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Evaluating the effect of scattered *Moringa stenopetala* trees on yield of sorghum crop and soil physico-chemical properties in Derashe District, Southern Ethiopia

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Abstract

Moringa stenopetala is one of the world's most useful plants; it is a fast-growing, much more drought-tolerant and multi-purpose tree. In Ethiopia it is a native tree in arid, semi-arid and semi-humid areas in the altitudinal ranged from 390 to 2200 m.a.s. The objective of this study was to evaluate the effect of *M. stenopetala* on intercropped sorghum yield and soil physicochemical properties. Six matured *M. stenopetala* trees found in 1 km^2 area were selected for the experiment. Collected data were subjected to ANOVA using the GenStat software version 16. The sorghum grain yield in open area and tree canopy of zone C was significantly higher than the grain yield of zone A and zone B, respectively. There was no significant variation in the texture of the soil laterally and vertically but soil bulk density (BD) showed a significant variation ($p<0.05$) with increasing distance from tree trunk. The soil OM was higher outside the canopy of the adjacent open area than under the canopy and showed an increasing trend with increasing distance from the base of the tree towards the open field and decreased with depth ($P<0.05$). There was higher soil pH in the adjacent open area than tree canopy and increased with depth. The soil OM, TN, and OC were higher in open area than tree canopy and showed an increasing trend with increasing distance from the base of the tree towards the open field and decreased with depth ($P<0.05$). Available phosphorus was significantly higher under canopy of the tree than in the open areas. Higher benefit cost ratio (BCR) was recorded with treatment that integrates *M. stenopetala* with sorghum, thus it is a feasible option than sorghum mono-cropping to generate more income and other benefits derived from planted *Moringa stenopetala* trees.

Keywords: Agroforestry; Benefit cost ratio; Intercropping; Scattered Moringa; Tree canopy

1. Introduction

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; 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 (Palada.,2003; ECHO, 2009; Morey, 2010; Meless *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 *al.,* 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). Its English names are Africa Moringa tree, Ben oil tree, Cabbage tree, Horse-

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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 *et al.,* 2011). It grows well in areas receiving annual rainfall amounts that range from 250 mm to 1500 mm and between 25 °C to 35 °C and can tolerate up to 48 °C and survive light frost (Amaglo, 2006). *M. stenopetala* is found in scattered manner in the farms of lowland areas of Derashe district. The effect of these scattered trees’ canopy in the farm on understory plants is complex and context-dependent. Scattered trees can exert positive, negative or neutral effects on production, composition and diversity of understory plant communities, depending on local environmental conditions and position in the landscape (Schade *et al.,* 2003). Besides this agroforestry trees can enhance soil fertility in terms of plant-available nitrogen and phosphorus (Hailemariam *et al*. 2010), efficient in P uptake through mycorrhizal infection. They are redistributed to the soil system via litter and root decomposition and mineralization (Rao, *et al*, 1998). Thus, tree may contribute to the nutrient supply to the soil reducing the need for external inputs and increase the soil organic matter. The improvement in soil physical properties under trees is widely established. Tree root systems have been reported to reduce bulk density, increase porosity and improve aggregate stability. These changes lead to higher rain water infiltration and, thus, higher water availability (Ilstedt *et al.,* 2007).

Sorghum crop is one of the best performing cereal major crop widely cultivated being intercropped with *M. stenopetala* tree**.** However, rarely few studies have been undertaken regarding the effect of *Moringa stenopetala* species on intercropped cereal crops and soil physico-chemical properties and are not supported by empirical studies. Therefore the objective of this study was to evaluate the effect of *Moringa stenopetala* on intercropped sorghum yield and soil physicochemical properties.

