree, Horse-radish tree. Besides, it is also known as Shiferaw in Amharic and Aleko, Aluko and Haleko in the Southern Rift Valley of Ethiopia, in Gamo-Gofa areas (ETFF, 2004; Demeulenaere, 2001; Yisehak *et al.,* 2011).

M. oleifera and *M. stenopetala* are the two most common species among the species of the Moringa family, both species have many characteristics in common (Schneemann, 2011). They are commonly grown, but *M. oleifera* is widely cultivated and got research and development attention (Seifu, 2014). *M. oleifera* differs in growing habit, leaf, flower, and pod characteristics from

M. stenopetala (Palada and Chang, 2003; Amaglo, 2006). The trunk of *M. stenopetala* is considerably thicker at the base; the tree seems more vigorous, produces larger seeds and leaves than *M. oleifera;* but, *M. stenopetala* leaves taste similar to *M. oleifera* when cooked and milder if tasted raw (ECHO, 2007). The roots of *M. oleifera* are used as a condiment similar to horseradish while the thick bark of *M. stenopetala* is used; the first flowers of *M. stenopetala* appeared after 2.5 years compared to 2 years for *M. oleifera* raised from seeds and both continues year round after begin to first flower, while *M. oleifera* grown from cuttings start flowering after 8 to 12 months (ECHO, 2007). Bosch (2004) recommended *M. stenopetala* as important multi–purpose tree for semi-arid climates than *M. oleifera*.

M. stenopetala is often named as African Moringa tree because it is native to southern Ethiopia, North Kenya and Eastern Somalia (Bosch, 2004; Jiru *et al.,* 2006; Gebregiorgis *et al.,* 2011). It is not as widely known as its close relative *M. oleifera* which is native to India, Africa, Arabia, Southeast Asia, South America, and the Pacific and Caribbean Islands (Amaglo, 2006; Jiru *et al.,* 2006; Coppin, 2008). *M. stenopetala* is a deciduous tree 6-12m tall having more or less 60cm in diameter at breast height; its crown is strongly branched sometimes with several trunks and its wood is soft (Edwards *et al.,* 2000). Leaves alternate, up to 55cm long, 2–3-pinnate, with about 5 pairs of pinnate; stipules absent, but petiole with stipulate glands at base; 3-9 leaflets elliptic to ovate per pinnate, 3.5–6.5cm × 2–3.5cm, with stipple-like glands at base of stalk, rounded to connate at base, apex acute, with thickened apiculum; flowers are very fragrant with cream flushed pink sepals, white, pale yellow or yellow-green petals, white filaments and yellow anthers (Bosch, 2004). The ovary is ovoid and densely hairy and its Pods are elongate, reddish with grayish bloom having grooved valves (Beyene, 2005). *M. stenopetala* is planted either by direct seeding, transplanting, or using hard stem cuttings (Palada and Chang, 2003). *M. stenopetala* does not have any specific soil requirements, but it prefers a well-drained sandy loam or loamy soils, it tolerates a clay soil except it does not grow on waterlogged or swampy soils and it does not tolerate prolonged flooding; it tolerates a wide range of soil pH (5–9) from slightly acidic to slightly alkaline (Moges, 2004; ECHO, 2007; Radovich, 2011).

In Ethiopia *M. stenopetala*, is a native tree in arid, semi-arid and semi-humid areas in the altitudinal ranged 1,000 to 1,800 m.a.s.l (Mark, 1998) but it also grows from 390 to about 2200 m.a.s.l in the Southern Rift Valley of Ethiopia (Jiru *et al.,* 2006). It is found widely distributed in Konso, Wolayta, D'irashe, Gamogofa, Sidama, Bale and Borana areas (Aynalem, 2008; Gebregiorgis *et al.,* 2011). It grows well in areas receiving annual rainfall amounts that range from 250 to 1500 mm and between 25 to 35^{o}C, can tolerate up to 48^{o}C in the shade and survive light frost (Amaglo, 2006). In marginal dry parts of Ethiopia *M. stenopetala* tree is found intercropped with agricultural crops by the Konso people and as on farm tree (home-garden) that supports nearly high population density in South Ethiopia (Jiru *et al.,* 2006). *M. stenopetala* is a multipurpose tree that is cultivated as agroforestry in Southern Ethiopia; used as living hedges (alley cropping) and windbreaks to reduce the rate of erosion; sometimes the trees are also used to provide partial shade for crops like sorghum; leaves can also be used as a green manure (Demeulenaere, 2001; Beyene, 2005; Schneemann, 2011). In Arba Minch, Ethiopia, the tree is mainly grown in home gardens of up to 0.1 ha with 5–15 trees per garden; other crops usually grown in these gardens are papaya, coffee, banana, cassava, maize, sugar cane, cotton and Capsicum peppers (Schneemann 2011). The choice of vegetables that are adapted to alley cropping is important, such as shade-tolerant leafy vegetables and herbs, since Moringa hedgerows are highly competitive and can reduce yields of companion plants significantly (Palada and Chang 2003;, Amaglo, 2006). In Konso areas *M. stenopetala* is definitely grow in fields, where it is among the most common indigenous species, along with *Terminalia brownii, Cordia africana, Croton macrostachyus*, various acacias, *Carica papaya, Berchemia discolor* (Demeulenaere, 2001).

