Expansion of *Acacia decurrens* plantation on the acidic highlands of Awi zone, Ethiopia, and its socio-economic benefits

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Expansion of *Acacia decurrens* plantation on the acidic highlands of Awi zone, Ethiopia, and its socio-economic benefits

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**Abstract:** Expansion of *Acacia decurrens* plantation on the acidic highlands of Awi zone, Ethiopia, and its economic benefit was undertaken in Fagita-Lekoma district to assess major motives of farmers behind the expansion of *A. decurrens* plantation. Cost–benefit analysis, benefit–cost ratio, net present value, and internal rate of return (IRR) were used to compare benefits. *A. decurrens* plantation was introduced as a public forest plantation by government and expanded as private plantation for charcoal making in which experts and traders were eye openers for the innovation. High economic benefit, source of firewood and fencing, improving soil fertility and decreasing run-off, tolerance to natural hazards compared to annual crops, and sources of employment were found to be the major motives behind the expansion of *A. decurrens* plantation. Over 5-year period, crop production generated a net present value of 5,430.54 Ethiopian Birr/ha with benefit–cost ratio of 1.09 while *A. decurrens* plantation generated a net present value of 26,682.68 with benefit–cost ratio of 1.53 and IRR of 58%. Farmers are fetching attractive financial benefits from *A. decurrens* plantation that indicates plantation is a more attractive business than crop production. Further study on the soil properties and environmental aspects of *A. decurrens* plantation, marketing, and value chain is recommended.

**ABOUT THE AUTHORS**

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**PUBLIC INTEREST STATEMENT**

*Acacia decurrens* is one of the trees being planted and used as source of fuel wood, construction, fencing, wind break, etc., in Ethiopia, in general, and in the study area, in particular. *A. decurrens* plantation was introduced as a public forest plantation by government initially but now expanded as private plantation for charcoal making in which experts and traders were eye openers for the innovation. This study was undertaken to explore major motives of farmers in expanding the tree plantation and its socio-economic benefit for the community in Fagita-Lekoma district, Ethiopia. Therefore, the information generated from this study would help to design research and development interventions points in terms farmers and other value chain actors on *A. decurrens* plantation would be benefited more.
**Subjects:** Agriculture & Environmental Sciences; Soil Sciences; Environment & Business; Environment & Economics; Food Laws & Regulations; Social Work; Rural Development; Economics

**Keywords:** Acacia decurrens; innovation; charcoal; cropping system; Fagita-Lekoma; plantation system

1. **Introduction**

The *Acacia decurrens* tree belongs to the species *Acacia* section Botrycephalae, a group of 44 mostly arborescent species, characterized by having bi-pinnate adult foliage and flower heads normally arranged in elongated racemes that are predominate in temperate areas of eastern and southeastern Australia (Orchard & Wilson, 2001). It is endemic in New South Wales where it occurs chiefly on the coast and tablelands from the Hunter Valley south to the Australia Capital Territory (Maslin et al., 1988; Orchard & Wilson, 2001). *A. decurrens* are shapely erect trees with 5–10 m tall but sometimes attaining 20–22 m tall under favorable conditions, commonly with single, straight to almost straight main stems, strong, shallow lateral roots (Boland, 1987; Pryor & Banks, 1991). It is a relatively short-lived species that declines in vigor after 10–15 years (Pryor & Banks, 1991).

Forests play important provisioning and supporting roles in the livelihoods of rural households, and many of those who live in extreme poverty are to some degree reliant on forests for their livelihood (Byron & Arnold, 1999; Sunderlin et al., 2005). Recent comparative evidence suggests that forest and environmental income contributes 28% of total income to households in or near forests (Angelsen et al., 2014). Trees have multiple purposes in rural Ethiopia, providing significant economic and ecological benefits. Planting trees supplies rural households with wood products for their own consumption, as well as for sale, and decreases soil degradation. *A. decurrens* is an excellent source of fuel wood, used for building poles, pulpwood, tanning of hides, mine props, fence posts, hardboard production, valuable timber species, etc. (Allen & Allen, 1981; Gamble, 1902; Maiden, 1889). *A. decurrens* is also a moderately deep-rooted, drought-tolerant, nitrogen-fixing tree, widely planted to windbreaks, control wind erosion, stabilization of ash spoil, and ornamental plantings (Streets, 1962; Vivekanandan, 1979).

*A. decurrens* (J.C. Wendl.) Willd was introduced into the central highlands of Ethiopia in the early 1990s for short-rotation forestry (Sawyer, 1993) to counter urban wildfire shortages arising from deforestation (Pohjonen & Pukkala, 1990). Moreover, *A. decurrens* was introduced into state-owned plantations of the northwestern highlands around the same year (Kassie, 2015). Recently, the tree species has also been recommended for large-scale watershed rehabilitation in the country (GIZ, 2015).

