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Full Length Research Paper

Current extent of Evergreen Agriculture and Prospects for Improving Food Security and Environmental Resilience in Ethiopia

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Agroforestry in Ethiopia has received increasing attention in recent years as a way of improving food security and environmental sustainability. This paper reviews and assesses the current status and potential of *Faidherbia (acacia) albida* (Del.) A. Chev. to contribute to evergreen agriculture (integration of trees with annual food crops to maintain vegetative soil cover and nutrient supply through nitrogen fixation and nutrient cycling) in Ethiopia. A total of 115 farmers were randomly selected from different altitudinal zones for interview and observations of their farms. About 95% of the respondents confirmed that *Faidherbia albida* increases grain yield of cereal crops from 1 t/ha to 2.5 t/ha through enhancement of soil fertility and soil moisture retention. In addition, almost all respondents (97.5%) consider *Faidherbia albida* as beneficial tree species for improving their livelihood by providing livestock fodder, bee forage, fuel wood and income (through sale of mortars, wooden car stoppers, tables and stools). It also serves as vegetative soil cover during the long dry season, reduces soil erosion and provides shade for livestock and people. The paper concludes that there are good prospects for evergreen agriculture (for example, Faidherbia based farming practices) in the country as a means of improving smallholder food production, livelihood and the environment. The paper recommends experimental research and farmers testing on succession of fertilizer tree species which can fix N in short-, medium- and long-terms. In addition to N fertilization, evergreen agriculture should also consider other plant nutrient requirements like P and K through application of small dose of mineral fertilizer or other low cost inputs.

Key Words: Agroforestry; climate change; Ethiopia; Evergreen Agriculture; Faidherbia albida; food security

INTRODUCTION

Many sub-Saharan African countries are severely affected by extreme poverty and shortage of food and health problems (Ehui and Pender, 2005). Deteriorating soil quality resulting in diminished water and nutrient availability is the root cause for reduced crop productivity (Snapp et al. 2005; Garrity et al., 2010). These problems are especially serious in drought prone areas of sub-Saharan Africa. Soil quality is severely impacted by long term cultivation, especially if no or little organic materials are added (Stroosnijder, 2009).

This paper focuses on Ethiopia where some of the soils have been in agricultural production for more than 1000 years and are severely degraded in most areas (Nyssen

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et al., 2004). Ethiopia is Africa's second most populous country with about 80 million people which is expected to double every 30 years. The smallholder agriculture in Ethiopia accounts for over 95% of the cultivated land and production, largely characterized by a focus on subsistence, low levels of external inputs, dependency on rainfall, and limited market integration. Principal crops include coffee, pulses (*e.g.,* beans), oilseeds, cereals, potatoes, sugarcane, and vegetables. In many parts of Ethiopia, the crop growing period is short (60 to 90 days) and livestock are allowed to roam freely across cultivable land during the longer dry season (Bekele and Drake, 2003).

One of the constraints to crop growth and yield in Ethiopia is failure to capture sufficient rain water. Although the annual rainfall ranges from 500 to 1600 mm at different altitudes in the Ethiopian highlands (Deurloo and Haileselassie, 1994), the uneven distribution that results in water excess and run-off in the main rainy season (June-September),and water limitation at other times of the year, including the short rainy season (March and April), forces farmers to plant some of their crops after the start of the rains to allow time for land preparation so that they cannot take advantage of the relatively high annual rainfall (Hadgu, 2008). It may be possible to avert the majority of the production loss by conserving the excess water during the rainy season so that plants can use this water in the later dry-spells between rainfall events, since the moisture stress, coupled with low soil quality, during the dry spells is responsible for most crop yield reductions and sometimes even total crop failures (Rockström et al., 2002; Mkoga et al., 2010). The problem is compounded by the high rate of deforestation, which is a major concern for Ethiopia, as studies suggest that the loss of forest and agroforestry trees contribute to soil erosion, loss of nutrients, loss of soil moisture and declining food production (Amsalu et al., 2007).

Besides the uneven rainfall distribution and deforestation, another constraint to crop productivity is the poor soil quality, including poor soil structure associated with low organic matter contents, a hard pan at the ploughing depth, poor water infiltration and water holding capacity, and low innate soil fertility (especially the phosphorous and nitrogen contents and availability). Poor soil quality has been associated with soil erosion and reduced productivity (Sanchez, 2002). There is a general lack of organic materials, since crop residues are fed to farm animals and manure is used for cooking as well as house-building (Giller et al., 2009**)**. Water infiltration and water storage in the soil is limited due to the low soil organic matter content and general poor soil quality. Percolation of water beyond the root zone is limited and therefore aquifers that provide flow to rivers during the dry season are not recharged (Reeves, 1997**)**.