2. Material and methods

2.1. Description of study site

The study was conducted in Derashe district, Southern Ethiopia. The Destrict is located at about 540km south of Addis Ababa. It is bordered by Konso zone in the south, Gamo Zone in the North, Alle district in the west and Amaro and Burji districts in the East. Geographically, the experimental site is located at 5^{o}044’06” N and 37^{0}24’47”E. Meteorological records reveal that rainfall pattern in Derashe district is bimodal (“Belg” and “Meher”). “Belg” is the main cropping season that lasts between January and May. Most of the crop production takes place during the “Belg” season. The mean annual rainfall ranges between 1000 mm-1500 mm, whereas the average temperature is 27 °C. The altitude of study site is 1328 meters m.a.s.l. (BoARD, 2007).

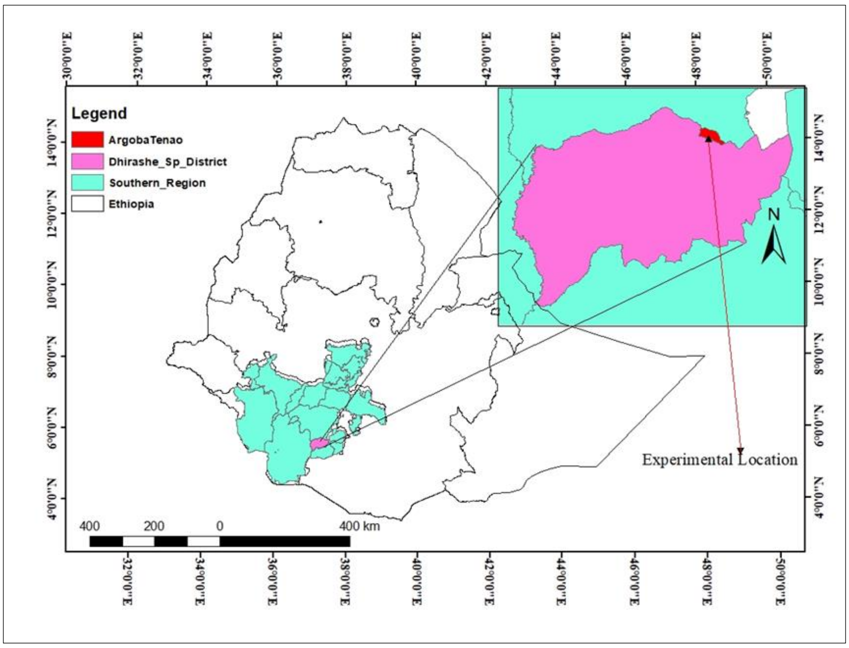

Figure 1 Location map of study area

2.2. Site selection

Six matured *Moringa stenopetala* trees found in 1 km^2 area was selected for the experiment based on their position relative to other trees to ensure that no nearby trees could shade them. On the other hand site biophysical uniformity was considered. Tree height, canopy cover as area of tree influence, trunk diameter measurement was done. Tree stand history was documented through discussion with local farmers.

Table 1 Characteristics of the scatterd *Moringa stenopetala* trees studied in Derashe District, Southern Ethiopia

Tree (Replication)	Tree height (m)	DBH (cm)	Canopy radius (m)			Area (m^2)			Total area (m^2)
			ZA	ZB	ZC	ZA	ZB	ZC	
1	6.2	19.7	1	2	5	3.1	12.6	62.8	78.5
2	4.8	30.3	1.5	3	6	7.1	21.2	84.7	113.0
3	6.4	50.9	0.9	1.8	4.8	2.5	7.6	62.2	72.3
4	4.2	28.7	1.8	3.6	6.6	10.2	30.5	96.1	136.8
5	3.6	28	1.2	2.4	5.4	4.5	13.6	73.5	91.6
6	4.1	31.9	1.2	2.4	5.4	4.5	13.6	73.5	91.6

ZA: from the trunk to half of the crown projection radius, ZB: from half of the crown projection radius to the edge of the crown projection, ZC: from the edge of the crown projection to a distance of 3 m and DBH: diameter at breast height