*A. decurrens* plantation in the highlands of Awi zone of Fagita-Lekoma district, Ethiopia, has been started in the last few years, but the practice is expanding quickly competing for annual cropping and grazing land. All acacia have been used for charcoal production except the foliage and some thin twigs left on the ground that are used for fencing and firewood. Charcoal making (charring) has been practiced on the same land on which plantation was done or nearby farms on a series of heaps. There is no coppice after harvest unlike to eucalyptus, and it is easy to plow the land for farmers due to its bare root. After harvest, the land would be plowed and used for crop production so that, in the second year, farmers intercrop *A. decurrens* with annual crops for future (next) wood lot plantation so that the cycle of plantation goes like this.

Land-use transformation from crop lands to *A. decurrens* and charring on the farmlands in the highlands of Awi zone of Amhara National Regional State of Ethiopia could have the potential to ameliorate the degraded soil, can mitigate climate change by sequestering carbon, and can have economic benefit from the two systems of annual crop and *A. decurrens* charcoal productions. From researchers’ own practical field observations since it is the mandate area of their research center and priory key informant interview as well as according to the annual reports of the district
office of agriculture and document reviews, studies on the *A. decurrens* expansion and its benefits are so scanty and nonexistent. Therefore, this study was initiated to evaluate the motives and status of *A. decurrens* expansion and its economic benefit for the society in the study area. The main objectives of the study were to assess major motives of farmers that make them to shift from annual food crops to *A. decurrens* and to evaluate the economic benefit of *A. decurrens* versus annual food crops produced by smallholder farmers.

2. Methods

2.1. Study area description
The study was conducted in Awi zone of Fagita-Lekoma district of Amhara National Regional State of Ethiopia in four kebeles (the smallest administrative unit in Ethiopia), namely Endewuha, Gaffera, Gulla-Giorgis, and Gezehara (Figure 1). Awi zone is one of the 10 zones, and Faggeta-Lekoma is one of the 105 districts in the Amhara Regional State of Ethiopia. Fagita-Lekoma district has an area of 653.39 km² and is bordered in the south by Banja-Shikud, in the west by Guangua, in the north by Dangla, and in the east by West Gojam zone. The district has a total population of 146,848 people from which about 90% live in rural areas with population density of 224.7 people per km² (CSA, 2015). The topography of the district is rugged and undulating, and land use in the district is dominated by a mixed crop-livestock system (Kassie, 2015). The main crops grown in the district are barley (*Hordium vulgare*), teff (*Eragrostis tef* Zucc.), wheat (*Triticum vulgare*), and potato (*Solanum tuberosum*). The major sources of cash for the community of the area are crop production and tree (*Eucalyptus* and *A. decurrens*) products. These days, *A. decurrens* plantations are abundant in the study area and established mostly by replacing crop and grazing lands.

2.2. Data sources, types, sampling, and method of data collection
Data sources were both primary and secondary. The primary data was collected from interview of farmers and key informants (elders, traders, brokers, and office of agriculture experts) as well as

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*Figure 1. Map of Fagita-Lekoma district, Awi zone, 2014/15.*
focused group discussion (FGD) while secondary data was collected from the office of agriculture, Central Statistical Authority (CSA) of Ethiopia and published and unpublished documents. A multi-stage sampling procedure was used so that Awi zone and then Fagita-Lekoma district were selected purposively based on volume of A. decurrens production and representativeness in the first and second stages, respectively. Then in the third stage, four kebeles, namely Endewuha, Gaffera, Gulla-Giorgis, and Gezehara, and in the fourth sampling stage 25–30 respondent farmers per kebele that sum up to 108 were selected randomly for interview (Table 1). Respondent farmers living in the district who entirely depend on crop-livestock mixed agriculture for their livelihood were randomly selected and interviewed based on structured questionnaire. Two to three key informant interviews and one FGD were conducted per kebele as well as field observations were made in the study district to complement the data by qualitative analysis and triangulation. Hence, the major sources of soft data in this study are key informant interview, FGD, and field observations.

The price of output (crop and Acacia decurrens yield) and inputs (seeds, fertilizer, and chemicals) were collected from farmers, local market, input dealers, and district/zonal office of finance and economic development during the survey. The primary data collected includes socioeconomic profile of farm households, livestock holding (cattle, ruminants, equine, chickens, and beehives), area planted (allocated) for A. decurrens (ha), and annual crops with yield obtained of each crops grown during the survey year, rotation cycle of A. decurrens, crop grown before and after A. decurrens and their productivity per ha with price of produce per ton per ha, volume (sacks) of charcoal per area or ha and its price per charka or sack or ha, cost of production per ha for crops and A. decurrens (on that specific land), trends of land-use change from cropland to A. decurrens, and motives of farmers’ behind expansion of A. decurrens (economic, soil conservation, drought resistance, or any other motives).