M. stenopetala is described as providing multifunctions in nutrition through decrease hunger; improve health and human nutrition by suppling different food products as all parts of the tree are edible; it also described as Africa's solution to malnutrition and also called mothers' best friend (Fuglie, 2003). A single plant of *M. stenopetala* is able to support a large family for several years (Abuye *et al.,* 2003; Yisehak *et al.,* 2011). In the study area of Alamata district of southern Tigray zone the species is dispersedly planted and introduced at households' backyard (homestead) as agroforestry, in compounds, Farmers Training Center, nursery sites, schools, farm lands and marginal patchy lands. It was distributed for demonstration and promoted as food, feed, commercial product purpose and totally for its socioeconomic significance. The dissemination of *M. stenopetala* in the study area is in its early stage. There had been interests by different stakeholders to the promotion of its socio-economic significance and nutritional values. However, it didn't receive significant research attention to select, develop as well as potentially evaluate the already introduced *M. stenopetala* plantation in the homesteads and nearby marginal planted areas. Therefore, to support the expansion efforts of its socio-economic significance and understand its interaction with soils we studied the effects of *M. stenopetela* trees on some key soil properties and socio-economic benefits. We assessed effect of planting *M. stenopetala* on key soil properties, benefits to household income, farmer's perception on *M. stenopetala* plantation and its distribution in homestead areas.

MATERIALS AND METHODS

Study Areas

Alamata, the study area is located in Southern zone of Tigray Regional State, Ethiopia. It is the south most district of the region and it is one of Southern Tigray zone "*Developmental Corridor*" district where commercial agriculture is developing. Geographically the district is situated at 12^{0}25'N and 39^{0}33'E. It is located about 180 km south of Mekelle the capital city of Tigray region and 600 km north of Addis Ababa (Figure 1). Altitude of the district ranges between 1450 and 3000 m.a.s.l. Topographically, Alamata is divided into western highland and eastern lowland. There are two zones (urban and rural areas) namely the rural area called Raya Alamata zone and it has 15 *tabias* and Alamata zone also called Alamata town, comprised of four kebeles (WoARD, 2012). The western highland includes five rural *tabias*; areas have not *M. stenopetala* trees categorized under the northern highlands of Ethiopia, having an altitude range of 2000 to 3000 m.a.s.l. It is characterized by steep slopes, gorges and undulating terrain having scattered flat lands used for grazing livestock and farming. It covers 25% of the Woreda (WoARD, 2012). The eastern lowland part includes the rest ten rural *tabias* and Alamata town having *M. stenopetala* areas is generally plain in topography surrounded by a chain of mountains from the west and partly north with an altitude ranging from 1450 to 1750 m.a.s.l. It covers 75% of the Woreda and has plain low landscape (WoARD, 2012). The study sites are located within the Eastern lowland because *M. stenopetala* is found within these eastern lowland plain.

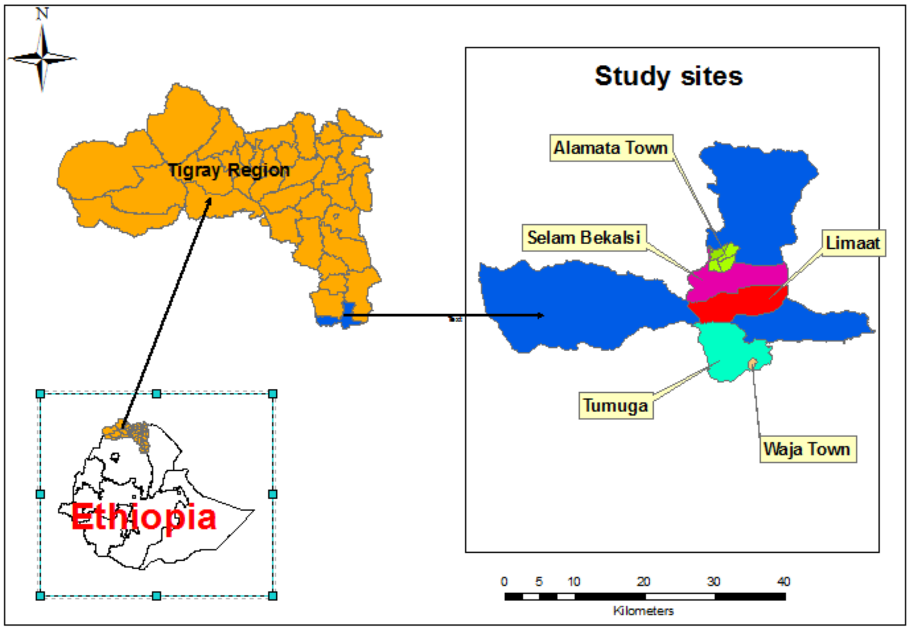

Figure 1: Location map of study areas

The mean annual rainfall and temperature and average monthly rainfall and temperature distribution of the one decade (2002 – 2011) ranges from 25 to 76.7 mm/year and 12°C to 31°C, and 10 to 199 mm/month and 14°C to 33°C, respectively (Figure 2, TNMA, 2012). It experiences bimodal rainfall, the short rain ranges from February to April and the main rain season from June to early September. Climate of the area differs between the lowland and highland. The study plantation area of eastern lowland sites are characterized by hot to warm sub-moist type of climate where the mean annual rainfall is between 41 to 82 mm and the mean annual temperature is 18°C to 31°C. A semi-bimodal rainfall pattern with a small peak in April and maximum peak in August dominates this area. The rainfall of the area is highly variable and evapo-transpiration is high (WoARD, 2012). The major soil types *are Eutric vertisols*, *Lithic leptosols* (Cambic) and *Lithic leptosols* (Orthic) (IPMS, 2010). The soil pH for profiles tested from the valley bottoms indicate that it ranges from 7.4 to 8.5 and is reported to increase with depth (REST, 1998).