Crop-tree-livestock system and Evergreen Agriculture in Ethiopia

In this paper, we reviewed and assessed the current status and potential of *Faidherbia (acacia) albida* (Del.) A. Chev. based farming, as one example of evergreen agriculture in Ethiopia. Evergreen agriculture is the integration of trees with annual food crops (Garrity et al., 2010) to maintain vegetative soil cover and nutrient supply through nitrogen fixation and nutrient cycling. It also suppresses insect pests and weeds, improves soil structure and water infiltration, provides food, fuel, fiber and income from tree products, enhances carbon storage and organic matter and conservation of above- and below-ground biodiversity. Evergreen agriculture delivers extended growing seasons, better water utilization efficiency, drought resilience, healthy soils, increased food crop productivity and overall profitability at lower costs of production (Garrity et al., 2010).

The traditional farming system in the study areas is a mix of crop-tree-livestock system with scattered agroforestry trees such as *Faidherbia albida* as a major tree species mainly in many arid and semi-arid areas of the country. *F. albida* has a special phenology as it sheds its leaves during the rainy season and keeps its leaves during the dry season. As a result, *F. albida* sheds its leaves when ploughing begins and therefore it barely competes for light, water and nutrients during the crop growing season (Hadgu et al., 2009b).

Land and livestock are the basic sources of livelihood to the farmers in the study sites. A number of different crops are produced by a household because of the strong orientation towards self-sufficiency. Livestock provide the draught power and household members the labour that is needed for the farming operation. Livestock ownership is also used as a measure of wealth status of households; hence the social standing is attached to the number of livestock owned regardless of economic value and feed shortage.

The main objective of the survey was to assess the current extent and potential of *Faidherbia* based farming practices, as an example of evergreen agriculture, for improving food security and environmental resilience.

MATERIALS AND METHODS

Study area description

The study was conducted in East Shoa zone ($7^0 32^{'}$ - $9^0 25^{'}$ N and $38^0 59^{'}$ - $42^0 7^{'}$ E), Eastern Haraghe ($8^0 40^{'}$ - $10^0 25^{'}$ N and $39^0 23^{'}$ - $39^0 26^{'}$ E) and Tigray ($4^0 82^{'}$ - $5^0 10^{'}$ N and $15^0 66^{'}$ - $15^0 28^{'}$ E) which are located in central, eastern and northern Ethiopia, respectively (Figure 1). The distances to East Shoa, Eastern Hararghe and Tigray from Addis Ababa, capital of Ethiopia, is about 100, 500 and 900 kms respectively.

Figure 1. Location map of the study sites: Tigray, northern Ethiopia, East shoa, central Ethiopia and Eastern Hararghe, eastern Ethiopia.

In terms of topography, the study sites are characterized by diverse conditions. The study sites lie in different altitude zones: central Ethiopia (East Shoa) in low altitude zone (<1500 meters above sea level), eastern Ethiopia (Eastern Hararghe) in mid-altitude zone (1500 - 2000 meters above sea level) and northern Ethiopia (Tigray) in high altitude zone (> 2000 meters above sea level).

East Shoa is characterized as semi-arid with hot and dry climate with annual rainfall averages 600 mm per year. Soil types are Rendzinas, Phaeozomes, Andosols, Vertiluvisols, and Luvisols. Eastern Hararghe is characterized as dry sub-humid tropics with annual rainfall average of 870 mm per year. The soils of the area are Lithosols, regosols, cambisols, fluvisols and vertisols. The average annual rainfall in Tigray is 740 mm. Soils are predominantly Cambisols, Fluvisols, Xerosols, Vertisols and Luvisols.

Data collection

Data collection involved desk studies, expert consultations, discussion with key informants and household surveys. A participatory approach was followed in surveying the current extent and potential of evergreen agriculture (with an example of Faidherbia based farming practices). In the survey, we selected sample sites based on an East-West and North-South transect from the different altitude zones in the country. A stratified random sampling was used, i.e. strata being altitude zones across transects (East-West, North-South). In our approach, historical information on the extent of agricultural land uses and agroforestry practices were gathered from farmers, extension workers, local administrators and decision makers. In our discussion on the historical information, sketch maps coupled with topographic maps of the study areas were used to help visualize and make our communications easy with the farmers, extension workers and local administrators.

Desk studies

The desk studies included analysis of resource problems based on literature. Secondary data were collected from maps, reports and other publications. Development related secondary information (e.g. reports and policy documents) were reviewed/synthesized to get idea of agricultural and development policies, their implementation and impact in the country.

Key informants

Key informants included elders and personnel from government, Community Based Organizations (CBOs) and non-governmental organizations (NGOs). They included extension workers, local administrators, decision-makers and leaders of relevant NGOs.

Focus group discussion

Focussed group discussions with community leaders, elders and experienced farmers were carried out using guide checklist questions so as to explore current and historical information on *Faidherbia albida* on farms, conservation agriculture and related land uses. Interviews were held at the farmer's fields where *Faidherbia albida* trees and conservation agriculture practices were quantified, observed and discussed.

Household survey

A sample of 115 households were used in selected sample sites in Ethiopia after general observations which were made through the transect survey (East-West, North-South) prior to the start of the field survey. Semi-structured questionnaire for individual farmer interviews and guide checklist for the focus group discussions were used. The sample farms for observation, field measurements and

Table 1. Characteristics of samples villages and farmers (mean) participated in the survey in 2010 in Ethiopia.