2.3. Method of data analysis
Cross-sectional data that was collected from sample farmers and other organizations/individuals was analysed by descriptive statistics followed by economic analysis. In order to describe the overall agricultural production system with respect to the desired characteristics, descriptive statistics such as mean, standard deviation, percentages, graphs, and charts were used. Economic analyses like cost–benefit analysis (CBA), benefit–cost ratio (B/C), and internal rate of return (IRR) were used to compare annual crops production and A. decurrens plantation. The two land-use systems considered in the study (annual crops production and A. decurrens plantation) have different production cycles, that is, the production cycle for annual crops is 1 year while it is 5 years for A. decurrens plantation. To compare the costs and benefits of land-use systems, a 5-year time horizon (maturity of A. decurrens for charcoal making) was considered in an analysis based on inputs, outputs, and farm-gate prices of each produce. To facilitate the comparison, all costs and benefits were brought to present value by using a discounting method (Rasul, 2009). This is done due to the time value of money, so that future cost and benefit values were discounted to enable comparison with present values. The opportunity cost of labor in the study area varies by gender and season. Following the prevailing wage-labor rates, ETB 50 (US$ 2.5) was considered to be the daily per capita opportunity costs of adult workers. Given the scarcity of land in the study area, both private and social objectives aim to maximize returns from a unit of land. Returns to land are expressed by net present value (NPV), which discounts the streams of benefits and costs back to a base year (Gittinger, 1982; Macharia et al., 2006). The

| Kebeles | Endewuha | Gaffera | Gulla Giorgis | Gezehara | Total |
|---------|----------|---------|---------------|----------|-------|
| Number  | 26       | 30      | 27            | 25       | 108   |
| Percent | 24.07    | 27.78   | 25            | 23.15    | 100   |

Source: Survey data, Ethiopia, 2015.
NPV of both annual crops production and A. decurrens plantation over a period of 5 years was calculated using the following equation:

$$\text{NPV} = \sum_{t=1}^{5} \frac{(B_t - C_t)}{(1+r)^t}$$

where

$$B_t = \text{land-use specific benefits accrued over the 5 years},$$

$$C_t = \text{land-use specific costs incurred over the 5 years},$$

$$r = \text{the discount rate, 12\% according to current Ethiopian condition, and}$$

$$t = \text{time period, 5 years in this case.}$$

The discount rate or interest rate should be equal to the opportunity cost of capital, that is, the rate of interest that could be obtained in the best alternative investment or the rate of interest on borrowed capital. It was assumed as 12\% for the analysis of the present study depending on the Ethiopian condition.

$$\text{B/C Ratio} = \frac{\sum_{t=1}^{5} \frac{B_t}{(1+r)^t}}{\sum_{t=1}^{5} \frac{C_t}{(1+r)^t}}$$

If $$B/R > 1$$, then the total revenue is greater than the total cost; if $$B/R = 1$$, then the total revenue is equal to the total cost; and if $$B/R < 1$$, then the revenue is less than the total cost.

The IRR is the discount rate where the net present worth of costs is equal to net present worth of benefits, that is, the NPV equals zero. IRR is $$r$$

$$\text{IRR} = \sum_{t=1}^{5} \frac{\text{NPV}}{(1+r)^t} = 0$$

Statistical Package for Social Science (SPSS) and STATA computer software were applied to analyse the data.

3. Results and discussion

3.1. Descriptive results of the socio-demographic characteristics of respondents

All sample households were male-headed, and average age of sample respondents was found to be 48.6 years with minimum and maximum age of 30 and 74 years, respectively. The education level of the sample households was 2.61 grades, and the mean family size was 6.76 numbers of persons per family. Moreover, the active labor force proportion (15–64 years of age) of the sampled households was about 57.42\% (Table 2). Farm households who have large family size in active labor force have more chance to cultivate (plowing, land preparation, weeding, harvesting, storage, and transportation) their farming activities. Education helps farm households to acquire and interpret information on agricultural technologies and rationally allocate existing farm resource to achieve their household farming objectives and goals.

Livestock production is an integral part of the farming system in the study area that contributes a lot for crop production like source of draught power, food (meat and milk), cash, animal dung for organic fertilizer (manure), and fuel and means of transport. For standardization and understanding purpose, livestock number was converted to Tropical Livestock Unit (TLU) (Storck et al., 1991).
The overall average TLU of the households was 6.74. Moreover, sampled households own mean of about two oxen and two horses (Table 3). Horses and/or mules are common animals than oxen for plowing purposes since the area is high land. Although A. decurrens plantation is sharing most of the grazing lands of livestock, farmers are still trying to feed their animals buying straw by the income they generate from charcoal of A. decurrens. Moreover, farmers can grow and harvest animal feed (grass) under the A. decurrens trees plantation for the first 2–3 years until the trees become big and prevent grasses to grow due to shade effect.
Land is a very scarce resource and important asset, which is an indicator of wealth and perhaps a proxy for social status and influence within a community for farmers in Ethiopia. The total owned land size of sample respondents varied from 0.00 to 2.00 ha with an average holding of 1.01 hectares with a standard deviation of 0.49. The average total cultivated land (including lease in) was found to be 1.40 ha with a standard deviation of 0.48 (Table 4). Farmers also rented in or out land in the study area for annual crop cultivation and/or A. decurrens tree plantation based on cash payment or share cropping base. Moreover, some innovative and progressive farmers, experts, and urban dwellers rent in land for A. decurrens tree plantation purpose mostly based on cash payment.