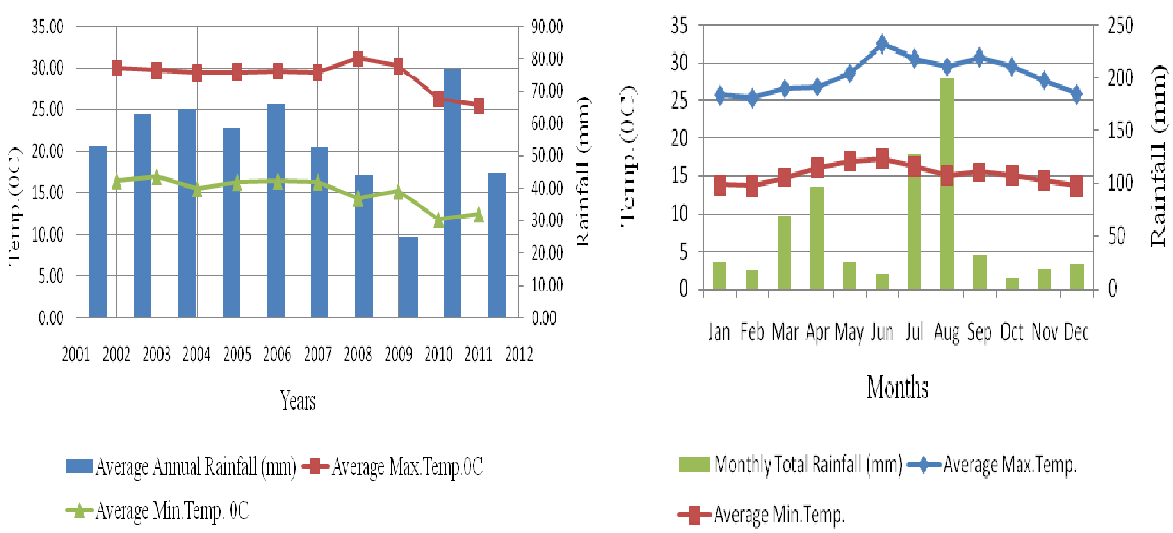

Figure 2: Annual and monthly rainfall and temperature distribution (2002-2011) of Alamata (TNMA, 2012)

Study Site selection and Household Selection

The criteria used to select the study sites for soil sampling and socioeconomic benefits were areas that have *M. stenopetala* in homestead agroforestry system. Discussion with the staff members of WoARD and Tigray Agricultural research Institute (TARI) Alamata branch was conducted for the abundances and distribution of the selected tree in all *tabias* of the Woreda. After discussion a reconnaissance survey was conducted to obtain an over view on localities that have *M. stenopetala* tree species that were planted in different homesteads and other nearby areas. According to the reconnaissance survey conducted, the distribution of *M. stenopetala* in the Woreda was planted mostly in homesteads and live fence in the rural *tabias* and urban areas as agroforestry system. *M. stenopetala* trees found in the eastern lowland plain topography areas of ten rural *tabias* and Alamata town. Vigorous *M. stenopetala* trees were found in homesteads having up to diameter at breast height of 66 cm and total height of 9 m. In such areas the *M. stenopetala* trees were found mixed with other species mostly in backyards. The trees in backyards were not selected as communities used to add external inputs like animal dung and related soil fertility enhancing inputs to the homesteads; so these areas were not preferable sites for trees selection in order to assess effects on soil properties. Here, in order to minimize confounding factors the trees for soil sampling were selected from marginal areas of nearby homesteads.

Selection of Trees and Sites for Soil Sampling

From the reconnaissance survey, nine *M. stenopetala* trees that were grown on marginal lands of nearby homestead areas were selected. The trees were selected randomly from isolated individuals and having nearly similar physiognomic characteristics and planted on similar site conditions, similar altitude, having similar height, DBH, age (all were ≈ 8 years age) and canopy diameter. Measurements of tree dimensions taken such as: diameter at breast height (DBH) using diameter tape, total tree height using suunto clinometer and crown diameter at crown base using measuring tape. All the nine sampled trees had mean crown length (vertical crown distance) of 72.56%.

Experimental Design and Field Layout: For soil sampling the area under the canopy of each tree was divided into four different radial transects of the tree trunk (Takimoto *et al*., 2008). The factors studied were depth and distance. Soil sampling were taken at two depths: 0 – 20 cm and 20 – 50 cm; and at three horizontal distances from the tree trunk: near 1 m (under canopy), 3 m (at the boarder of canopy), and 10 m from the trunk outside the area under canopy (control) at four different directions East, West, North and South around the tree having size 0.5m x 0.5m where composite soil samples were collected.

Soil Sample Collection: A total of 54 composite soil samples were collected from the nine *M. stenopetala* trees from four different directions of each of three distances at two depths. At each distance and depth soils were mixed to obtain a composite sample for the analysis of soil texture, soil pH, soil organic matter (OM), total nitrogen (TN), available phosphorous, exchangeable bases (Ca, Mg and K) and Cation Exchange Capacity (CEC) and transported for soil analysis to Mekelle soil laboratory.

Household Selection for Socioeconomic Studies

Out of the reconnaissance surveyed sites having *M. stenopetala* areas, two rural *tabias (Limat and Tumuga)* and two towns (*Waja-tumuga* and *Alamata*) were selected. The selection of the study areas was purposive based on their potential for *M. stenopetala* and households practice involving the use of the tree as socioeconomic benefits. In each of the four different study areas first population census of *M. stenopetala* growers and number of M*. stenopetala* of each households were conducted and found a total of 616 households. From the total *M. stenopetala* growing households census conducted, 587 (95.3%) were urban dwellers whereas 29 (4.7%) were rural dwellers. After population census had been conducted, from all study sites 100 households were taken using simple random sampling method from the list of growers for the study. For qualitative data collection additional focus group discussion with experts of office of WoARD, Alamata branch of TARI, administration office and local administrators was conducted.

Socio-economic Survey: Data collection was done through interview and observation survey of households sampling from *M. stenopetala* tree growers and focus group discussion with experts of office of WoARD, Alamata branch of Tigray agricultural institute (TARI), administration office and local administrators. Household interview was used based on the selected random sampling procedure of sample households survey from each of the four study areas to address the specific objectives of the socio-economic benefits. Household survey was the main source of information.