2.3. Soil sampling

Layout and Experimental Design

The area under each tree was subdivided into three concentric zones: Zone A: from the trunk to half of the crown projection radius; Zone B: from half of the crown projection radius to the edge of the crown projection; Zone C: from the edge of the crown projection to a distance of 3 meters and Un-shaded control plot (4*4 m) at 40 meters distance from the edge of the crown of all sampled and any other trees was assigned. Teshale sorghum variety was sown in the circular plot under the shade trees as well as in control plot with 75cm between rows and 15 cm among plants with recommended fertilizer rate. Measurements of sorghum crop performance and soil nutrient status was made under the crown of all selected trees. All other Sorghum farming operations were performed manually following local practices. The design employed for soil assessment was a 3*2 factorial arrangement of treatments in randomized complete block design (RCBD) replicated six times, totaling 3*2*6*4=144 samples under tree canopy and 2 samples away from tree. Soil samples were taken at three distances under canopy (zone A, zone B and zone C) and 40m away from the base of tree trunk at 0-15cm depth representing the top soil and 15-30cm depth to represent subsurface soil. In this way soil were taken from six replicated trees and open fields. Soil samples taken from the same distance and depth in four directions from tree trunks were pooled or bulked to make composite sample (Jiregna *et al.,* 2005). After bulking the four sub- samples and by quartering a composite sample of 1.5kg was prepared for the chemical and physical analysis. But for bulk density assessment, a separate soil sample with 15cm^3 core sampler was collected.

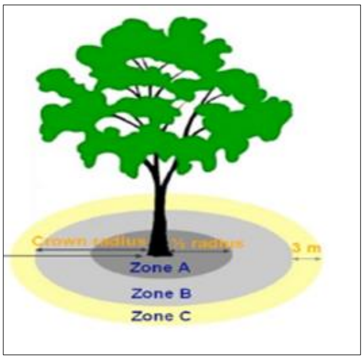

Figure 2 Experimental design

2.4. Data analysis

Collected data were subjected to one-way (for sorghum yield parameter) and two-way (for influence of the tree on soil physico-chemical properties) analysis of variance (ANOVA) using the GenStat software version 16. Comparison of treatment means was performed using Fisher's Least Significant Difference (LSD) test at $P<0.05$ probability level. Soil samples were air dried and sieved through a 2mm sieve to remove roots or microscopic litter, stones and gravel. Samples were secured, labeled and sent for analysis in the Soil Laboratory.

Table 2 Method of soil data analysis in the laboratory

Parameters	Methods
pH	Measured by pH
Texture	Hydrometer method (Bouyoucos)
Organic carbon and Organic matter	Walkley and Black method (Schnitzer, 1982)
Total Nitrogen	Kjeldahl method (Bremner & Mulvaney, 1982)
Available Phosphorus and potassium	According to Olsen et al., (1954)
Bulk density	Oven dry weight at 105 °C weight to soil volume (Brady and Weil, 2002)

3. Results and discussion

3.1. Sorghum grain yield and yield parameters

The result of this study showed that there was significant differences in all parameters under tree canopy of *Moringa stenopetala* and the open area ($p<0.05$). The sorghum grain yield in open area (3.29 t ha^{-1}) and tree canopy of zone C (3.09 t ha^{-1}) was significantly higher than the grain yield of zone A (1.78 t ha^{-1}) and zone B (1.77 t ha^{-1}), respectively. Highest biomass yield was recorded in open area (6.09 t ha^{-1}) than tree canopy of *Moringa stenopetala.* The plant height and panicle length were significantly affected by canopy, thus it increases with increasing distance from tree trunk to out ward. Hundred seed weight was also affected by the canopy of *M.stenopetala,* as a result zone A was significantly lowered than the rest three treatments (Table 3).

The reduction of sorghum grain yields under *M.stenopetala* trees was could be due higher above ground (sun light) and below ground (nutrient) competition. On the other hand, high grain yields on open area and zone C was might be due to absence of completion for sun light and nutrients. Reduced growth due to intercepted photo synthetically active radiation (IPAR) has been reported by Sinclair and Muchow (1999) and Liu *et al* (2012).

