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Research Article

Growth, Productivity and Charcoal Conversion Efficiency of *Acacia decurrens* Woodlot

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Abstract

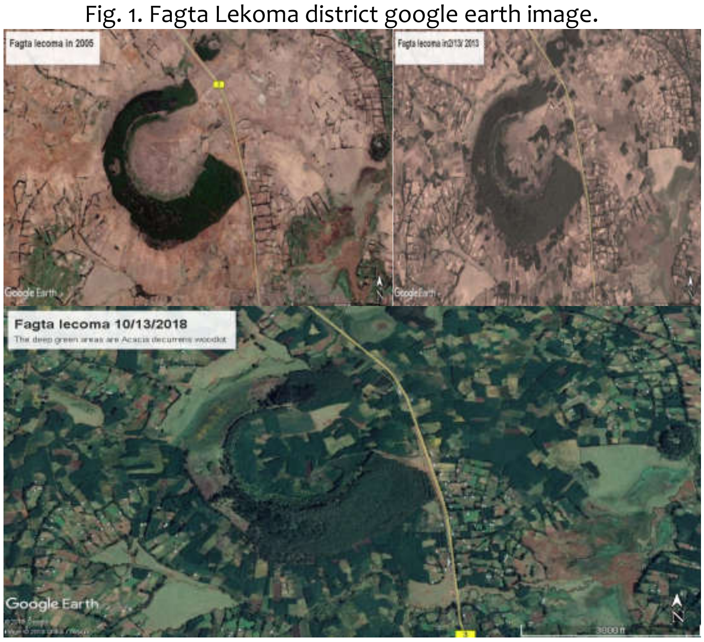
This study evaluated the productivity of *Acacia decurrens* woodlots and charcoal conversion efficiency and financial feasibility of the woodlots. Purposive and probability-based sampling strategies were applied. The primary data was collected from 20 woodlots and 60 producer households. In addition to the individual interview and woodlot inventory, group discussion, key informant interview and field observations were conducted to complement the data. Data was analyzed using descriptive and inferential statistics using SPSS and Microsoft Excel software. The woodlot inventory revealed that *A. decurrens* trees attain a height of 11.51±0.19 m and 5.92±0.07 cm DBH within 5.5 years. The basal area and volume growth of *A. decurrens* woodlot were 45.95±3.8 m^2/ha and 262.15±23.06 m^3/ha for 5.5 years respectively. The MAI of *A. decurrens* woodlot was highest (47.37 m^3/ha) for 5.5 years. Charcoal productivity varied according to the age of woodlots which was 3989.95±204.8 and 5226.53±320 sacks/ha from 4.5 and 5.5 years respectively with traditional earth mound kiln production technique. The conversion efficiency of wood to charcoal was 25.16±1.2% for 4.5 years and 28.35±2.2% for 5.5 years woodlot in weight base. The charcoal production system is profitable that smallholder producers gain 63,963.9 ETB and 71,520.04 ETB NPV in the entire woodlot and charcoal production with the rotation age of 4.5 years and 5.5 years respectively. This study indicates that both the charcoal productivity and charcoal conversion efficiency increases with the age of the woodlot. It is highly recommended to increase the rotation age of the *A. decurrens* woodlots from 4.5 years to 5.5 years for enhanced charcoal productivity and farmer's net income.

Keywords: *Acacia decurrens* woodlots, charcoal conversion efficiency, rotation age, charcoal productivity.

Introduction

Fagta Lekoma district forest coverage can be increased from time to time due to *Acacia decurrens* woodlot expansion. From 1995 to 2015, the district forest coverage increased by 1.2% per year, while areas covered by cropland decreased by 1% per year (Menale and Wolde, 2018). In the same way, from 2003 up to 2017, forest land area coverage has increased by 256% from the expense of cultivated lands and wetlands. The district forest area coverage could reach 25.6% (Menale and Wolde, 2018). This forest cover change was due to the expansion of *A. decurrens* woodlot having socioeconomic and environmental implications that improve rural livelihoods and revitalize the degraded lands (Yigezet *al.*, 2018). Almost 90% of the local population both rural and urban parts of communities could participate directly or indirectly related to the production of *A. decurrens* woodlot (Bireda, 2015). Its production system can minimize the internal migration of the rural community. These days youths, men and women are busy with all the value chains of *A. decurrens* woodlot production system (Yazie and Anteneh, 2018).

Fig. 1. Fagta Lekoma district google earth image.