Soil Laboratory Analysis

In the laboratory, the composite soil samples were analyzed in Mekelle soil laboratory for soil texture by using hydrometer method (Gee and Bauder, 1986); soil pH was measured potential metrically using a digital pH meter in 1:2.5 soils to water suspension (Jackson, 1973). Organic carbon was determined following the Walkley-Black method (Walkley-Black, 1934) and OC was converted in to the organic matter by multiplying by a factor 1.724. Total nitrogen was analyzed by Kjeldahl procedure as described by (Ranst *et al*., 1999); available phosphorus was analyzed by Olsen method (Olsen and Sommers, 1982); Exchangeable Ca and Mg were determined by extraction of Ammonium Acetate with titration method while exchangeable K was determined from the same extraction (Ammonium Acetate) using flame photometer and CEC was determined by Ammonium Acetate method (Schollenberger and Simon, 1945).

Statistical Analysis

The experiment was laid out with single tree species, three radial/horizontal distance and two soil depths in factorial arrangement with factorial randomized complete block design. Two-way ANOVA was used to test whether or not a significant difference exists for mean soil parameters at 5% level of significance using the GLM of SAS 9.1 and JMP-5 statistical software's. Treatment means were compared using Fisher's Least Significant Difference (LSD).

The data collected from socio-economic survey were first coded and fed into SPSS 16.0. To assess share of income from *M. stenopetala* on total household income and perceptions of local communities on the tree*,* data were analyzed, compared and contrast using descriptive statistics and t-Test mean comparisons was used among rural and town study areas and how *M. stenopetala* contributes to total household income and different income components such as sales, food own consumption, medicinal value, fodder and fuel wood.

RESULTS AND DISCUSSION

Effect of *M. stenopetala* Tree on Soil Properties

Soil Texture and pH

The texture at the study sites were sandy loam to loam soils according to USDA textural classification. The sand proportion was (47.3%), silt (34.9%) and clay (17.6%) (Table 1). The soils of the areas were predominantly sandy (> 44.2%). The clay content in the soil was small (< 20.4%). The pH of the study areas ranged from 7.49 to 8.05. Soil pH was significantly different for both distance from the tree and soil depth (P<0.0001). The interaction effect between distance from the tree and soil depth was not significant (Table 2). There was a higher pH in the adjacent open area than under the canopy of *M. stenopetala* tree between the radial distance from the tree trunk and increased with depth (lower at 0-20 cm as compared to the 20-50 cm depth). The slight decrease in alkalinity under the canopy than the open area could be attributed due to break down of litter fall and dead roots from the tree, which means there was higher organic matter (OM) under the canopy and upper soil layer than the open area and subsoil layer, respectively. This more OM provides resilience (preventing rapid exchange) of pH. The finding of this study is in agreement with other species Bhatia *et al.,* (1998) who observed a significant reduction in soil pH under the canopies of *Prosopis juliflora.* Similarly Kahi *et al.* (2009) reported a significant difference (P<0.05) in pH between the soils within and outside the canopies of *Prosopis juliflora* and *Acacia tortilis*, The pH was found higher in the open cultivated land than under the canopy areas. Kamara and Haque (1992) reported a significant variation in soil pH horizontally under *F. albida* tree canopies which is different to the findings of Manjur (2011) under *F. albida* and *C. macrostachyus* tree species there were no significant differences in soil pH under the canopies compared to open area and depth differences.

Table 1: Soil texture class (USDA) at different distance from the canopy (1m, under the canopy; 3m, edge of canopy & 10m, outside the canopy), soil depth (cm) of *M. stenopetala* tree

Distance	Depth	Sand (%)	Silt (%)	Clay (%)	Soil Texture
Total	0-20cm	47.9	34.85	16.85	Loam
	20-50cm	46.8	34.96	18.26	Loam
1m		49.4	34.8	15.2	Loam
3m	Total	48.4	34.6	17	Loam
10m		44.2	35.3	20.4	Loam

Soil Organic Matter

Soil organic matter (OM) of the study area ranged from 1.3 to 3.8 falling in to very low OM level. There was a significant difference in soil OM between the radial distance from the tree canopy and soil depth (P<0.05). The interaction effect between distance from the tree and soil depth was not significant (Table 2). The soil OM was higher under the canopy of the tree than outside the canopy of the adjacent open area and showed a decreasing trend with increasing distance from the base of the tree towards the open field (P<0.0004) and decreased with depth (P<0.006). This variation in OM with distance away from the tree canopy could be due to decompositions of the plant residue: leaf litters fall, elongated pods contained many seeds fall and dead roots from the tree as compared to the adjacent open areas while the source of OM outside the canopy was mostly grass residues. There could be more recent decomposed and accumulated organic matter at the topsoil than subsoil layer as the leaves of trees were not cut for market value for the selected trees found on the marginal lands. Ashfaq *et al*. (2012) found similar result on *M. oleifera* tree and strongly recommended for Agro-forestry and rangelands of Pakistan to improve organic matter in soil and ultimately to improve the soil fertility. Hiawatha (2010) reported that, *M. oleifera* can grow on harsh and drier soils; it can be used as green manure to improve soil fertility. Yadessa *et al.* (2001) had reported a significant decrease in OC and OM away from the tree trunk to the open cultivated land on *Cordia africana* tree. Gindaba *et al.* (2005) also reported the surface soil OC under both *C. macrostachyus* and *C. africana* tree species was significantly higher (P<0.05) than that at the subsurface.

Total Nitrogen

Mean total nitrogen (TN) of the study area was 0.11 ranged from 0.07 to 1.14 rate falling into low to very low. TN was significantly different between the distance from the tree trunk and soil depth (Table 2). TN was higher under the canopy of the tree compared to the open area (P<0.0001). There was a decreased in TN with depth, higher at 0-20 cm as compared to the 20-50 cm depth (P<0.003). Higher TN under the canopy than the open area could be attributed to higher OM and nitrogen mineralization under the canopy and upper soil layer. The deep rooted system can operate as a nutrient pump for leached nitrogen from deep soil or slow down leaching. Studies conducted on *M. oleifera,* reported introduction of this plant into a farm can be beneficial for both the owner of the farm and the surrounding ecosystem; the seed cake of *M. oleifera* can be used as a nitrogen-rich plant fertilizer (Foidl *et al.,* 2001). Ashfaq *et al.,* (2012) reported that *M. oleifera* is deep rooted and does not compete with crops for nutritional concerns; it does not have any direct competition with food crops. Palada and Chang (2003) reported that Moringa once established the extensive and deep root system of Moringa is efficient in mining nutrients from the soil.