3.2. Cropping pattern of farm households
Crop-livestock mixed farming system is the basic feature of Fagita-Lekoma district farmers and crop production is the most important farm activity in this area. However, A. decurrens tree plantation for charcoal making is becoming the major farming activity these days. The most dominant crops grown by farm households in the district were found to be tef, potato, maize, finger millet, noug, wheat, and barley with 26%, 21%, 16%, 11%, 10%, 7%, and 5% of area allocation, respectively (Figure 2). Lupine, field pea, faba bean, and linseed are crops grown in small proportion.

3.3. Overview of A. decurrens tree plantation in Fagita-Lekoma district
A. decurrens plantation was introduced as a public forest plantation on mountainous areas by the then Derg Regime of Ethiopia in the 1980s in Fagita-Lekoma district of Awi zone, Ethiopia (personal communication and key informant interview). Moreover, the tree was also introduced for roadside planting as fence and decoration. Then, farmers were exercising in planting A. decurrens tree around their farm land and used it as live fence and firewood too. A. decurrens plantation for charcoal making was started lately after farmers saw its charcoal making quality from boarder trees that were used as live fences (key informant interview). In addition, the emergence of

Table 4. Land ownership of sampled households

| Description                      | Minimum | Maximum | Mean  | St.Dv |
|----------------------------------|---------|---------|-------|-------|
| Land ownership (in ha): own     | 0       | 2       | 1.01  | 0.49  |
| Rented in                        | 0.13    | 1.25    | 0.56  | 0.30  |
| Total cultivated                 | 0.50    | 2.38    | 1.40  | 0.48  |

Source: Survey data, 2015.
attractive regional charcoal markets and the need for soil fertility improvement have led to its wider expansion into woodlot plantations on cultivated land.

Agricultural experts and traders in town were eye openers for the innovation of *A. decurrens* tree plantation for charcoal-making purpose that become the main source of livelihood for the households. And now it has become one of the “best innovation of farmers” in the country since the practice is totally new in Ethiopia that needs further research and development effort. According to the Fagita-Lekoma District Office of Agriculture annual report, the area under *A. decurrens* tree was 720 ha in 2009 and reached about 4083 ha in 2014 (Figure 3). According to the office report, currently the area under *A. decurrens* tree plantation reached more than 14,000 ha of land, which is more than 50% of the total land in the district. Moreover, Google Earth’s images of the Fagita-Lekoma district in 2005 and 2014 show the clear expansion of *A. decurrens* tree plantation in the district (Figure 4).

3.4. *A. decurrens* plantation system of farm households in Fagita-Lekoma district

3.4.1. Experience of farmers’ *A. decurrens* in plantation

Farm households in Fagita-Lekoma district usually plant and cultivate *A. decurrens* trees for charcoal making as usually they do the same as annual crops production. Farmers’ experience of *A. decurrens* plantation for charcoal making varies from 4 to 15 years with mean value of 7 years in the study district (Table 5). About 10.53%, 23.68%, 18.42%, 23.68%, 5.26%, 5.26%, 7.89%, and 5.26% of farmers have an experience of 4, 5, 6, 7, 8, 10, 12, and 15, respectively, years of *A. decurrens* plantation for charcoal making (Figure 5). Figure Moreover, farm households have an experience of 1–5 number of plantation rounds with mean number of 1.82 times since the start of the *A. decurrens* plantation for charcoal-making process in the area. About half (52.6%) of the farmers have plantation rounds of one time while 23.7% have two times of plantation rounds. Only 2.6% of farmers have five times of plantation rounds experience of *A. decurrens* plantation (Figure 5). Farmers usually harvest *A. decurrens* tree for charcoal making from 4 to 5 years’ time after planting (Table 5). Land renting-in and sharing-in are common phenomena in the study district for *A. decurrens* plantation for charcoal making. On average, farmers allocated about 0.58 ha (minimum of 0.125 ha and maximum of 1.25 h) for *A. decurrens* plantation per year or per plantation round and the process goes like that after harvesting and planting.