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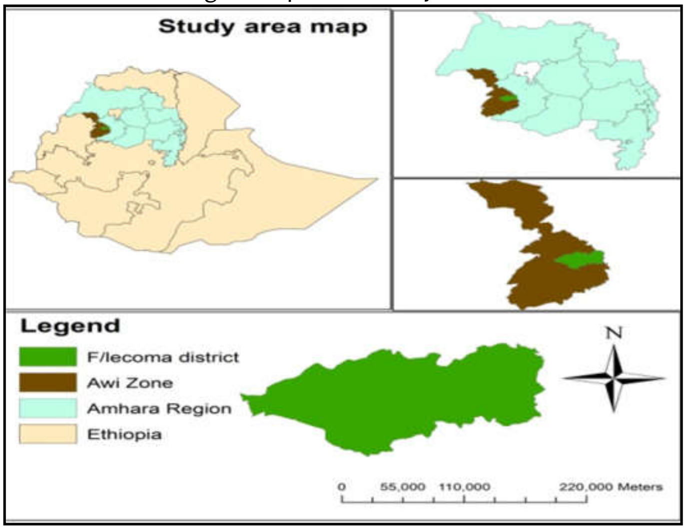
This study was a concern to investigate the production potential, charcoal conversion efficiency and financial feasibility of *A. decurrens* woodlot in Fagta Lekoma district. The area was selected for this study due to the high rate of *A. decurrens* woodlot expansion and commercialization of charcoal production. Its cultivation for charcoal production is becoming an integral part of the farming system for the district. The area covered by *A. decurrens* woodlot as an annual crop is shown in google earth map (Fig. 1).

Materials and methods

Description of the study area: The study was conducted in Fagta Lekoma district of Awi Zone. It is located about 460 km northwest of Addis Abeba and 100 km southwest of Bahir Dar on the main road of Bahir Dar to Addis Abeba. Geographically it is situated at 10°57'23" to 11°11'21" North latitude and 36°40'01" to 37°05'21" East longitude (Fig. 2). The Altitudinal range is from 1887 to 2902 m above sea level and the district covers a total area of 65,579 ha (Menale and Wolde, 2018). The district is part of the moist subtropical agro-ecological zone of the North-Western highlands of Ethiopia which have two agro-climatic zones. Dega and Weyina Dega regions which covering 55% and 45%, respectively (Bireda, 2015). The area is characterized by flatlands and moderately steep rolling topography (Abiot and Ewuketu, 2017) which is dominated by the tertiary volcanic rock and Quaternary Basalts. The relief type consists of 62% plain, 23% mountains, and 15% others (Bireda, 2015). It experiences a mean annual rainfall of 1629.77 mm with the high rainfall occurring from June to October. The maximum and minimum monthly rainfall occurred in July 414.55 mm and January 4.68 mm respectively and the average mean monthly rainfall was 141.86 mm. The mean annual minimum and maximum temperatures were 8.47°C in February and 26.2°C in March and the average annual temperature is 18.16°C (NMA, 2019). The farming system is mixed agriculture under the rain-fed farming system. The major annual crops in the study area are Potato, Teff and Barley (Achamyeleh *et al.*, 2015). The major land use categories of the district are forest land, cropland, grassland, and settlement. Croplands (52.5%) and forest land (25.6%) account for the largest share (Menale and Wolde, 2018). The district has a total population of 126,367. From this 117,467 are rural people whereas; the remains 8,906 are urban dwellers (CSA, 2007). There are various sources of livelihood for local communities living in the district. These include crop production and livestock production, timber, charcoal, and other non-timber forest products (Yigez *et al.*, 2018).

Sampling and data collection techniques: From Fagta Lekoma district, Gefera and Gulla was purposively selected because the two Kebeles are the hotspot area for *A. decurrens* based woodlot production system.

Fig. 2. Map of the study area.