Table 3 Effect of scattered *M. stenopetala* on sorghum yield at Derashe District, Southern Ethiopia (combined)

Treatment	Plant height (m)	Panicle length (cm)	Biomass weight (t ha^{-1})	Grain yield (t ha^{-1})	1000 seed weight (gm)
Control	1.71^{a}	22.81^{a}	6.09^{a}	3.29^{a}	23.84^{a}
ZA	1.52^{b}	19.08^{c}	3.13^{c}	1.78^{b}	20.82^{b}
ZB	1.60^{ab}	19.81^{bc}	4.08^{bc}	1.77^{b}	23.63^{a}
ZC	1.70^{a}	21.45^{ab}	4.83^{b}	3.09^{a}	24.92^{a}
Mean	1.6	20.79	4.5	2.5	23.31
CV (%)	11.3	12.6	30.1	29.5	13.4
LSD	0.15	2.17	1.13	0.61	2.58

ZA: from the trunk to half of the crown projection radius, **ZB**: from half of the crown projection radius to the edge of the crown projection, **ZC**: from the edge of the crown projection to a distance of 3 m. Means showing different letters are significantly different in a column at a 5% probability level

3.2. Soil physico-chemical properties

3.2.1. Soil physical properties

Soil Texture

The texture of the study site was loam soil according to USDA textural classification. The result of textural analysis in Table 4 below showed that there was no significant variation in the texture of the soil laterally as function of distance from tree trunk and vertically as function of depth under canopy and outside canopy. The sand fraction content of the soil sampled from under canopy of *M.stenopetala* tree showed neither vertical nor horizontal significant difference ($P>0.05$). However, there was numerically higher sand fraction on top soil (0-15cm soil depth) as compared to sub-soil (15-30cm soil depth) under canopy and outside canopy. Similarly, the silt fraction content of the soil was also not significantly ($P>0.05$) affected by distance from the trees trunk and soil depth. The clay fraction content of the soil showed the same trend as that of the silt fraction. The mean value of the clay fraction under canopy was higher than clay fraction at its open field.

Results of textural analysis revealed that the soils under the tree canopy and open area were texturally similar being loam and having been derived from the same parent material under the same climate, similar topography and vegetation cover for 0-15cm depth and 15-30 cm depths. The findings of the current study on the sand fraction are in agreement with that of Tadesse *et al.* (2000) who observed non-significant variation of sand fraction content of soils both laterally and vertically under canopy and outside canopy of *Millettia ferruginea* in southern Ethiopia. Similarly, the findings of this study also agree with the reports of Abebe, (1998) from evaluation of *C. africana* under cropland and rangeland ecosystem reported that the sand fraction in cropland was non-significant both vertically and horizontally from the tree base. Similarly, Aweto and Dikinya (2003) found no significant differences in the mean proportions of sand fraction between the soils under the canopies of *Peltophorum africanum* and *Combretum apiculatum* and in open grassland from Botswana.

The result for soil silt fraction showed that the silt fraction of the soil was not significantly affected by distance from both trees base and soil depth (Table 4). Findings of the present study are in agreement with Hailemariam *et al*. (2010) who observed non-significant variation in silt fraction content of soils under *Balanites aegyptiaca* at Goblel and Korbebite sites from Northern Ethiopia. Similarly Tadesse *et al.* (2000) found silt content that did not significantly vary with increasing distance from tree trunk and increasing soil depth under *M. ferruginea* while Aweto and Dikinya (2003) observed similar trend i.e. no significant differences in the mean proportions of silt content between the soils under the canopies of *Peltophorum africanum* and *Combretum apiculatum* trees and in the open grassland in a semi-arid savannah rangeland in Botswana. Contradicting the present investigation, Abebe, (1998) found significant variation in silt fraction content under cropland and rangeland ecosystem of *Cordia Africana.*

The clay content of the soil was not affected significantly by distance from the tree and soil depth. The present study is in agreement with Hailemariam *et al*. (2010) who observed non-significant variation in clay fraction content of soils under *Balanites aegyptiaca* at Goblel and Korbebite sites from Northern Ethiopia. Similarly Tadesse *et al.* (2000) observed non-significant variation in clay fraction content of soils both laterally and vertically under canopy and outside canopy of *M. ferruginea* from southern Ethiopia. Besides, Abebe (1998) found statistically no significant difference laterally from *Cordia africana* under both cropland and rangeland ecosystems.