Regional State	Zone	District	Village (Kebelle)	Respondents		Family size
				Female	Male	
Oromiya	East shoa	Adama	Guraja furda	0.4	0.6	7.8
Oromiya	East shoa	Adama	Hadulala Hate Haroreti	0.5	0.4	6.5
Oromiya	East shoa	Boset	Siiffa Batte	0.3	0.7	6.2
Oromiya	East shoa	Boset	Hurufa kurkurfa	0.3	0.7	6.2
Oromiya	East shoa	Boset	Tri Bireeti	0.0	1.0	10.5
Oromiya	E. Hararghe	Kersa	Arada Lenca	0.5	0.5	7.1
Oromiya	E. Hararghe	Kersa	Kallu	0.0	1.0	6.0
Oromiya	E. Hararghe	Kersa	Gole Walu	0.5	0.5	5.6
Oromiya	E. Hararghe	Fedis	Eddobaaso	0.5	0.5	8.8
Oromiya	E. Hararghe	Fedis	Balina Arba	0.0	1.0	6.5
Harari	Harari	Sofi	Sofi	0.4	0.6	7.4
Harari	Harari	Sofi	Aberkele	0.5	0.5	3.5
Tigray	Central zone	Weri-Leke	Zongi	0.4	0.6	6.4
Tigray	Eastern zone	Wukro	Abreha-WeAtsibha	0.6	0.5	6.0

interview were selected randomly from the sample villages included in the different altitude zones (Table 1). The sample farmers included in the study were both male and female headed households selected randomly. In addition to the sample farmers, key informants who practiced Faidherbia based farming as compared to others in the sample villages were also included in the survey.

Ancillary data

Altitude and spatial position of each sample farm were measured using a pressure altimeter and Garmin etrex Summit 2000 hand held GPS (GARMIN International Inc., Kansas). Areas of farmers' fields were measured using the GPS, and the number of *Faidherbia albida* trees and crops growing under the tree were recorded. Wherever possible, crop yield estimates (farmer's estimate per ha), amount of mineral fertilizer used per ha and reasons for maintaining Faidherbia trees at farm level were collected. Visual assessment and quantification of the sample farms in terms of conservation agriculture practices were also made. Farmers were also asked why they decided to practice conservation agriculture and the benefits they derive from *Faidherbia albida* based conservation agriculture practices on their farms.

The physical environment which was considered in the study includes altitude and farmers' soil fertility classes (e.g. high, medium and low fertility of soils) at farm level. Soil fertility classification from farmers' perspective was assessed based on yield, soil water holding capacity, colour, texture, depth, stoniness, and steepness.

Spatial data included in this study were elevation maps, proximity of farm point maps to towns and proximity of farm point maps to major roads. Spatial data of urban area and roads was derived from topographic maps of the study sites (Ethiopian Mapping Agency, Addis Ababa). Proximities of farms to buffered urban area and major road were calculated by overlaying the farm point map over the buffered urban area and major road. Moreover, farm point map was overlaid over the elevation map of the study areas. Digital Elevation Model (DEM) was derived from Shuttle Radar Topographic Mission (SRTM) (USGS, Sioux Falls, SD) and was used to generate elevation, slope and contour maps of the study areas.

Statistical analysis

The data were analysed with SPSS and the multivariate analysis program CANOCO 4.5 (Ter Braak and Smilauer, 2002). The data were transformed to log normal distribution, and an alpha value of 0.05 was used to test for significance in all statistical tests. Linear regression analysis was used to reveal relationships between relative grain yield, *Faidherbia* tree density and mineral fertilizer use per ha. Discriminant analysis was employed to identify factors responsible for farm resource endowment and management differences between female and male headed households. In the discriminant analysis household sex was used as dependent variable, and other variables (plot size, *Faidherbia* tree density per ha, number of crop types planted per ha, farmers' estimate crop yield per ha, farmers' estimate mineral fertilizer used per ha, livestock number per farm household and beehive number per farm household) were used as independent variables. Descriptive statistics and frequency analysis were also employed to describe characteristics of sampled villages and farms as well as current extent of *Faidherbia albida* and conservation practices.

To obtain a graphical relationship between *Faidherbia* tree density and explanatory variables including farm altitude, number of crop types per ha, farmers' estimate crop yield per ha, farmers' estimate fertilizer use per ha, plot size, beehives number per farm household and livestock number per farm household, redundancy analysis (RDA) was employed using CANOCO 4.5 statistical package (Ter Braak and Smileur, 2002). *Faidherbia* tree density was classified equally into three groups: high (>25 trees per ha) , medium (13 to 25 trees per ha) and low (<12 trees per ha) density per ha. The explanatory variables contributing to the distribution among the three *Faidherbia* tree density groups were displayed as