A total of 20 *A. decurrens* woodlots were selected from five different age classes (1.5, 2.5, 3.5, 4.5, and 5.5 years) from the selected Kebeles. Each age was replicated four times. The selected woodlots were planted for the same purpose (charcoal production). On each sample woodlots, four (5x5m^2) sample quadrants were randomly selected. To lay the quadrant from a single woodlot, the length and width of the woodlot was measured. Then the total woodlot area was divided into 5 m x 5 m sample quadrant area. A total of 80 quadrants were selected randomly from 20 woodlots. There were obligatory situations to use this way of sampling method because the woodlot area that lay the sample quadrant was small which is from 0.25 to 0.5 hectares. Hence it was difficult to use the transect line method. Besides, the woodlot tree distribution is uniform through the woodlot because the management of the woodlot is uniform. And also, there were enough sample trees (40 to 70 trees per quadrant). Tree diameter, height, number of trees per plot and age of the woodlot as well as wood and charcoal weight before and after charcoal production was recorded. For social-economic survey; 60 household heads were selected randomly from the total 848 of households which makes about 7% sampling intensity. The required data were collected through a semi-structured and structured questionnaire. In addition to this, group discussion and key informant interviews were conducted to complement individual interviews. For the estimation of charcoal conversion efficiency, data were collected from the charcoal preparation units. The common harvesting ages for charcoal production are 4.5 and 5.5 years woodlot. Therefore, eight woodlots were selected purposively as soon as harvested woodlot for charcoal production purposes. The weights of the wood were measured before the wood is stacked for charcoaling and the weights of the charcoal were measured after charcoaling.

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Data analysis: Collected data were analyzed using data analyzing software. The estimation of woodlot productivity and charcoal conversion efficiency were evaluated on standard parameters. The quantitative data obtained from the household interview and field measurement were analyzed using descriptive statistics (Mean and percentage) by using Microsoft excel 2007 and IMB SPSS 20 statistical software. The collected empirical data were presented in Tables and Graphs. While inferential statistics such as T-test, correlation, and regression were applied for comparing woodlot productivity and charcoal conversion efficiency with the different woodlot age, evaluated the relationships of woodlot density, height, DBH and volume of the woodlot as well as charcoal conversion efficiency and woodlot productivity with age. The quantitative data were calculated using the following formulas.

Mean annual and current annual increment of the woodlot (West, 2009)

$$\mathrm{MAI} = \frac{V}{A} \ldots\ldots\ldots.. \mathrm{Eq1}$$

Where, MAI= main annual increment, V= Current stand volume, A=Age of the woodlot

$$\mathrm{CAI} = \frac{P}{A} \ldots\ldots. \mathrm{Eq1}$$

Where, CAI= Current annual increment, P= One year growth stand volume, A=Age of the woodlot

The productivity of *A. decurrens* woodlot (West, 2009)
$V = B * H * r$...... Eq2

Where, V= Stand volume in a specific unit area, B= Basal area of the stand, H= mean height of the trees, r=0.4875 (form factor of *A. decurrens* trees) (Biazen *et al*., 2018).
Charcoal conversion efficiency in traditional earth mound kiln (Okello *et al*., 2001) and (Schenkelb *et al*., 1998)

$$f = \frac{\mathrm{Wcharcoal}}{\mathrm{Wwood}} \ldots\ldots \mathrm{Eq3}$$

Where, f= conversion factor, W_{wood}= Weight of wood, $W_{charcoal}$ = Weight of charcoal

The financial feasibility of investments should be based on financial indicators (Eq4-Eq6).

Net present value (NPV)(Whitman and Terry,2012)

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(B-C)}{(1+r)^{\wedge}t} \ldots\ldots\ldots \mathrm{Eq4}$$

Where, B = Total benefit generated from the investment, C = Total costs invest for the investment, r = the discount rate, 12% according to current Ethiopian condition (Eshetu et al., 2018) t = time period

Benefit cost ratio (BCR)(Whitman and Terry, 2012)

$$\mathrm{BCR} = \frac{\sum_{t=0}^{n} \frac{B}{(1+r)^{\wedge}t}}{\sum_{t=0}^{n} \frac{C}{(1+r)^{\wedge}t}} \ldots\ldots.. \mathrm{Eq5}$$

Internal rate of return (IRR)(Whitman and Terry, 2012)

$$\mathrm{IRR} = \sum_{t=0}^{n} \frac{B-c}{(1+r)^{\wedge}t} = 0 \ldots. \mathrm{Eq6}$$

These financial indicators, Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) were analysis by Microsoft Excels 2007 (Whitman and Terry, 2012). The NPV determines the net returns of the production system by discounting the streams of benefits and costs back to the establishment year using an appropriate discount rate (12 %) over the lifetime (Eshetu *et al*., 2018).