3.5. Cultivation and management of *A. decurrens* plantation

Seed sources of farm households for *A. decurrens* plantation are public and/or church forests as well as age-old plants around their farms. Farmers usually prepare seedlings of *A. decurrens* in February near rivers or their backyards. It is customary that youths prepare seedlings by renting small plots of land near rivers from farmers and sell to growers by 0.25–0.35 Eth.Birr per seedling.
when planting time comes. The spacing of *A. decurrens* plantation varies from farmer to farmer being $1 \text{ m} \times 0.75 \text{ m}$ to $0.75 \text{ m} \times 0.75 \text{ m}$ with total population of 16,000-18,000 per hectare. Moreover, there are some farmers who plant it with a spacing of $0.50 \text{ m} \times 0.75 \text{ m}$ and $0.50 \text{ m} \times 0.50 \text{ m}$ and the population would reach about 26,700-40,000 in this case. This needs research and development intervention so that the economic spacing or plant population/density should be studied according to the farmers’ current production objectives.

| Description                                      | Min | Max | Mean | St.Dv |
|--------------------------------------------------|-----|-----|------|-------|
| Experience of farmers in acacia plantation       | 4   | 15  | 7.05 | 2.86  |
| Harvesting time of acacia for charcoal making (years) | 4   | 5   | 4.5  | 0.51  |
| Number of plantation rounds of farmers           | 1   | 5   | 1.82 | 1.06  |
| Area allocated for acacia plantation (ha)        | 0.125 | 1.25 | 0.58 | 0.243 |

Source: Survey data, 2015.
Planting time for *A. decurrens* is June, July, and July–August if plantation takes place on fallow land, intercropped with tef land, and intercropped with wheat land, respectively. Crops sown before *A. decurrens* plantation are tef, wheat, lupine, and barley in order of importance. Most of the time, farmers’ plant their unproductive fallow land with *A. decurrens* and change it to productive crop land after *A. decurrens* first harvest. On the other hand, crops sown after *A. decurrens* plantation include tef, wheat, and finger millet in order of importance (Figure 6).

Some of the farmers prepare their charcoal from *A. decurrens* plantation on the same land that was used for plantation while some of them charred out of the production site. Charring in the crop lands has beneficial effect for the soil chemical and physical properties because many charcoal residues (leftover) can be left there and can be incorporated to the farm land during plowing. This charcoal leftover will serve as a soil amendment for the degraded soils of the area (Figure 7). After charcoal preparation, farmers collect the charcoal into sacks and transported to nearby roadside for distant markets and to some extent retail markets. If the plantation site is accessible for transport, cars/lorries went to the site and just load it for distant market.

3.6. Motives of farmers in expanding *A. decurrens* plantation: from farmers’ perspectives

*A. decurrens* plantation has many advantages in Fagita-Lekoma district. As the multiple response analysis result (Figure 8) shows, the main objective of farm households planting *A. decurrens* is to
derive economic benefit from it by making and selling charcoal and its byproducts from the tree. Other benefits of planting A. decurrens tree are sources of firewood, fencing, source of employment for the society, soil fertility improvement, minimizing run-offs, windbreaks, etc. Farmers are expanding A. decurrens plantation from year to year; shifting from annual crops production to A. decurrens due to the following main reasons (Figure 8).

High economic benefit: Sale of charcoal from A. decurrens plantation is the main source of income for farmers, and from this truth, farmers call it “The Black Sesame … ” Tikuru Selit” in local Amharic language” since they knew that sesame is the main cash crop in the low land part of Awi zone and they have experience of the crop when they go for seeking seasonal employment opportunities in sesame cultivation process. Moreover, during FGDs, farmers stated that “planting A. decurrens means putting money in the bank” that you will find your money being increased through attractive interest. This can be testified as indicated in Tables 7–11 that farmers are fetching good income from the charcoal of A. decurrens plantation (gross income of 104,192 and net return of 62,854 Eth. Birr per ha), and it was by far better than the income from annual crops, although it is long-term investment. Similarly, based on a financial analysis, Achamyeleh 2015 reported a NPV of 127, 128.75 ETB ha−1 (5,968 USD ha−1). Those who lacked sufficient financing and labor for making charcoal sold their wood to charcoal makers so that charcoal makers would sell the produce and pay back the money to them. Moreover, planters got the tree fitted for their production system so that, the system allowed them to produce food crops (tef, wheat, barley, and finger millet) and animal feed (grass) to support their livestock during the tree establishment phases (mostly for 2–3 years after planting). More importantly, the local government is collecting high revenue from A. decurrens charcoal production and marketing by imposing tax of 8–10 Eth. Birr per bag.

Source of fuel wood and fencing: Biomass energy at the national level provides more than 96.9% of the total domestic energy consumption: 78% from woody biomass, 8% from crop residues, and 11% from animal dung (IBC, 2012). Rural farm households living in developing countries like Ethiopia use forest and forest products as main source of fuel wood for cooking (baking “inejira”, roasting and boiling grains, and making stew), lighting, used as source of heat during cold seasons/times, etc., where other energy sources like electricity are not available and/or affordable. Branches of A. decurrens trees that remain after poles are prepared for charcoal making and remains of charcoal (small sized) are the main sources of fuel wood for farmers and source of income if sold. Moreover, branches of A. decurrens are used for fencing residential areas and farm boundaries to keep safe from human and animal interference (Figure 8).