Available Phosphorus

Available phosphorus (Av. P) of the study area ranged from 1.34 to 15.98 having mean value 7.7 ppm falling into low to medium level. Available phosphorus was significantly higher at 0-20 cm as compared to the 20-50 cm soil depth (P<0.0001). This initial high phosphorus in the upper than sub soil layer could be due to high availability of OM on the upper soil layer. Available phosphorus was higher in the open areas than under the canopies of the tree but, didn't show significant difference (Table 2). However, Palada and Chang (2003) reported Moringa once established the extensive and deep root system of Moringa is efficient in mining nutrients from the soil. Available phosphorus was significantly higher in the open areas than under the canopies of A. *tortilis and P. juliflora* trees in Kenya (Kahi *et al.,* 2009), and Young (1989) also observed low phosphorus in sub-canopy zones and attributed it to being utilized in biological nitrogen fixation by the Rhizobium bacteria

Table 2: The effect of *M. stenopetala* tree on soil pH, Organic carbon (OC %), Organic Matter (OM %), Total nitrogen (TN %) and available phosphorus (ppm) at different distances from the canopy (1m, under the canopy; 3m, edge of canopy and 10m, outside the canopy) and soil depth (cm)

Distance	Depth	Soil Chemical Properties				
		pH	**OC**	**OM**	**TN**	**P**
		Mean ± Std. Dev				
1	0-20	7.58 ± 0.06	1.79 ± 0.3	3.09 ± 0.52	0.126 ± 0.01	9.33 ± 3.2
	20-50	7.86 ± 0.09	1.51 ± 0.31	2.61 ± 0.53	0.109 ± 0.02	4.86 ± 3.2
3	0-20	7.61 ± 0.08	1.68 ± 0.3	2.89 ± 0.51	0.118 ± 0.02	9.28 ± 3.4
	20-50	7.86 ± 0.09	1.38 ± 0.34	2.39 ± 0.58	0.108 ± 0.02	4.65 ± 3.06
10	0-20	7.72 ± 0.064	1.3 ± 0.36	2.24 ± 0.63	0.098 ± 0.01	11.87 ± 3.16
	20-50	7.95 ± 0.08	1.12 ± 0.3	1.92 ± 0.53	0.085 ± 0.01	5.97 ± 3.13
Total	0-20cm	7.64 [b]	1.59 [a]	2.74 [a]	0.114 [a]	10.16 [a]
	20-50cm	7.89 [a]	1.34 [b]	2.3 [b]	0.101[b]	5.16[b]
LSD		**0.0428**	**0.1748**	**0.3013**	**0.0082**	**1.7395**
P - Value		**0.0001**	**0.006**	**0.006**	**0.003**	**0.0001**
1m	Total	7.72 [b]	1.65[a]	2.85 [a]	0.117 [a]	7.1
3m		7.74 [b]	1.53 [a]	2.64 [a]	0.113[a]	6.97
10m		7.83[a]	1.21 [b]	2.08 [b]	0.092[b]	8.92
LSD		**0.063**	**0.2575**	**0.4439**	**0.0121**	**2.5626**
P - Value		**0.001**	**0.0004**	**0.0004**	**0.001**	**0.1**

* Means with the same letter are not significantly different at (P< 0.05)

Cation Exchange Capacity (CEC) and Exchangeable Cations

CEC of the soils was significant for distance from the tree (*P*<0.005) but not significantly different for both soil depth and their interaction effect. There was a higher value of CEC under the canopy of the tree than the adjacent open fields (Table 3). It decreased significantly with increasing distance from the tree trunk. This could be mainly due to high organic matter accumulation under the tree canopies than the open fields. The higher amounts of soil organic matter under the tree canopies may imply that more cations would be released to the soil through mineralization as a result; the amount of negative charges in the soil would be higher. There was no significant different for the soil depth, but was higher value of CEC at 20-50 cm soil depth than 0-20 cm soil depth, it increased with increasing soil depth.

Table 3: The effect of *M. stenopetala* tree on soil cation exchange capacity (CEC), Exchangeable Calcium (Ca) Exchangeable Magnesium (Mg) and Exchangeable potassium (K) at different distances from the canopy (1m, under the canopy; 3m, edge of canopy and 10m, outside the canopy) and soil depth (cm).

Distance from the tree (m)	Depth of Soil (cm)	Cations			
		CEC	**Exch. Ca**	**Exch. Mg**	**Exch. K**
		Mean ± Std. Dev (Meq/100g soil)			
1	0-20	36.56 ± 5.04	20.6 ± 2.45	6.93 ±1.08	1.197 ± 0.48
	20-50	37.85 ± 4.94	21.6 ± 1.7	7.46 ± 1.56	0.99 ± 0.21
3	0-20	34.8 ± 4.22	20.02 ± 2.28	6.68 ± 1.24	1.18 ± 0.49
	20-50	35.37 ± 3.88	20.21 ± 1.98	6.94 ± 1.29	0.96 ± 0.21
10	0-20	31.3 ± 3.69	17.94 ± 2.16	5.13 ± 1.36	0.7 ± 0.43
	20-50	32.96 ± 3.98	19.48 ± 1.54	5.32 ± 1.56	0.64 ± 0.32
Total	0-20	34.22	19.52	6.25	1.03
	20-50	35.39	20.43	6.58	0.87
LSD		**2.4059**	**1.1177**	**0.7429**	**0.2044**
P - Value		**0.3**	**0.1**	**0.3**	**0.1**
1	Total	37.2 [a]	21.1[a]	7.2 [a]	1.095 [a]
3		35.09[ab]	20.12[ab]	6.81 [a]	1.072[a]
10		32.13[b]	18.71[b]	5.23[b]	0.67[b]
LSD		**3.5422**	**1.6466**	**1.0945**	**0.3011**
P - Value		**0.005**	**0.004**	**0.0002**	**0.002**