Results and discussion

Height and DBH growth trend along with woodlot age: On average, *A. decurrens* trees in the study area attain 11.71±0.24 m height and 6.29 ±0.25 cm DBH within 5.5 years under traditional farmer's management (Fig. 3). The growing trend of height and DBH is the logarithmic function. This result revealed that *A. decurrens* tree has fast growth potential in the study area. This is highest compared to other species even if Eucalyptus and the growth of *A. decurrens* for another place (Kindu *et al*., 2006). This could be due to the suitability of agro-ecology in the study area for the production of *A. decurrens* tree. The height and DBH growth performance of *A. decurrens* in the study area indicates the potential of the area which is better from another area of Ethiopia (Tesfaye and Belachew, 2003; Tatek *et al*., 2018). It is also competent to Mount Merapi, Indonesia height growth performance (Afrianto *et al*., 2017).

Fig. 3. Height and DBH growth trends along with woodlot age.

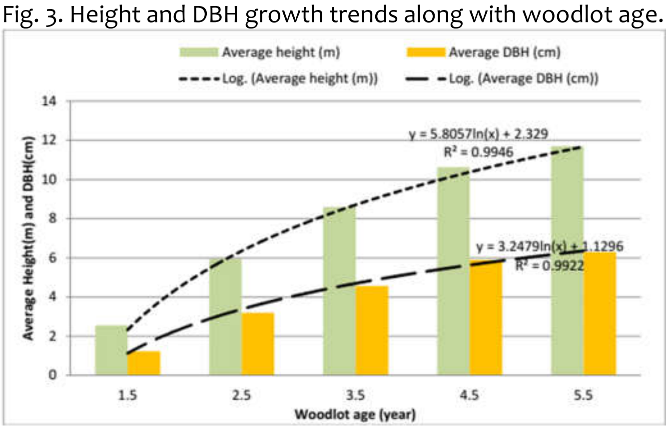

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Fig. 4. Basal area and volume growth trend.

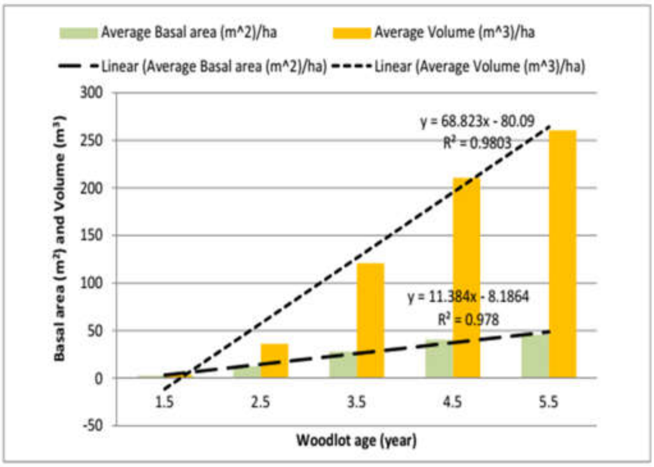


Fig. 5. *Acacia decurrens* woodlot basal area MAI and CAI trend.

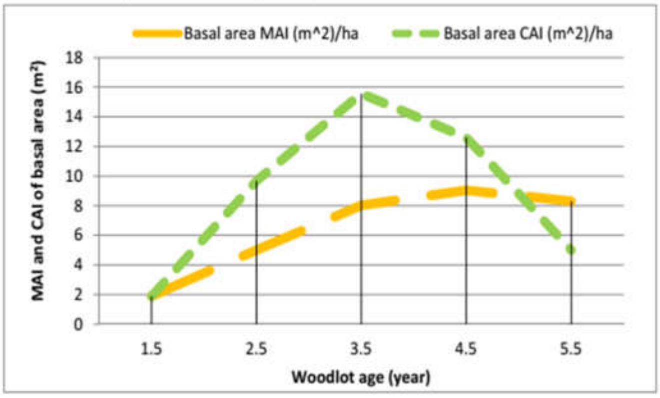
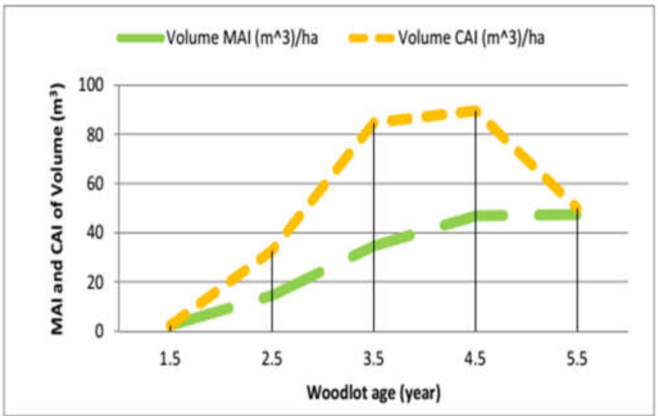


Fig. 6. *Acacia decurrens* woodlot Volume MAI and CAI trend.