Soil fertility improvement: Farmers perceived that, and it is also a real fact according to the researcher’s field observation, whatever process or reaction is going on the farmers' A. decurrens plantation fields, the soil becomes more fertile than ever after the immediate harvest of A. decurrens plantation. In addition to the improvement of soil physical properties like soil depth, soil structure, texture, and color; farmers witnessed and proved the soil fertility improvement by calculating the yield difference of annual crops before and after A. decurrens plantation. Farmers reported a double yield increment of annual crops due to the soil fertility improvement on A. decurrens plantation field and the yield difference was statistically and significantly different for the before and after acacia plantation crop yield (Table 6). Therefore, the growers used A. decurrens plantation for soil reclamation or amendment in addition to other multiple advantages of its plantation and this strategy seems feasible for farmers who own marginal lands owing to continuous cultivation, soil acidity (Kassie, 2015) and lack of money to buy fertilizer. Farmers also reported that, due to soil fertility improvement, we minimized the amount (dose) of chemical fertilizer application by half, and we could have extra chemical fertilizer to be applied for other non-fertile fields that are not planted by A. decurrens trees (Table 6). As indicated in the table, there was statistical mean difference between before and after acacia plantation fertilizer demand/application rate of farmers. Moreover, farmers stated that A. decurrens plantation decreases weed infestation for annual crops production since it suppresses weed emergence.
Table 6. Productivity of annual crops (quintal/ha) on farm sites (on the same plot of land) and fertilizer application before and after A. decurrens plantation

| Descriptions                  | Before A. decurrens plantation | After A. decurrens plantation | Mean diff | T-value |
|-------------------------------|--------------------------------|--------------------------------|-----------|---------|
|                               | Min | Max | Mean | St.Dv | Min | Max | Mean | St.Dv |        |        |
| Crop productivity (Qt/ha: tef)| 2   | 16  | 9.20 | 4.14 | 4   | 18  | 11.5 | 3.26 | 2.30   | 1.98** |
| Wheat                         | 4   | 20  | 18   | 2.35 | 11  | 42  | 22.34| 3.15 | 4.34   | 2.68***|
| Potato                        | 10  | 120 | 65   | 3.64 | 70  | 185 | 124.5| 3.84 | 59.5   | 3.67***|
| Mean DAP fertilizer rate for crops (kg/0.25 ha) | 12  | 50  | 30.67| 12.74| 5   | 25  | 18.88| 7.17 | −11.79 | −4.89***|
| Mean urea fertilizer rate for crops (kg/0.25 ha) | 12  | 25  | 21.79| 5.09 | 10  | 25  | 13.44| 5.82 | −8.35  | −2.49***|

Note: Min = minimum; Max = maximum; and St.Dv = standard deviation.

**and ***mean significant at the 1% and 5% probability levels, respectively. Qt/ha = Quintal per hectare and 1Qt is equivalent to 100 kg. Source: Survey data, 2015.
Minimization of run-off and improvement of climate variability: Farmers suggested that A. decurrens plantation can minimize soil erosion since there is no soil disturbance after plantation and due to its branched tap roots that keeps the soil from being eroded. Farmers recognized and replied that, due to A. decurrens plantation in the area, rain comes early these days, which was not common previously.

Tolerance to natural hazards: Most smallholder farmers in Ethiopia are subsistence and are risk averse and decide their farming depending on nature. Farmers reported that, A. decurrens tree tolerates natural hazards like storms and disease/pest unlike annual crops, which are susceptible. This may be significantly noticed by farmers since the area is highland and natural hazards like storm usually happen and damage annual crops being grown by farmers. A. decurrens plantation is also used as shelter belt or wind breaks for farmers around their annual cropping fields.

Employment opportunities: A. decurrens plantation minimized migration of people for work to other areas, usually to productive low land areas that are potential for sesame production that need huge seasonal labor but not suitable for permanent dwelling. Farmers explained that, these days youths, men and women are busy on all the value chains of acacia, that is, seedling preparation, plantation, charcoaling, brokerage, etc., activities (Figure 9). For instance, among the growers, about 30% of them purchased seedlings usually from youths who raise it for sale, and this indicates that youths are users on the value chain. In Fagita district of the study area, it is common to see youths (boys and girls) raising seedlings in the nearby rivers renting land from farmers and establishing nursery sites and sell for A. decurrens growers by 0.25–0.35 Eth. Birr per seedling when planting time comes. This is a really good opportunity for rural youth job creation if it would be properly planned in the future. A. decurrens growers employee many labors and/or engage their families during plantation,
harvesting, charcoal making, transporting and storing. For example, growers pay about 8–10 Eth. Birr per bag for making charcoal and about 1–7 Eth. Birr per bag for transporting (usually done by women and youths) from charcoaling site to road side or market place. Moreover, there are a lot of brokers on A. decurrens plantation and marketing systems including selling of whole plantation to charcoal marketing. Generally, the value chain of A. decurrens plantation and consumption absorbs a lot of labor force that is good opportunity for the district.