* Means with the same letter are not significantly different at (*P*< 0.05)

The values of three primary exchangeable cations (Ca, Mg and K) were significantly different between distances from the tree ($P<0.05$). There was higher exchangeable Ca, Mg and K under the canopy of the tree than the adjacent open fields similar to CEC (Table 3). The amounts of cations in the soils significantly decreased as the distance from the tree trunk increased. This could be due to the high accumulation of litter under the tree canopies as the cations would be released when the accumulated litters from the canopies of the trees undergo microbial decomposition followed by mineralization and release of simple products to the soil; and decrease their reduction from leaching or erosion. It was reported that the content of K, Ca and Mg decreased from the top to the lower soil depths and from the closest to the midst and distant positions of the soil under *H. abyssinica, Senecio gigas* and *Chamaecytisus palmensis* trees (Mekonnen *et al.,* 2009). There was no significant difference showed for soil depth and their interaction effects for all the three exchangeable Cations but gradually increased with increasing depth for Ca and Mg where as decreased with increasing soil depth for K under the canopy of the tree (Table 3).

Homestead Agroforestry Practices and Distribution of *M. stenopetala*

The average sizes of homesteads of the households ranged from 0.01ha to 1ha; mostly 41% of the households own from 0.02 ha to 0.0625 ha areas of homesteads in the study areas. Traditionally, in the study areas, the homestead system of agroforestry trees commonly grown as home garden, live fence (boundary planting) and wind breaks. There were different number and types of tree species commonly grown (conserved) mixed together in homesteads based on their uses. About 28 tree species were recorded within the homesteads. Each of the respondents had from 1 - 16 tree species mixed together in their homesteads. These homestead agroforestry trees provide a wide range of uses. The products include food, medicinal value, livestock feed, construction material, fuel wood, farm tools, lumber and cash income for home use and sale. Other services that the trees provide includes boundary marking, windbreaks, live fence, soil erosion control, soil fertility enhancement, beauty and shade.

The distribution of *M. stenopetala* in the study areas was mostly in homesteads and live fence in the rural *tabias* and urban areas respectively. From the total respondents owned *M. stenopetala*, 95% had 1 - 10 *M. stenopetala* plant in their compounds/homesteads; whereas 5% of them owned 16 - 40 *M. stenopetala* plants. There were a total of 409 trees and on average 4 *M. stenopetala* per household. However, from the total number of trees 135 (33%) were less than one year old which were not ready for leaf harvest. A total of 274 *M. stenopetala* trees (2.7 *M. stenopetala* per household) between 2 and 12 years of tree age were ready for leaf harvest. In addition to homesteads, the species is found in the marginal lands, field farmers training center, schools, health centers, compound of different offices and on few farm lands. Higher abundance of M. *stenopetala* trees were observed in the towns (83%) than rural *tabias* (17%).

Socioeconomic Values of *M. stenopetala* Tree

There was no significant difference in household characteristics due to age, sex, educational level, household size and marital status between the households in the rural and town of *M. stenopetala* growers. Type of employment showed a significant difference in the income obtained from the tree between the rural and town households (Table 4).

Table 4: Chi-square Tests of sampled households characteristics by rural *tabias* and towns of study areas

Household characteristics	Chi-square Value	*P*-value
Age of head of the household	0.153	0.926 ns
Sex	0.014	0.906 ns
Educational status	8.886	0.064 ns
Household size	2.117	0.548 ns
Marital status	0.016	0.999 ns
Type of employment	12.267	0.002*

Significance level: *= $P<0.05$ significant and ns=not significant $P>0.05$

Households earned on average 4022.2 Ethiopian Birr/year/household from diversified income components of *M. stenopetala* products (Table 5). There was higher income (5013.5 Birr/year/household) in towns whereas 294.8 Birr/year/household in rural *tabias*. There was significant difference in incomes between households that purposefully include the tree as one source of income and those who didn't ($P<0.000$). The income of households was 61077, 564.5 and 232.5 Birr/year/household for Moringa growing and selling, off farm and farming workers, respectively (Table 5). Urban households earned better income than the rural households due to a better information access on *M. stenopetala* use for different purposes and accesses to market. The highly significant diference between households that include as one source of income than those didn't might be due to the difference in value addition. The once that depend mainly on the species prepared powder of *M. stenopetala* leaves for market and sale as a source of income to major town such as Alamata (local market), Mekelle (regional market) and to Addis Ababa (national market).

Table 5: Mean comparisons of annual incomes earned in Birr/year/household from *M. stenopetala* among rural and towns based on occupational differences

Occupation	Name of study areas		Total income earned	Sig
	Rural *tabias*	Towns		
Farming	264.4	215.6	232.5	0.61
No.	18	34	52	
Off farm	476.7	571.3	564.5	0.61
No.	3	39	42	
Moringa member (Moringa growing and selling)		61077	61077	0.000
No.		6	6	
Total	**294.8**	**5013.5**	**4022.6**	
No.	**21**	**79**	**100**	