Basal area and volume growth trend along with woodlot age: Both basal area and volume showed a linear growth trend up to 5.5 years (Fig. 4). The result indicates that it has fast growth in terms of basal area and volume and has the highest production potential in the study area.

The mean basal area was 40.9±4.3 m^2/ha and 45.95±3.8 m^2/ha at the age of 4.5 and 5.5 years respectively, While the mean volume growth was 212.65±9.68 and 262.15±23.06 m^3/ha in volume for 4.5 and 5.5 years respectively. This result indicates *A. decurrens* woodlot has a fast-growing trend and more productive in the area. The result is nearly similar from Matthews *et al*. (2016) report in Mount Merapi, Indonesia.

MAI and CAI of Acacia decurrens woodlot: The basal area of *A. decurrens* woodlot can increase in the first 3.5 years at an increasing rate but after 3.5 years, it has a decreasing rate. However, the MAI and CAI of *A. decurrens* basal area was equal at five years of age of the woodlot (Fig. 5). The volume growth rate of *A. decurrens* woodlot increases for the first 4.5 years with an increasing rate, but after 4.5 years it has a decreasing rate (Fig. 6). The maximum CAI of the volume was 86.65 $m^3ha^{-1}year^{-1}$ at 4 years age. The average volume MAI of the *A. decurrens* woodlot in the study area is 47.37 m^3/ ha/year at 5.5 years. This result is better than the MAI of Eucalyptus woodlots in Ethiopia (Million, 2011). The MAI and CAI can be intercepting at 5.5 years of woodlot age. Therefore, the rotation period of *A. decurrens* woodlot in the study area is 5.5 years (Matthews *et al*., 2016). The peak growth rate year of *A. decurrens* woodlot is between 3.5 and 4.5 years. In general, this is more productive stand and has a short rotation period which shows an earlier peak growth and a steeper growth decline (Matthews *et al*., 2016).

Acacia decurrens woodlot productivity under the farmer's management: *Acacia decurrens* woodlot has a higher growth rate and productivity in the study area. Mean basal area and volume productions were 40.9±3.4 m^2/ha and 121.65±9.68 m^3/ha for 4.5 years, and 45.95±3.8 m^2/ha and 262.15±320 m^3/ha for 5.5 years woodlot. This is more productive than eucalyptus species (Zenebe, 2013; Muluneh, 2011). It is also the highest than average Ethiopian plantation forest production potential (Million, 2011). The total charcoal yields that harvested from rotation age of 4.5 and 5.5 years woodlot were 3,989.93±204.84 and 5,226.5±320.01 sack/ha respectively (Table 1). *Acacia decurrens* woodlot production system in Fagta Lekoma district is more than any other species. This might also be one of the motivating factors for the expansion of the production system in the entire district as well as the adjacent district. Due to this, the district can be a positive hope to balance the gap between fuel wood demand and supply at regional and national levels. This result indicates that the substantial amount of charcoal produced in the study area with the potential to reduce the pressure on the natural forests for charcoal production. This is indirectly reducing natural forest degradation.

The effect of tree density on woodlot productivity: The correlation between the different woodlot and tree parameters with the basal area and DBH of *A. decurrens* woodlots is shown in Table 1. Both DBH and height are positively correlated to volume but negatively correlated to stand density. Volume and DBH have a higher positive correlation than volume and height but DBH and height are positively correlated with each other (Table 2). The woodlot tree density was negatively correlated to volume. This is because the initial planting space of *A. decurrens* woodlot in the study area was very crowded up to 0.35 m between trees which was 14700±1075 trees/ha in 5.5 years woodlot to 23800±1716 tree/ha in 1.5 years woodlot. This is similar to Suryanto *et al*. (2010) report. This is the cause of earlier natural mortality due to resource computation and also increasing establishing cost. In the study area, production system of *A. decurrens* woodlot productivity was affected by stand density because the number of trees in the stand is very crowded which was planted up to 28000 trees/ha. Due to this, the plant cannot get the required resources abundantly and efficiently. Therefore the growth rate of the woodlot reduces by the cause of the highest resource computation between trees. Very crowded plant spacing reduces tree height and DBH growth rate. Then the volume incremental rate of *A. decurrens* woodlot also decreases (Suryanto *et al*., 2010).