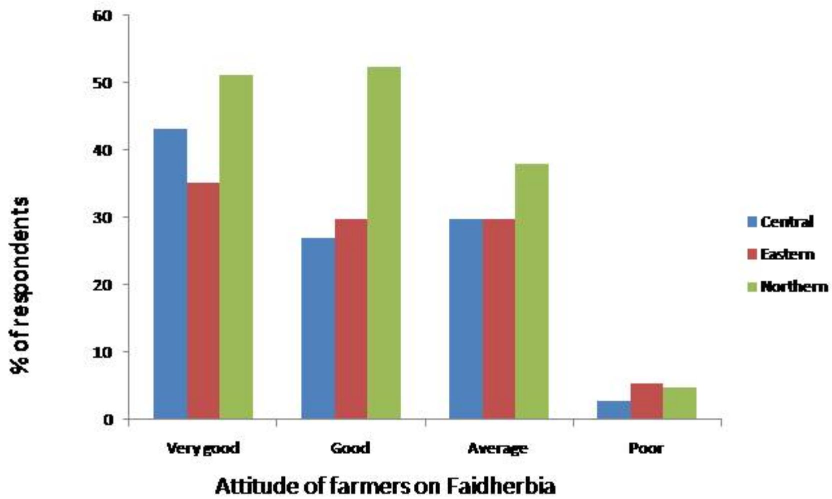

Figure 2. Attitude of respondent farmers on Faidherbia albida in 2010 in Ethiopia.

arrows radiating from the centre of the diagram with the length of the arrows representing each variable's contribution to explain the variation in sample scores on each axis. A Monte Carlo permutation test was performed to determine the relative importance of each variable in explaining the variation in *Faidherbia* tree density.

RESULTS

Faidherbia distribution and benefits

A large number of *Faidherbia albida* trees were observed in farmers' fields in each of the surveyed sites. The number of *Faidherbia albida* goes up to 52, 41 and 26 per ha in central, northern and eastern Ethiopia respectively. As shown in Figure 2, most of the respondent farmers (72%), rated *Faidherbia albida* as very good and good. Meanwhile, only 3 % of the respondent farmers rate Faidherbia as poorly performing plant species in their farming systems. The Faidherbia trees were grown in association with diversified crops including cereals, pulses and oil seeds. The integration of Faidherbia trees into the farming systems is highly efficient and the trees have multiple functions. For instance, farmers in eastern Ethiopia maintain naturally regenerated *Faidherbia albida* in their farms for one or more benefits: soil fertility improvement (84%), feed for livestock (59%) and income from sale of products (3%). In northern Ethiopia, benefits farmers derive from Faidherbia include soil fertility improvement (95%), soil moisture retention (90%), rain water infiltration (88%), bee forage (80%) and livestock feed (88%). In central Ethiopia, soil fertility improvement (92%), livestock feed (84%), fuelwood (100%) and income from sale of products (81%) were the most important reasons why farmers maintain Faidherbia on their farmlands (**Figure 3**).

Faidherbia and crop production

In the surveyed areas, different crop types were observed grown by the respondent farmers to fulfil their various needs (Table 2). On average the number of crop types per ha were 5, 4 and 7 in eastern, central and northern Ethiopia respectively.

About 37% of the respondent farmers indicated that high Faidherbia tree density per ha was positively associated with higher crop yield per ha. Whereas, low (30%) and intermediate (33%) Faidherbia tree density per ha were associated with low and intermediate crop yield per ha.

Inorganic Fertilizer

Rate of mineral fertilizer use as estimated by farmers varied from farmer to farmer and ranged from 0 to 160 kg per ha. On average, 37 kg per ha of mineral fertilizer (both Urea and DAP) was used. Relatively higher rates of mineral fertilizer were used on farms with less and medium Faidherbia tree density per ha. Conversely, low rates of mineral fertilizer were used on farms with high Faidherbia tree density per ha. Figure 4 indicates that farms with no Faidherbia albida trees where mineral fertilizers were applied showed increased crop yield with increasing rates of mineral fertilizers. Similarly, farms with *Faidherbia albida* trees with no mineral fertilizers revealed an increased crop yield although the yield increment was slightly lower than the yield gained when there was a combination of both mineral fertilizer and high density of Faidherbia. This indicates that small amount of mineral fertilizer combined with high *Faidherbia albida* can significantly increase yield of food