Soil Bulk Density (BD)

Soil bulk density (BD) showed a significant variation ($p<0.05$) with increasing distance from tree trunk. The soil BD under zone A and zone B was lower than zone C and the open area for both depths of soil. However, the differences for both depths of tree canopy and open area were not significant ($p>0.05$). Lower soil BD under the tree canopy is presumably due to the effect of higher concentration of tree roots near the base of the trees may have had the effect of loosening the soil, thereby reducing soil BD. Furthermore, the soil outside the tree canopies dries out more, being exposed to direct solar radiation. On account of the higher soil bulk density in the open field, infiltration is lower in the soil at open field. Hence, soil outside the trees canopy will be more prone to surface runoff and erosion on account of reduced infiltration capacity. In addition to increased infiltration, trees in farm help to reduce soil erosion by improving soil aggregate stability by binding soil particles together.

Findings for this study are in concert with the findings of Jiregna, Rozanov and Legesse (2005) who reported lower BD levels under *C.africana* and *C.macrostachyus* canopies as compared to open farm. Tadesse *et al*. (2000) on BD under and outside *Millettia* trees showed that both the BD of the surface soils (0.61 g cm^3) and the subsurface soils (0.76 g cm^3) under the trees were lower than the bulk density of the surface soils (0.69 g cm^3) and the subsurface soils (0.80 g cm^3)

in the open areas. Pandey *et al*. (2000) also reported lower BD under the canopy of *A. nilotica* in a traditional agroforestry system in central India, while Aweto and Dikinya (2003) reported lower BD under the canopies of *P. africanum* and *C. apiculatum* as compared to open rangeland from Botswana.

Table 4 Soil physical properties as influenced by radial distance and soil depth of *M. stenopetala* tree in Derashe District

Concentric zone	Upper soil surface (0-15cm)				Sub-surface (15-30cm)			
	Sand (%)	Silt (%)	Clay (%)	Soil BD (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	Soil BD (g/cm^3)
Zone A	49.4	34.8	15.2	1.22^b	49.2	35.1	15.1	1.27^b
Zone B	48.4	34.6	17	1.23^b	48.3	35.2	17.9	1.26^b
Zone C	44.2	35.3	20.4	1.39^a	44.4	35.4	19.5	1.49^a
Control	48.1	34.3	16.4	1.40^a	48.0	34.5	15.5	1.52^a
G. mean	47.53	34.75	17.25	1.31	47.5	35.1	17	1.39
CV (%)	15.3	17.6	16.12	15.04	16	11.5	13.7	8.3
LSD	NS	NS	NS	0.121	NS	NS	NS	0.123

ZA: trunk to half-crown projection radius, ZB: half-crown projection radius to the edge of the crown projection, ZC: the edge of the crown projection to a distance of 3 m. NS: not significant, BD: bulk density, Means showing different letters are significantly different in a column at a 5% probability level

3.2.2. Soil chemical properties

Soil Organic Matter

Soil organic matter (OM) of the study area ranged from 4.81 to 8.14. It was higher outside the canopy of the adjacent open area than under the canopy and showed an increasing trend with increasing distance from the base of the tree towards the open field and decreased with depth (P<0.05). The interaction effect between soil depths was not significant (Table 5).