Charcoal conversion efficiency of Acacia decurrens woodlot: Charcoal producers in the study area stacked 3.5 m^3 to 4.6 m^3 woods for a single traditional earth mound kiln. They harvested 650 to 950 kg (65 to 95 sacks) of charcoal from one kiln. The charcoal conversion efficiency of *A. decurrens* woodlot was different across the woodlot age but did not show a significant (P=0.05) difference. However, the woodlot age can affect charcoal conversion efficiency which is 25.16±1.2% for 4.5 years age and 28.35±2.2% for 5.5 years respectively in weight base (Table 3). And also, wood volume in 4.5 and 5.5 years age woodlot were not statistically significantly different (p=0.16). On the other hand, the charcoal yield has a difference significantly (P=0.017) at 95% confidence interval across the age of the woodlots that could be associated with the size of logs attained at 4.5 and 5.5 years harvesting. This study result was higher from FSS (2013) report of traditional earth mound kiln efficiency in Ethiopia. This could be because of the process of charcoal production that the producers give higher attention to every stage of the production process. However lower than higher wood density tree species such as *Prosopis juliflora* conversion efficiency (Getaneh *et al*., 2012). In general, the traditional earth mound kiln that was used in the study area has a lower efficiency than the steel kiln method (Mesfin, 1997).

Factors affecting charcoal conversion efficiency:Traditionally in the study area, charcoal producers stacked from 2347 kg to 3831 kg or 3.5 m^3 to 4.6 m^3 woods for a single traditional earth mound kiln. Therefore, the correlation of charcoal conversion efficiency to traditional charcoal producing kiln size was negative but not significantly affected. This means, when the amounts of wood increase, the charcoal conversion efficiency slightly decreases. This is because the larger mound size could increase the lifetime of carbonization that causes for decreasing the conversion efficiency which means it changes to ash. The woodlot age and charcoal producer's experience has a positive correlation with charcoal conversion efficiency. This is could be due to increasing the wood density in woodlot age and more experienced people can manage the process and cause to increase efficiency. This result is similar to Getaneh *et al*. (2012) study for *Prosopis juliflora* charcoal production using traditional earth mound kiln. The woodlot age has a slightly positive correlation to charcoal conversion efficiency but statistically not significant (Table 4).

Financial feasibility of Acacia decurrens woodlot and charcoal production system: *Acacia decurrens* woodlot production system has higher NPV and BCR than annual crops (the average of Teff, Potato, and Barley). However, IRR was higher in annual crop than *A. decurrens* woodlot. This is because the required cost of the annual crop is lower than *A. decurrens* woodlot (Table 5). This result indicates that woodlot production is a capital intensive activity than an annual crop (Zerihun *et al*., 2016). And also, 5.5 years harvesting woodlot has more profit than 4.5-year harvesting woodlot (Table 5 and 6). The woodlot producers can get additional NPV (7,556.94 ETB) which will extend the woodlot harvesting from 4.5 years to 5.5 years. This is greater than annual crop NPV (6,584.53 ETB) for one-year production. From the financial point of view, *A. decurrens* woodlot production can offer above 2 times NPV than annual crop production for a 4.5 year rotation period. *Acacia decurrens* woodlot has a 240.61% benefit advantage than annual crop production for 4.5 years rotation. The net non-discount profit of *A. decurrens* woodlot production for 4.5 and 5.5 years rotation is 124,504.8 ETB/ha and 153,563.95 ETB/ha respectively. This is 7.65 times more from net non-discount profit 16,270.48 ETB/ha of annual crop productions that produce from 4.5 years production period. However, the initial required cost of the annual crop is lower than the initial required cost of *A. decurrens* woodlot (Table 6). The benefit obtained from *A. decurrens* woodlot is better than benefits from fast-growing tree species including Eucalyptus (Eshetu, 2018). And also higher from estimation in the same area and rotation period of *A. decurrens* woodlot but he uses social survey data (Yazie and Anteneh, 2018).

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Table 1. The production potential of *A. decurrens* woodlot in the study area.