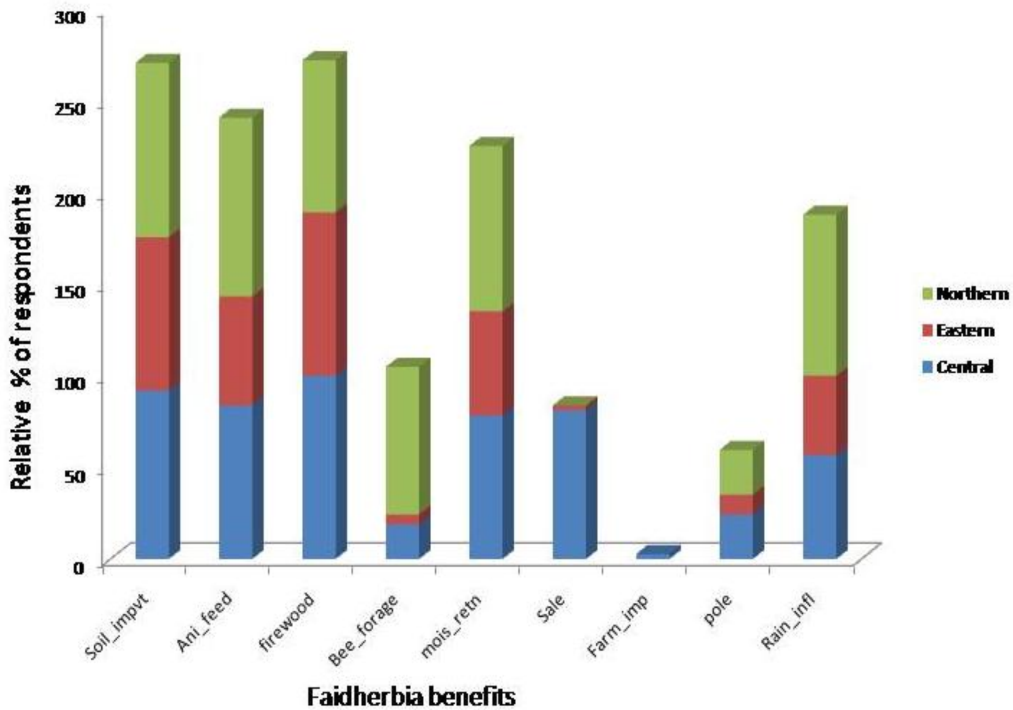

Figure 3. Benefits of Faidherbia albida according to the respondent farmers in 2010 in Ethiopia.

Table 2. Major crops in the different study areas in 2010 in Ethiopia.

Central shoa zone	Eastern Hararghe	Northern Ethiopia
Sorghum (*Sorghum bicolor*)	Sorghum (*Sorghum bicolor*)	Tef (*Eragrostis tef*)
Maize (*Zea mays*)	Maize (*Zea mays*)	Maize (*Zea mays*)
Pulses	Pulses Sweet potato Vegetables Ch'at (*Catha edulis* Forsk.).	Sorghum (*Sorghum bicolor*) Barley (*Hordeum vulgaris*) Wheat (*Triticum spp.*) Finger millet (*Eleusine coracana*)

crops.

Farm condition and Faidherbia

Farm Soil fertility

Respondent farmers categorized farms into three major soil classes based on soil fertility: low, medium and high fertile soils. Most of the farms (89%) with high soil fertility were observed having high density of Faidherbia trees per ha. While farms (72%) with low soil fertility class were associated with less Faidherbia tree density per ha. However, farms with medium soil fertility class did not show any clear relationship with Faidherbia tree density.

Tree density *on-farm* in relation to altitude

Faidherbia tree density varied at different farm altitude zones. The density was moderate at low altitude zones land (<1500 metres above sea levels), high at intermediate altitude (1500 - 2000 metres above sea levels) and low at highland (>2000 metres above sea levels) indicating a moderate altitude zone where Faidherbia density is optimum.

Livestock holding

The types of animals kept by farmers in the study areas were cattle, sheep, goats, pack animals, chickens and

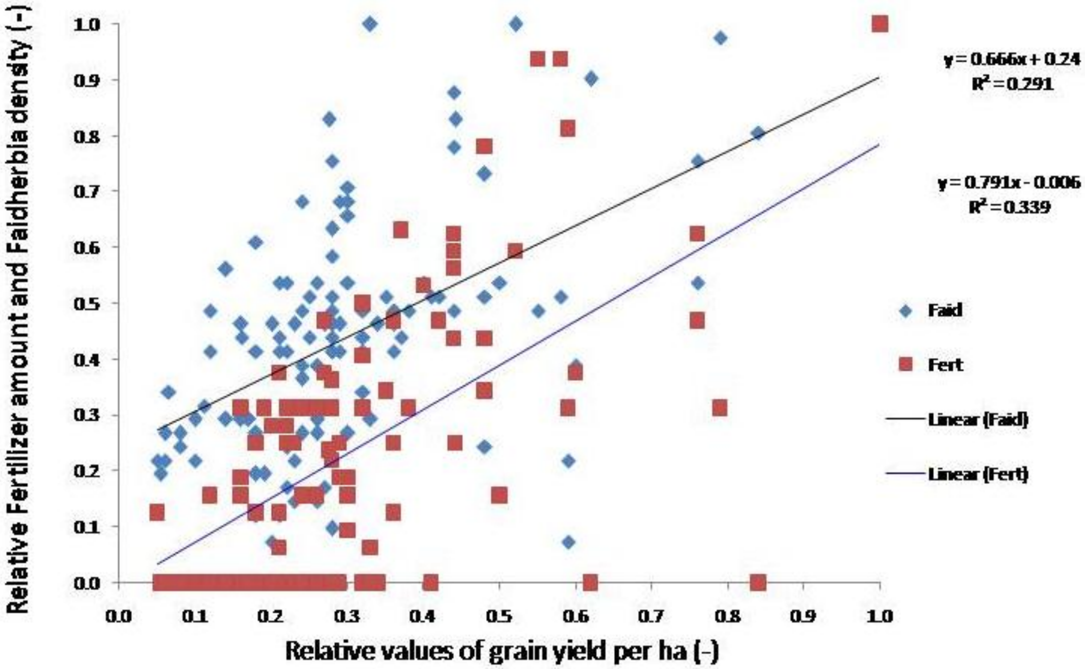

Figure 4. Relationship between relative Faidherbia density, mineral fertilizer amount and grain yield in 2010 in Ethiopia (Collected from the field).