The average gross incomes of households earned per year was 25% from farming, 53.4% from off farm, 18.9% from *M. stenopetala* and 2.7% was from homestead agroforestry trees excluding *M. stenopetala* (Table 6). In the study areas from the total respondents, 87% of them used *M. stenopetala* as income source, and 13% didn't. The respondents earned on average 4022.6 Birr/ household/year from *M. stenopetala* and it comprised an average of 18.9% share of the total annual gross incomes (Table 6). The species perceived by the communities as more valuable than fruit trees due to the higher income contribution to the household. The average income of households' from *M. stenopetala* had significant contribution to the total incomes shares (Table 7). ETFF (2004) and Demeulenaere (2001) reported that, in some parts of southern Ethiopia, especially among the Konso people, the one with many Moringa tree in the garden or on farmland has a higher social status and also considered rich. *M. stenopetala* used to diversify income; 74% for direct sales, 41% for food own consumption, 35% for medicinal value, 7% for fodder, 37% for fuel wood and environmental service (soil conservation, soil fertility improvement, windbreaks, live fence, beauty and shade) values (Table 7). It was reported *M. stenopetala* is a multipurpose tree that is cultivated as agroforestry in Southern Ethiopia used for human food, fuel wood, livestock forage, medicine, dye, water purification, green manure and its seeds as soil fertilizer, both leaves and seeds used for oil extraction as well as for environmental service and socio-cultural values (Seifu, 2014). Leaves and seeds are rich in oils and the tree is used as source of income for Moringa growers. The tree is called a 'miracle tree' (Seifu, 2014; Amaglo, 2006; Jiru *et al.,* 2006; Demeulenaere, 2001; Schneemann, 2011) due to its multipurpose uses.

Table 6: Total incomes earned from different sources estimated monetary value

S/N	Income sources earned	No. of households income earned		Annual incomes earned in Birr/year/ household				%
		Yes	No	Min.	Max.	Sum	Mean	
1	*M. stenopetala*	87	13	0	69840	402260	4022.60	18.9
2	Homestead agroforestry trees (excluding Moringa)	30	70	0	18,000	56670	566.7	2.7
3	Farming	78	22	0	65680	530535	5303.35	25
4	Off farm/ other sources	65	35	0	80000	1135895	11358.95	53.4
	Total annual incomes earned			**1100**	**113940**	**2125160**	**21251.60**	

M. stenopetala leaves had high market demand and becoming income source for the study areas because the tree is in full leaf throughout the year especially at the end of the dry season when other food sources are typically scarce. *M. stenopetala* leaves used for local markets sale and leaf powder also marketed as a source of income to the local, regional and national markets. It is growing fast, drought-tolerant and its leaves can cut several times per year. The price of fresh leaves from a single tree vary with location, size of trees, time and awareness of households. Market price of single tree for fresh leaves varied from 30 to 300 Birr per plant and the average price of a single tree to harvest the leaf was 200 Birr per plant. Leaves from a single tree can be harvested on average 3 to 4 times per year for fresh leave product. There were households that harvested less than 3 and more than 4 times per year per single tree for fresh leaf products. 74% of households used *M. stenopetala* leaves as income source. The average income earned from the sale of leaf was 3649.60 Birr/household/year (Table 6). Leaf productions can be viable economic endeavors to meet the growing population demand by planting in their homesteads with small expenses incurred. Moringa cooperative members found in towns buy fresh leaf products from *M. stenopetala* growers in towns and they collect the leaves from different farming households that maintain the tree in their farming system. The cooperatives prepared powder of *M. stenopetala* leaves for market as a source of income and sale to major towns due to the value chain established by the local authorities since 2010. The Moringa members' market price of *M. stenopetala* leaf powder was 100 Birr per 1kg. All the Moringa members found in Alamata town were youth females. The tree had great role for females as can be done with less labor and earns fair economic values. The members were first trained on the uses of Moringa as human food, medicinal values and promotion of its commercial product purposes on the processing of Moringa leaves in to different food items for marketing, to create rural –urban linkage source of income.

The tree is used as food in the study area. 41% of the respondents used *M. stenopetala* leaves as main ingredient of food (Table 8). They had eaten the leaf as vegetables either fresh or dried as raw, cooked like *cabbage*, cooked with carrot & potato or made into a powder. The powder can be added to any types of sauce (1-3 teaspoons in each sauce), soups, tea and coffee. Flour is also prepared with rice in the study area. Abuye *et al.* (2003) and Melesse *et al.* (2011) reported *M. stenopetala* has various benefits to Ethiopian subsistence agricultural community as a source of daily diet and local medicinal value and the leaves contain protein, carbohydrate, fat, fiber, minerals (Na, K, P, Ca, Fe and Zn) and vitamins. Single plant of *M. stenopetala* is able to support a large family for several years (Yisehak *et al*., 2011). The average estimated value used as human food per household was 158.78 Birr/year (Table 7). The leaves have slightly bitter taste and has not good smell which restrict many people to use. Demeulenaere (2001) reported the criterion adopted for the selection is associated with the taste of leaves; the farmers' favor the less bitter varieties and they use the less disintegrating leaf variety while cooking.

M. stenopetala tree had been used mostly for its nutritional and medicinal values. The leaves used as traditional medicinal values to protect and treat from causing different diseases (Table 7). In the study areas 35% of the respondents used the tree as traditional medicinal values and its average medicinal values was estimated at 170.61 Birr/household/year. The local communities used the leaves to treat different problems such as; *hypertension* (27%), *diabetes* (3%), *asthma*

(9%), *gastritis* (2%), *cold (cough)* (31%), *Nephritis (Kulalit)* (1%), *Arthritis (Kurtmat)* (6%), *Hemorrhoid (Kintarot)* (2%), and *malaria* (13%). The chopped leaves are used to treat *fungal infection (capotes, corporals, Athletics) wound* healing (4%). Moringa tree parts such as leaves, flowers, seeds, pods, roots, barks used for traditional medicine and treats for more than 157 different diseases (Hiawatha, 2010). All parts of *M oleifera* tree have been used in folk medicine practices; its leaves, bark, roots, flowers, pods and seeds has been used for about 41, 16, 23, 8, 5 and 9 types of traditional medicinal use respectively (Fahey 2005; and Rajangam *et al*. 2001). Local people in Ethiopia used the boiled leaves as tea or chopped and mixed it with water to treat malaria, hypertension, stomach problems, expulsion of retained placenta and in some other problems like asthma and diabetes (Mokonnen and Gessesse, 1998; Fuglie, 2003; Palada and Chang, 2003; Amaglo 2006; Jiru *et al.,* 2006; ECHO 2007; Mekete 2008; Morey 2010; Yisehak *et al.,* 2011; Melesse *et al.,* 2011).