Age of woodlot (year)		Stand stock/ha	Average Height (m)	Average DBH (cm)	Basal area (m^2)/ha	Wood Volume (m^3)/ha	Charcoal Yield (Sack=10 kg)
1.5	Mean± S.E	23800±1716	2.56± 0.37	1.24± 0.21	3.07± 0.99	4.36±2.0	-
2.5	Mean± S.E	18300± 971	5.95± 0.36	2.95± 0.15	12.63± 1.26	37.08± 5.3	-
3.5	Mean± S.E	15400± 1064	8.48± 0.13	4.82± 0.16	28.17± 1.84	121.65± 9.68	-
4.5	Mean± S.E	14900± 806	10.63±0.26	5.9± 0.25	40.9± 3.4	212.65± 21.5	3989.95± 204.84
5.5	Mean± S.E	14700± 1075	11.71±0.24	6.29± 0.26	45.95± 3.8	262.15± 23.06	5226.5± 320.01

Table 2. The correlations of *A. decurrens* woodlot stand density and volume.

Variables	Number of trees per hectare	
Average tree height (m)	Sig. (2-tailed)	.000
	Pearson Correlation	-.719**
	Sig. (2-tailed)	.000
Average tree DBH (cm)	Pearson Correlation	-.810**
	Sig. (2-tailed)	.000
Wood volume (m^3)/ha	Pearson Correlation	-.712**
	Sig. (2-tailed)	.000

**. Correlation is significant at the 0.01 level (2 tailed). N= 20.

Table 3. The productivity of *A. decurrens* woodlot through farmer's management.

Measuring variables	4.5-year-old woodlot (mean ± S.E)	5.5-year-old woodlot (mean ± S.E)	T-value	P-value
Wood volume (m^3)/ha	212.65±21.5	262.15±23.1	1.57[n]	0.16
Charcoal yield (Sack)	3989.95±204.8	5226.53±320	3.25*	0.017
Charcoal conversation efficiency (%)	25.16±1.2	28.35±2.2	1.235[n]	0.275

*= significant, n= non-significant.

Table 4. The correlation of charcoal conversion efficiency to kiln size.

Variables	Number of trees per hectare	
Woodlot age (year)	Sig. (2-tailed)	.450
	Pearson Correlation	.263
	Sig. (2-tailed)	-.527
Mound Volume (m^3)	Pearson Correlation	.180
	Sig. (2-tailed)	.330
Charcoal producers experience (year)	Pearson Correlation	.425
	Sig. (2-tailed)	.450

N= 8, *=significant, n= non-significant.

Table 5. Financial feasibility of *A. decurrens* woodlot production.

Investment option	Investment evaluation methods		
	NPV	BCR	IRR
Annual crop for one year/ha	6,584.53	1.52	105%
Annual crop for 4.5 years/ha	26,584.05	1.52	105%
4.5-year rotation woodlot/ha	63,963.90	2.58	64%
5.5-year rotation woodlot/ha	71,520.04	2.31	54%

Table 6. Cash flow of annual crop and *A. decurrens* woodlot investment option.

Year	Investment option cash flow in ETB			
	Annual crop for one year/ha	Annual crop for 4.5 years/ha	4.5-year rotation woodlot/ha	5.5-year rotation woodlot/ha
0	-7,942.68	-7,942.68	-18,742.7	-18,742.69
1	16,270.48	8,327.79	12,794.54	12,794.54
2		8,327.79	7,97.19	7,97.19
3		8,327.79	0	0
4		8,327.79	0	0
5		16,270.48	124,504.8	0
6				153,563.95

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Table 7. Socio-economic importance of *A. decurrens* woodlot production.

Key attributes	Minimum	Maximum	Mean	St. deviation
The total land area of the woodlot producers (ha)	0.50	4.00	1.86	0.17
The irrigated land area of woodlot producers (ha)	0.25	1.00	0.38	0.17
Experience *A. decurrens* planting	5.00	12.00	7.45	1.6
Number of seedlings planting per (ha)	10000	30000	16698	4468
The total land area covered by *A. decurrens* woodlot (ha)	0.25	1.75	0.87	0.41
A. decurrens woodlot sold for the last 10 years	1.00	6.00	1.64	0.3
Income get from *A. decurrens* woodlot in 2018/2019	15000	50000.0	28428.6	8792.26

At year two, the woodlot cash flow is positive because the farmers get income from grass sale which grow under the canopy of the woodlot. After two years the cash flow is zero means there is no income or cost in the third and fourth year of the woodlot but the annual crop production can generate positive income throughout each year except the initial period. The net non-discount profit of annual crop and *A. decurrens* woodlot are 16,270.48 ETB and 124,504.8 ETB respectively for 4.5-year rotation investment. Moreover, 5.5 years of woodlot harvesting can generate 153,563.95 ETB non-discounts benefit (Table 6). Therefore *A. decurrens* woodlot production system in the study area is the most attractive investment than other agricultural annual crop production. This result is highest than Yazie and Anteneh (2018) and Zerihun *et al*. (2016) estimation.