honeybees. The average number of cattle was highest (5.5 per farm household) in central part of Ethiopia and lowest (2.1 per farm household) in eastern part of Ethiopia. The average number of bees (4.7 colonies per farm household) was highest in northern part of Ethiopia and lowest (less than 1 colony per farm household) in eastern part of Ethiopia. In all the study areas, there was high Faidherbia tree density per ha in 72 % of the farms having high number of cattle per farm household. Similarly, high Faidherbia tree density was observed in 84 % of the farmers with high number of bee colonies per farm household while pack animals did not show any clear relationship with Faidherbia tree density per ha.

Factors related to Faidherbia density and its benefits

Figure 5 shows Faidherbia tree density groups (low, medium and high per ha) and explanatory variables (crop grain yield per ha, crop diversity per ha, livestock number per farm household, beehive number per farm household, plot size, mineral fertilizer use per ha and farm altitude) plotted on the first two axes of the Redundancy Analysis (RDA).

Results of the redundancy analysis (Figure 5) showed that *Faidherbia* tree density: low, medium and high and other explanatory variables revealed clear separation of the groups (low, medium and high Faidherbia tree density per ha). The Monte Carlo test indicated that variation of Faidherbia tree density per ha was significantly ($P < 0.01$) related to each of the explanatory variables included.

The length of the vectors in the redundancy analysis plot show that crop grain yield per ha, crop diversity (number of crop types per ha), livestock number per farm household, beehive number per farm household, plot size and farm altitude were the variables that explained most of the variation in the Faidherbia tree density groups (low, medium and high). Looking at the Faidherbia tree density groups and the other explanatory variables in the redundancy analysis including crop grain yield per ha, crop diversity per ha (number of crop types) and number of bee hives per farm household were positively associated with high Faidherbia tree density per ha. Number of livestock and plot size per farm household were the only ones which showed positive relationship with medium Faidherbia tree density per ha. Whereas, higher farm altitude was positively associated with low Faidherbia tree density per ha (**Figure 5**).

Discriminant analysis

In order to identify factors responsible for farm resource endowment and management differences between

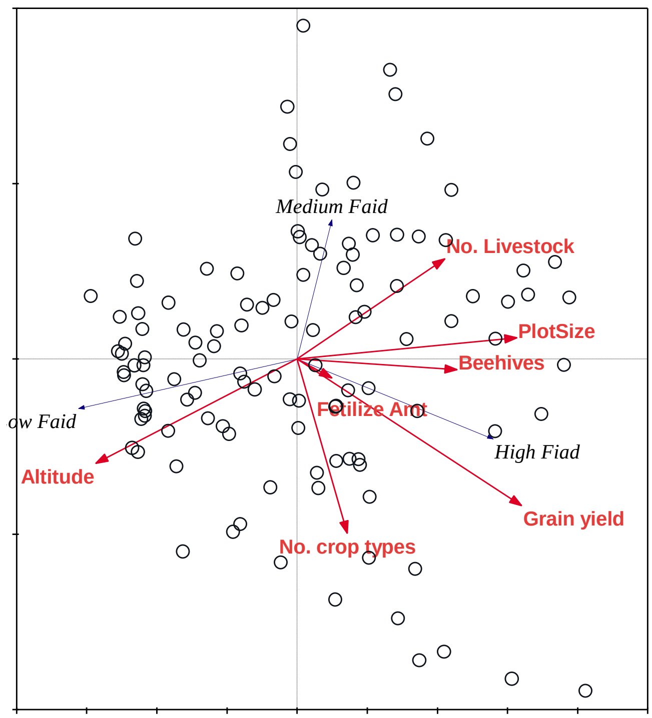

Figure 5. A CANOCO redundancy analysis (RDA) plot showing the relationship between Faidherbia tree density per ha; and explanatory variables. Arrows represent the directions of maximum variation of Faidherbia tree density and explanatory variables.

female and male headed households, eight variables were considered. The variables were family size, Faidherbia tree density per ha, amount of mineral fertilizer applied per ha, crop diversity (number of crop types grown per ha), crop grain yield per ha, livestock holding and number of beehives per farm household. The discriminant analysis classification was significant ($P < 0.05$) and classified the group for more than 72.2% correctly between female and male headed households.

Four variables were significant; Faidherbia tree density per ha ($P<0.05$), family size ($P<0.01$), number of crop types grown per ha ($P<0.01$) and beehives per farm household ($P<0.01$) discriminated farm resource endowment and management significantly between female and male headed households (Table 3). Because of low mineral fertilizer inputs, the difference on grain yield between female and male headed households is mainly dependent on Faidherbia density and barely on mineral fertilizer (Table 3).