The lower OM under tree canopy could be due to the frequent harvesting of leave for human consumption and removal of branches at every two years by pruning. Besides these, nutrient uptake by crops and the tree itself could be resulted the lower OM under tree canopy. The higher source of OM outside the tree canopy might be resulted from mulching of crop residuals as the district is known by its soil and water conservation activities. There could be more recent decomposed and accumulated organic matter at the topsoil than subsoil layer as the grasses and annual crop residuals were not cut for market value.

Total Nitrogen and Organic Carbon: The total nitrogen (TN) of the study area was ranged from 0.24 to 0.41 rates falling in medium to high. TN was significantly different between the tree canopy and open area (Table 5). TN was higher under in open area compared to the canopy of the tree (P<0.05). There was a decreased in TN with depth, higher at 0-15 cm as compared to the 15-30 cm depth (P<0.05). Higher TN in open area than under tree canopy could be attributed to lower OM accumulation due frequent harvesting of *M. stenopetala* leafs and removal of pruned branches from farm land every two years. Furthermore, the accumulation of crop residuals in the form of mulching is the known practice in the district might contribute higher TN in open area.

The soil organic carbon was significantly influenced between tree canopy and open area (P<0.05). However, organic carbon was not significantly affected by soil depths both for tree canopy and open area.

Soil pH

The pH of the study areas ranged from 5.40 to 6.41. Mean soil pH was significantly different between tree canopy and open area (P<0.05). The interaction effect between distance from the tree and soil depth was not significant (Table 5). There was a higher pH in the adjacent open area than under the canopy of *M. stenopetala* tree and increased with depth (lower at 0- 15 cm as compared to the 15-30 cm depth). The lower soil pH values under canopy of *M. stenopetala* as compared to open field might be due to several mechanisms that release H+ ions, such as soil base cation uptake or depletion by biomass, decomposition of organic matter to organic acids and CO2, root respiration and nitrification.

Rhodes, (1997) suggested that increased accumulation of aboveground biomass and associated cation uptake by the tree component of agroforestry systems as possibly one of the causes for decreased pH in soils. 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, 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.

Available Phosphorus and Available Potassium: Available phosphorus (Av. P) of the study area ranged from 12.99 to 18.85ppm falling into low according to the classification of Landon, 1991. Available phosphorus was numerically higher at 0-15 cm as compared to the 15-30 cm soil depth (P<0.05). 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 significantly higher under canopy of the tree than in the open areas (P<0.05) (Table 5). Palada and Chang (2003) reported moringa once established the extensive and deep root system is efficient in mining nutrients from the soil. Similarly Pandey, Singh and Sharma (2000) studied the influence of three tree canopy positions found that P were greater under mid canopy and canopy edge positions compared to canopy gap. 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.

Available potassium (Av. k) of the study area ranged from 240.14 to 267.95 ppm. It was also significantly affected by tree canopy and open area. Like that of available phosphorus, available potassium was also numerically higher at 0-15 cm as compared to the 15-30 cm soil depth (P<0.05).

Table 5 Soil chemical properties as influenced by radial distance and soil depth of M*. stenopetala* tree in Derashe District

Concentric zone	Upper soil surface (0-15cm)						Sub-surface (15-30cm)					
	pH	%OM	TN	%OC	AV.P	AV.K	pH	%OM	TN	%OC	AV.P	AV.K
Zone A	6.21^{a}	5.7^{a}	0.28^{a} a	3.3^{a}	19.1^{b} b	272.1^{a}	6.4^{a}	4.46^{b} b	0.22^{b}	2.59 ^{b}	16.7^{b} b	268.0^{a}
Zone B	6.32^{a}a	5.01^{ab}	0.25^{ab}	2.91^{ab}	19.1^{b} b	265.2^{a}	6.21^{a}	5.07^{b}	0.25^{b}	2.94^{b}	17.1^{b}	247.0^{a}
Zone C	6.3^{a}	3.89 ^{b} b	0.2 ^{b} b	2.26^{b} b	19.5^{b} b	278.3^{a}	6.3^{a}	4..4^{b}	0.22^{b}	2.55^{b}b	20.0^{a}	257.3^{a}
Control	5.4^{b}	5.119^{a}a	0.26 ^{a} a	2.97^{a}	23.8^{a} a	265.8^{a}	6.2^{a}	8.14^{a}	0.41^{a}a	4.7^{a}	12.9^{c}c a	253.8^{a}
G. Mean	6.06	4.93	0.25	2.86	20.36	270.3	6.28	5.52	0.28	3.20	16.7	256.5
LSD	0.22	1.16	0.06	0.68	2.71	25.53	0.35	1.131	0.057	0.66	2.51	19.28
CV%	2.9	19.2	19.2	19.2	10.8	7.7	4.5	16.7	16.7	16.7	12.2	6.1