Socio-economic impact of Acacia decurrens woodlot charcoal production: On average the household has 1.75±0.17 ha of land. From this 0.8±0.04 ha (46.6%) of land were covered by *A. decurrens* woodlot (Table 7). They plant 10000 to 30000 seedlings per hectare. According to the interviewer's explanation, the reason for farmers to plant the high amount of seedling during establishment is the presence of seedling mortality which means the seedling performance is very poor and causes high seedling mortality in an early stage of the woodlot. The respondents have 7-12 years of experience in *A. decurrens* production and harvested a minimum of one time for the last 5 years. The main reason the farmer shift from crop production to *A. decurrens* woodlot production is the decline of crop yield, the increasing of input cost for crop production and the higher financial profitability and income generation potential of *A. decurrens* woodlot. In the 2018/2019 budgeting year, the households generated average incomes of 28,428±8,792.26 ETB from *A. decurrens* woodlot sale. *Acacia decurrens* woodlot production is the backbone of the district as well as an individual that participates in the chain of the production system. *Acacia decurrens* woodlot production can reduce the migration of local communities due to the availability of work employment in their home village. Currently, one adult worker can get 80 to 100 ETB per day who participate in any work of *A. decurrens* woodlot production system.

The value chain of *A. decurrens* is so wider which starts from nursery activity to final yield charcoal export to Addis Abeba and other nearby cities such as Bahir Dar, Gondar and Tigray (Asmamaw and Barbiche, 2016). All activity of the production system can be done by manpower. Therefore the system can demand a high amount of manpower. These workless youths, as well as students, can get the required income to satisfy their temporary want by participating in the value chain of *A. decurrens* woodlot production system. In addition to economic and social benefits, *A. decurrens* woodlot production system has an environmental advantage. Key informants, as well as group discussion participants, indicated that the expansion of *A. decurrens* woodlot can reduce natural forest load. This is because; natural forest products can be substituted by *A. decurrens* woodlots products.

Conclusion

The growth and development potential of *A. decurrens* in Fagta Lekoma district was highest but farmers plant seedlings was in a very crowded manner. This has an impact on the growth and productivity as well as the profitability of the woodlot. It has a fast-growing nature in the area. It can grow to 11.51±0.19 m height and 5.92±0.07 DBH under farmer's management for 5.5 years. The productivity *A. decurrens* woodlot is amazing. It can produce up to 212.65±21.5 m^3/ha and 262.15±23.06 m^3/ha for 4.5 and 5.5 years. Most of the producers harvest at 4.5 years old but 5.5-year-old harvesting is more productive than 4.5-year-old harvesting woodlot. And also, based on the commercial plantation management principle the rotation period of *A. decurrens* woodlot in the study area was 5.5 years ago. Therefore, the woodlot producer farmers' loss some benefits due to earlier harvesting of the woodlot. The main purpose of *A. decurrens* woodlot production in the study area is charcoal production. However, they use traditional earth mound kilns. This traditional earth mound kiln conversion efficiency was low compare to modern charcoal production technologies. The main factors that affect the conversion efficiency of *A. decurrens* woodlot in traditional charcoal production techniques are woodlot age, mound size, and expert experience. However, the productivity of *A. decurrens* woodlot in the study area is better than the other species as well as other areas.

The producer's farmers can generate better income than annual crop production. But *A. decurrens* woodlot production requires the additional cost of capital than the annual crop. According to this study result, the production system of *A. decurrens* woodlot in Fagta Lekoma district has a significant impact in economic, social and environmental aspects. However, there is a limitation to sustain the system and the benefits. Therefore anybody who concerned about this system should conduct the following recommendations to reduce the limitation and increase the benefits of the system. Therefore, the farmer should be reducing initial planting seedlings for more benefited in the system. And also, they should harvest the woodlot at 5.5 years for more productive. The government should adopt a modern charcoal production technology that increases woodlot productivity by increasing charcoal conversion efficiency.

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