Proximity of farmland to road and town in relation to Faidherbia distribution and density

Results of this study indicated that Faidherbia tree density decreased in northern Ethiopia as distance from major roads (less than 1.5 km) decreased. Faidherbia tree density was also found to be negatively affected as distance of farms to towns decreased in northern Ethiopia. Faidherbia tree density did not show any clear relationship with road proximity in central and eastern Ethiopia. Similar to road proximity, Faidherbia tree density did not show any variation in relation to farm distance from town in central and eastern Ethiopia. Farmers in central Ethiopia were rather using their proximity to major roads and towns as an advantage to generate income by selling Faidherbia products such as wooden mortars, wooden car stoppers and firewood (Figure 6). The respondent farmers in central Ethiopia revealed that they can prepare up to 6 mortars and 12 wooden car stoppers from a mature Faidherbia tree. On average, the market price for one mortar was 8 USD and 1 UDS per one wooden car stopper. Farmers confirmed that they could get up to 60 USD per mature tree which was one of the reasons why farmers in central Ethiopia maintain dense Faidherbia trees on their farmlands.

Conservation Agriculture (CA) practices

The study results indicated that there were conservation

Table 3. Discriminant analysis showing variables significantly contributing to the separation of resource endowment between female and male headed households in 2010 in Ethiopia.

	B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
							Lower	Upper
Familysize	.318	.111	8.153	1	.004	.728	.585	.905
No.Faidherbia	.103	.043	5.592	1	.018	1.108	1.018	1.207
PlotSize	.147	.166	.785	1	.376	.863	.624	1.195
Fetilizer	.008	.010	.646	1	.421	.992	.973	1.011
No.ofcrops	1.225	.360	11.599	1	.001	3.404	1.682	6.890
Grainyield	.000	.001	1.541	1	.214	.999	.998	1.000
Livestock	.037	.043	.730	1	.393	.964	.886	1.049
Beehives	.282	.100	8.001	1	.005	.754	.620	.917
Chicken	.010	.051	.040	1	.841	.990	.896	1.094
Constant	2.194	1.530	2.058	1	.151	.111		

Classification: 72.2 %

Figure 6. Farmers close to towns and major roads generating income by selling mortars (a and b), wooden car stopper (c) and firewood (d).

agriculture (CA) practices in almost all the study areas although the practices were not fully following the conservation agriculture principles: minimum soil disturbance (no-tillage/reduced tillage), permanent soil cover (cover crops, crop residue or agroforestry) and crop rotation/diversification. In all the study areas, farmers were practicing CA in their own way: minimum tillage (hoe- and ox-tillage), permanent soil cover through permanent Faidherbia trees covers, crop rotation and diversification (Figure 7a). For instance, minimum tillage

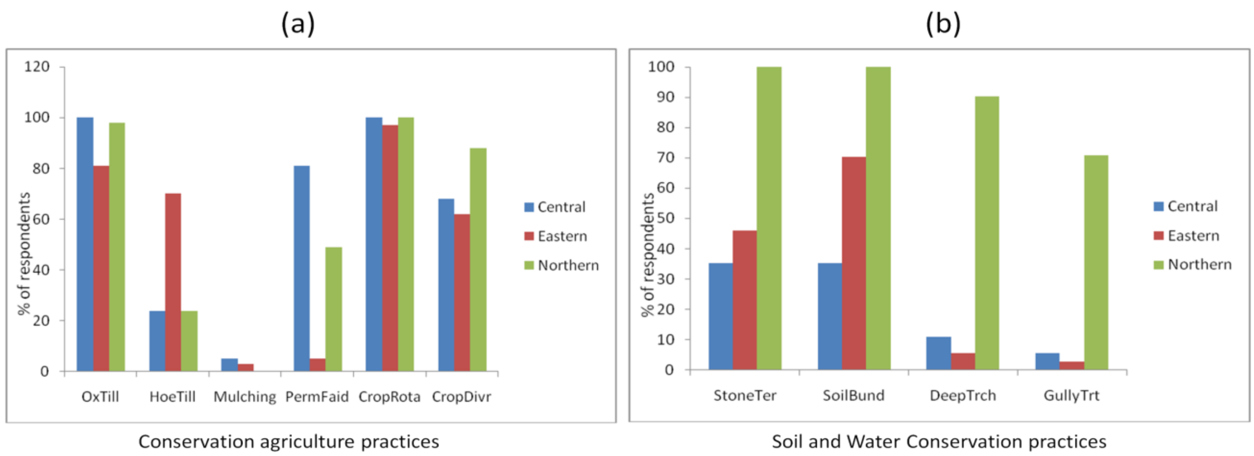

Figure 7. Percentage of respondents who practiced conservation agriculture (a) and Soil and Water Conservation (b) in 2010 in Ethiopia.

was practiced differently at the different study areas in the country. It was common to observe 70 % of the respondents practicing hoe-tillage in eastern Ethiopia; whereas, ox-plough was more common practice in 76 % and 80 % of farms in central and northern Ethiopia, respectively. In almost all the study areas (97 % of the farms), mulching or leaving crop residue on the farm was not well practiced as the residues were either collected or consumed by roaming livestock. Although not planted in regular pattern, Faidherbia albida trees were observed, in all the study areas with different density, which could serve as vegetative permanent soil cover during the long (8-10 months) dry season in all the study sites. Soil and water conservation structures were also observed in the study areas (Figure 7b).