### 3.7. Farmers’ perceptions about problems of A. decurrens plantation

About 65% of respondents agreed that, A. decurrens plantation shares grazing land of livestock production and it needs guarding (40%) for at least 2 years from livestock attacks after plantation (Figure 10). Farmers perceived that smoke of A. decurrens charcoal is hazardous for health especially for those who make charcoal under traditional ways. Moreover, farmers are planting fertile and irrigable lands with A. decurrens plantation attracted by income obtained from the plantation that should be allocated for annual crops. Farmers added that A. decurrens plantation is a long time investment that needs capital till it matures (4–5 years) for harvest so that it makes difficult for poor smallholder farmers to apply it and forced them to rent their land for rich and/or urban people. About 95% respondents replied that marketing problem is another obstacle so that farmers are not that much beneficiary but traders and brokers (Figure 10).
3.8. Cost–benefit analysis of annual crops production and A. decurrens plantation

Farmers have their own judgment on their production activities according to their limited physical capability, social and natural resources. Crop production arrangement is also following several principles within their limited land, labor, capital, technologies, and information. CBA analysis of major annual crops grown in the district and A. decurrens plantation was considered to compare their competition and comparative advantage on the limited resources available for growers. Financial profitability from the farmers’ point of view was assumed to affect farmers’ crop production choice including A. decurrens plantation given their limited resources. The smallholder farmers may not list and calculate costs and returns of each crop enterprise, but may go for farm enterprise crops that deserve lower cash outlay and fetch better prices.
Table 10. Discounted costs and benefits, CBA, NPV, and IRR

| Years | Crop (mean of tef + wheat) | Acacia |
|-------|----------------------------|--------|
|       | Cost | Benefit | Cost | Benefit |
| 0     | 0    | 0       | 0    | 0       |
| 1     | 11,806.22 | 16,906.67 | 11,806.22 | 16,906.67 (from crop) |
| 2     | 10,494.42 | 15,028.15 | 4,533.73 | 1,580.25 (from grass) |
| 3     | 9,328.373 | 13,358.35 | 4,029.98 | 351.17 (from branches*) |
| 4     | 8,291.887 | 11,874.09 | 3,582.21 | 624.30 (from branches*) |
| 5     | 7,370.566 | 10,554.75 | 19,558.72 | 57,819.16 (from charcoal) |

|       | NPV | B/C ratio | IRR |
|-------|-----|-----------|-----|
|       | 5,430.54 | 1.09 | 26.826.68 |
|       | 1.53 | 58% |

Note: Initial investment was 15,000 and 7,088 Birr for crops and A. decurrens respectively. Moreover, annual costs and benefits for crops were 13,282 and 19,020 Birr, respectively, while it varies for A. decurrens. * = Branches obtained after pruning the tree to initiate erect growth.

Source: Survey data, 2015.

Table 11. Annualized present values of benefits and costs (Birr/ha) of enterprises

| Description | Average of tef and wheat | Acacia decurrens | Difference in means (value) | T-Value |
|-------------|--------------------------|------------------|-----------------------------|---------|
| Gross benefit (Birr/ha) | 13,544.40 | 15,456.31 | 1,911.91 | 3.79*** |
| Total costs (Birr/ha) | 9,458.29 | 8,702.17 | –756.12 | –1.24 |
| Net return (Birr/ha) | 4,086.11 | 6,754.14 | 2,668.03 | 6.97*** |

Source: Survey data, 2015.

***Means significant at 1% probability level.

The CBA was mainly done using the average prices, inputs, and outputs. The analysis was done according to the yield and input data obtained from farmers during the survey. The CBA is presented in Tables 7 and 8. The benefit of each enterprise was calculated by multiplying yield by price. Since straw has market value, the benefits from crop residue were also considered in this analysis. Labor costs were considered mainly for the preparation of land and planting, weeding, harvesting, and threshing activities. The cost of oxen was for land preparation and threshing.

The result of the analysis indicated that total gross return from tef and bread wheat production was 20,640 and 17,400 Eth. Birr/ha, respectively, while the average total cost per hectare were 14,046 and 12,518 Eth. Birr in that order. Therefore, farmers gain the net profit of 6,594 and 4,882 Eth. Birr from the production of 1-ha land of tef and bread wheat crops, respectively. On the other hand, the total cost for A. decurrens plantation per 4 or 5 years per ha was found to be 41,337.5 Eth. Birr while the gross return from it was 104,192. Therefore, farmers/producers could gain a non-discounted net profit of 62,854.5 Eth. Birr from the production of 1-ha land of A. decurrens plantation after waiting 4 or 5 years. This means producers could get a non-discounted net benefit of 12,570.9 Eth. Birr per ha per annum from A. decurrens plantation. The non-discounted net return of A. decurrens per annum when compared with the net return of wheat and tef was greater by 90.64% and 157.49%, respectively.
In general, even though the farmer/producer has to wait up to 4–5 years to get the benefit, he/she is currently fetching good profit/benefit from A. decurrens plantation. The result indicated that A. decurrens plantation is financially more profitable than other competent annual crops production.