Table 7: Comparison of total income earned Vs different sources in Birr/year/household

Average annual income earned		Mean	N	Std. Deviation	Sig.
Pair 1	Homestead AF trees (excluding Moringa)	5.6670E2	100	2422.18	.033
	Total annual income earned	2.1252E4	100	23629.25	
Pair 2	Farming	5.3034E3	100	11254.22	.001
	Total annual income earned	2.1252E4	100	23629.25	
Pair 3	Off farm	1.1359E4	100	18961.93	.000
	Total annual income earned	2.1252E4	100	23629.25	
Pair 4	*M. stenopetala*	4.0226E3	100	14579.44	.000
	Total annual income earned	2.1252E4	100	23629.25	

Leaves and pods of Moringa are used for animal fodder. The use of leaves and pods for animal fodder was minor compared to the other contributions (Table 8), 7% of the respondents used as sheep and goat fodder. The estimated average value used as animal fodder was 8.76 Birr/household/year. It is reported that *M. stenopetala* leaves and pods can be used as cattle, sheep, pigs, and goats fodder. Supplementation of animal feed with Moringa is a viable option for improving the production and productivity of livestock (Abuye *et al.,* 2003; Palada and Chang 2003; Jiru *et al*., 2006; Gebregiorgis *et al*., 2011; Yisehak *et al.,* 2011). *M. oleifera* as livestock feed and fodder is rich in nutrients, which are essential for livestock for weight gain (up to 32%) and increase in milk production (up to 43-65%) and is also rich in iron, potassium, calcium and multivitamins (Mathur, 2006).

M. stenopetala trees had been collected for leaf powder and the leaves cut with its branches and the remaining parts of twigs/branches were dried and had been used for fuel wood. The supplies are small and is often used as a fuel in small quantity (Table 8). From the respondents 37% used the tree as fire wood source and estimated average value was 34.85 Birr/household/year. Similarly, studies by Palada and Chang (2003); Jiru *et al.,* (2006) reported that *M. stenopetala* grows rapidly, have softwood that is not particularly suitable for fuel and is often used as a fuel in small quantity in its natural range when other sources are scarce. *M. stenopetala* also provide environmental services such as boundary markers, windbreaks, live fence, soil erosion control, soil fertility enhancement, beauty and shade.

Perception and Knowledge of Communities' towards *M. stenopetala*

The leaves and stem (branches) were used as economic values of *M. stenopetala* tree parts (Table 8). 87% the respondents used the leaves for market as a source of cash income, human consumption, medicinal value, animal fodder and 37% of them used its stem (branches) for fire wood. Most of the communities' were well aware of the uses of *M. stenopetala* tree for its different uses. From the total respondent, 2% of them had no awareness on economic uses of the plant while 98% of them had positive perception that the tree has high contribution to their income. They stressed that if people in both rural and urban areas grow *M. stenopetala* in their respective localities, it will play the multiple roles of assisting farmers' income and health and help replenish the ever diminishing forest resource of the areas. According to the focus group discussion and 29% of the respondents stressed the species is perceived by the communities as more valuable than fruit trees and farmers have started deliberately to plant *M. stenopetala* trees in their homestead and other areas. The perception of the households' is in consistence with ETFF (2004) and Demeulenaere (2001) that state in some parts of southern Ethiopia, especially among the Konso people, the economic status of an individual is closely associated with the number of Moringa trees they have in their backyards. The abundance of Moringa species in the garden or on farmland indicates the social status of the owner among the society.

Table 8: Mean comparison of different uses of *M. stenopetala*, used tree parts and estimated monetary value of the tree parts used per year

Uses or benefits used	No. of households		Used Moringa tree parts	Estimated value of used parts from each benefit in Birr/year			
	Yes	No		Minimum	Maximum	Sum	Mean
Income sold (Market)	74	26	Leaves	0	60,000	364,960	3649.60
Human consumption (food)	41	59	Leaves	0	4,800	15,878	158.78
Traditional Medicinal value	35	65	Leaves	0	4,800	17,061	170.61
Fire wood	37	63	Stem(wood)	0	250	3485	34.85
Animal feed (Fodder)	7	93	Leaves	0	300	876	8.76
Soil erosion conservation	16	84	Leaves, pods, roots				
Improvement of soil fertility	14	86	Leaves, pods, roots				
Total incomes earned	**87**	**13**		**30**	**69840**	**402260**	**4022.6**

CONCLUSIONS

M. stenopetala is a plant of homestead agroforestry tree, provide options for sustaining environmental services and provide several socio-economic benefits in the study areas. Soil pH was significantly lower under the canopy of *M. stenopetala* tree. Soil OM, TN, CEC, and exchangeable Ca, Mg and K were significantly higher under the canopy compared to the open marginal land and declined with distance from the tree base to open area. *M. stenopetala* is efficient at increasing soil fertility. It enhances and conserves soil organic matter and upgrade the capacity of the soil to supply plant nutrients and helps for sustainable ecosystem. However, available phosphorus was not significant to conclude whether *M. stenopetala* tree can be competitive for phosphorus sensitive crops. *M. stenopetala* tree leaves cultivated for its different uses in the study areas. *M. stenopetala* can be used as an additional income sources and could improve households' income security. Local people perceive that *M. stenopetala* contributes to household income, conserve and enhance soil fertility, windbreaks, live fence, beauty and shade; and it is a tree with a fast growth, can grow within homesteads that requires little financial investment and management. The leaves of *M. stenopetala* can be stored for long times as powder that increase its shelf life. It is used as source of income for urban unemployed youths and had created employment means for rural and urban Moringa growers and urban processors. *M. stenopetala* leaf production could be viable economic ventures for the growing populations and help reverse soil fertility depletion and can improve agricultural productivity.

Conflict of Interest

Conflict of interest none declared.

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