DISCUSSION

The results of this study reveals that there is considerable Faidherbia tree density in Ethiopia: up to 52 Faidherbia trees per ha in central Ethiopia (East Shoa zone), 41 Faidherbia trees in northern Ethiopia (Tigray) and 26 Faidherbia trees in eastern (Eastern Hararghe highlands) Ethiopia. Soil fertility was greatest on farms where high density of Faidherbia trees per ha was observed which is attributed to the tree's N-fixation and OM from its leaves and shrubs (Garrity et al, 2010). Crop yield was also highest on farms with high Faidherbia tree density per ha. This is mainly attributed to the tree's contribution to soil fertility enhancement, soil moisture retention and soil OM. This corresponds well with results found in east Hararghe in eastern Ethiopia (Poschen, 1986) and Tigray, northern Ethiopia (Hadgu et al. 2009b). At higher Faidherbia tree density, there was also higher crop diversity grown in association with Faidherbia trees. From this relationship, we deduce that diversified crops were growing in a range of soils to exploit soil nutrient and micro-habitats contributed by *Faidherbia albida* trees (Hadgu, 2008).

Mineral fertilizer use, 37 kg per ha on average, is still lower than the recommended level in the study areas in Ethiopia. Research findings suggest that evergreen agriculture technologies, e.g., maintaining *Faidherbia albida* in farmlands, may increase yield from 1 t/ha to 2.5 t per ha even without mineral fertilizer application. A complement of a small fertilizer amount to the contribution of *Faidherbia albida* can improve yield of food crops for more than 4 t/ha (Garrity et al., 2010).

There was positive relationship between Faidherbia tree density and bee hives per farm household. Because of Faidherbia's reverse phenology in keeping its leaves and flowers during the long dry season and shedding them during short wet season (Hadgu et al., 2009), bees in the study areas were dependent on Faidherbia flowers as their main source of forage as most of other plants are dry during the long dry season. The high number of livestock per farm household was also positively associated with high Faidherbia density which could be attributed to farmers' demand to satisfy their livestock needs for fodder and shade. This is in contrast to the findings of Holling et al (1995) who discussed that dependence of livestock on resource rich patches leads to local extinction of many plant species and contributed to total extinction of some plant species. In our study areas, unavailability of appropriate germplasm, like *Faidherbia albida* seeds contributed more to reduced tree density than animal husbandry practices.

The relationship between crop diversity (number of crops planted per farm) and Faidherbia tree density is also clear from our findings that Faidherbia density in the farmers' fields increased as the number of crops increased. In case of crop failure, this increases the security of obtaining a satisfactory harvest. Farmers grow a range of crops in a range of soils and micro-habitats as risk aversion mechanism, for example, by maintaining Faidherbia trees to increase nitrogen in the soil from N-fixation and fallen leaves. In addition, Faidherbia contributes soil OM from leaves, twigs and branches as a result of pruning (Garrity et al., 2010).

Our results demonstrated that spatial distribution of Faidherbia tree density was not necessarily influenced by proximity to urban and major roads. Rather availability and quality of germplasm may influence Faidherbia tree density instead of proximity to urban and major roads. This study also demonstrates that spatial distribution of Faidherbia trees was influenced by altitude. Relatively higher Faidherbia remains at intermediate altitude farmlands.

CONCLUSION AND RECOMMENDATIONS

The paper assesses and reviews current status and potential of evergreen agriculture in smallholder farming system in Ethiopia. Promoting technologies like Faidherbia trees based evergreen agriculture in Ethiopia, at small scale farming, can help achieving food security and environmental resilience in the country. *Faidherbia albida* based farming in Ethiopia increases grain yield of cereal crops from 1 to 2.5 t/ha through enhancement of soil fertility and soil moisture retention. *Faidherbia albida* is considered as keystone species by local farmers as they derive benefits such as livestock fodder, bee forage, fuel wood and income through sale of wood products which contributes to the improvement of their livelihood. Besides, it is used as a vegetative soil cover during the long dry season (almost 10 months per year), and serves as shade for livestock.

The study concludes that evergreen agriculture (taking *Faidherbia albida* based cropping system as an example) in the country has good potential in improving smallholder food production, livelihood and the environment. To successfully promote evergreen agriculture, the study recommends research and testing on succession of fertilizer tree species which can fix N in short-, medium- and long-terms at farmers plots. Evergreen agriculture should also take into account other plant nutrient requirements (e.g., P and K) which can be supplemented from small dose of mineral fertilizer or other low cost inputs. Moreover, research needs to be done on how to implement evergreen agriculture to allow scaling-up and -out, and adapt recommendations to local conditions and share the methods and knowledge. To scale-up and –out, capacity building, awareness promotion and experience sharing must also be worked out with community based organizations, governmental and non-governmental organizations. If the scaling-up and –out is implemented successfully, the government is likely to demand for the evergreen agriculture technology to be included in its extension programme. Successful implementation of evergreen agriculture has the potential to contribute significantly in achieving food security, improving livelihood and environmental resilience.

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