3.9. Financial viability of A. decurrens plantation and annual crop production
Costs and returns do not serve as true yardsticks for making a decision to go for investing A. decurrens plantation due to the fact that costs incurred and returns obtained from plantation are not comparable without discounting such costs and returns. The present worth of costs and benefits was estimated by using 12% interest rate or discounting rate considering the present investment opportunities (financial condition) of Ethiopia. Present worth of benefits for the period of 1–4 years of A. decurrens were obtained from crop, grass, and braches (from pruning) that growers obtained before the tree reaches for harvest.

Net present worth was estimated to be Eth. Birr of 26,682.68 for A. decurrens, and it was 5,430.54 for annual crops production after 5 years of investment (Table 10). The benefit-costB/C was 1.09 and 1.53 for A. decurrens plantation and annual crops production investment, respectively. Although B/C is more than unity and total revenue is greater than the total cost for both A. decurrens plantation and annual crops production, A. decurrens plantation is more justifiable investment than crops production. More importantly, the IRR was 26% for annual crops and 58% for A. decurrens plantation, which are by far better than the 12% interest rate or discounting rate considered (Tables 10 and 11). There was statistical mean difference among annual crop production and A. decurrens plantation at 1% significant level on annualized gross benefit and net returns. This also indicates that A. decurrens plantation is more attractive investment for growers than annual crop production. All the financial viability indicators show that A. decurrens plantation investment is highly profitable from financial point of view that gave higher returns.

3.10. Marketing of A. decurrens charcoal: overview
Farmers usually sell their charcoal on-farm just after harvest. They use nylon sacks/bags of 100 kg size to put charcoal. Price varies from 80 to 120 Birr per bag. Charcoal is transported by human load paying 1–7 Birr/bag depending on distance of the plantation site to the main road/pilling place for whole sell. Charcoal buyers are mostly wholesalers coming from distant area through brokers. Of course, there are retail traders who sell charcoal on the main asphalt road sides whom they are either producers themselves or roadside retailers. The charcoal has only one main trade route and is taken to Addis Ababa by truck with capacity of 200–460 bags per car depending on the capacity of the car or lorry. It is customary to see lots of trucks either being loading charcoal or stopped in line for paying tax on the district revenue authority offices, usually the district office of agriculture.

4. Conclusions and recommendations

4.1. Conclusions
Although A. decurrens plantation was introduced as a public forest plantation on mountainous areas in the 1980s in Fagita-Lekoma district of Awi zone, Ethiopia, farmers are fully implementing as plantation agriculture in rotation with annual crops for charcoal production that become the main source of livelihood for the households and it is new practice in the country which could be considered as “best innovation of farmers”. High economic benefit, source of firewood and fencing, improving soil fertility and decreasing run-off, and tolerance to natural hazards compared to annual crops and sources of employment were found to be the major motives behind the expansion of A. decurrens plantation. Farmers are fetching attractive economic benefit and conserving their soils from A. decurrens plantation. All the financial viability indicators show that A. decurrens plantation investment is highly profitable from a financial point of view that gave higher returns. Marketing and land-use governance was not covered, and it could be considered as a limitation of the study. A. decurrens plantation in the study district is expanding very fast competing for annual crop production and livestock grazing land that indicates the need to develop proper land-use policy and the tree value chains.
4.2. Recommendations

Introduction of better *A. decurrens* species (if any) that are short maturing, give more wood yield, and less hazardous on the environment and human health during charcoaling is one of the recommendations. Nursery management (seedling preparation) is an area of intervention for employment creation for landless youths and women so that arranging nursery land, seedling raising materials, credit and marketing issues, etc., should be done and facilitated by the District Office of Agriculture and Trade and Investment Office. The traditional charcoal-making technique from *A. decurrens* being used by farmers should be modernized by introducing and testing improved charcoal making tools/techniques. *A. decurrens* charcoal marketing should be improved by forming “farmers charcoal producing and marketing cooperatives” or some other farmers’ collective/group action to make growers more benefiting from the plantation. *A. decurrens* plantation and charcoaling rotating it with annual food crops in the study area is a new “own best innovation practice of farmers” in Ethiopia, and this new experience should be introduced to other similar areas of Amhara Region that are degraded and unable to grow annual crops like Adama mountain areas of Yilma-Densa district and Guna mountain areas of South Gonder zone of Lai-Gaint district. Further study on the human health, soil properties, and environmental aspects of *A. decurrens* plantation and charcoaling as well as marketing and value chain aspects is recommended.

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Disclosure statement

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Authors’ contributions

All authors conceived the study. All authors helped to draft the manuscript.

Abbreviations

*A. decurrens*: Acacia decurrens; B/C: benefit-cost ratio; CBA: cost–benefit analysis; Eth. Birr: Ethiopian Birr (currency); IRR: internal rate of return; NPV: net present value.

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