OM= organic matter, TN= total nitrogen, OC = Organic Carbon, Av.P= Available phosphorus and AV..K=Available potassium. Means showing different letters are significantly different in a column at a 5% probability level.

3.3. Economic Analysis

The economic analysis of moringa based intercropping with sorghum and sorghum mono-cropping was assessed in terms of benefit cost ratio (BCR) to know which practice is more profitable for the producer. Accordingly, the analysis of returns to sorghum mono-cropping revealed lower BCR (7.56) than moringa intercropped with sorghum (8.43) (Table 6). Higher benefit cost ratio (BCR) was recorded with treatment that integrates *M.stenopetala* with sorghum (8.43). A project with benefit cost ratio greater, equal or less than unity, indicates profit, breakeven or loss, respectively. Since both ratios are greater than unity for this production system, the greater ratio was recorded in *M.stenopetala* intercropped with sorghum production which is more profitable than sorghum mono-cropping. Even though the moringa based agroforestry of Derashe district is not well documented, agroforestry practices increased income opportunities, economic stability, reduced cost of production, increased ability to manage sustained yield and improved the livelihood of the farmers in the area. Yohannes (2017) report the average total income earned from agro-forestry practice exceeds mono-cropping system in the same units of lands in Konso district, southern Ethiopia.

Table 6 Benefit cost analysis of *M. stenopetala* based agroforestry with sorghum crop in at Derashe District, Southern Ethiopia

Mean amount (ETB)					
Cost item	**Zone A**	**Zone B**	**Zone C**	**Control (mono cropping)**	**Agroforestry (A+B+C)**
Total Revenue/ha (TR)	65261	64981	101941	89204	103649
Total variable cost/ha (TVC)	10300	10300	10300	9800	10300
Gross marginal/ha (GM) = (TR-TVC)	54961	54681	91641	79404	93349
Total fixed cost/ha (TFC)	2000	2000	2000	2000	2000
Total cost/ha(TC) = (TFC+TVC)	12300	12300	12300	11800	12300
Net income (NI) = (GM - TFC)	52961	52681	89641	77404	91349
Benefit Cost Ratio (BCR)	5.31	5.28	8.29	7.56	8.43

Source: own data

4. Conclusion and recommendation

M. stenopetala is a plant of homestead and park land agroforestry tree, provide options for sustaining environmental services and provide several socio-economic benefits in the study areas. The sorghum grain yield and yield components were significantly affected by scattered *Moringa stenopetala* tree as compared to the open area. Soil pH and bulk density was significantly lower under the canopy of *M. stenopetala* tree. Likewise soil OM, TN, and K were significantly affected between under the canopy and adjacent open area. Available phosphorus was higher under tree canopy as compared to adjacent open area. Higher benefit cost ratio (BCR) was recorded with the production which integrates *M.stenopetala* with sorghum (8.43) than sorghum mono-cropping (7.56). Intercropping *Moringa stenopetala* with sorghum was financially attractive than sorghum mono-cropping. Therefore in sorghum and *Moringa stenopetala* growing moisture deficit areas of southern Ethiopia, integrating both crops is a feasible option than sorghum mono-cropping to generate more income and other benefits derived from planted *Moringa stenopetala* trees.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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