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Review

The role of *Faidherbia albida* tree species in parkland agroforestry and its management in Ethiopia

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Agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted the role of *Faidherbia albida* tree species in Parkland Agroforestry and its management. Large part of the Ethiopian agricultural landscape is mostly dominant by Parkland Agroforestry practice. These practices are characterized by well grown scattered trees on cultivated land. *F. albida* is a multipurpose tree grown in addition to its gum production, used in soil fertility improvement as well as fuel and fodder production in rural communities. These trees have been promoted in agroforestry as its characteristic reverse phenology allows satisfactory production of crops under a full stand of the species. Several trials have shown the positive effect of *F. albida* on crops. In areas where there is too little crop rotation, severe cases of Striga infestation are more noticeable, often resulting in total crop failure. One of the cheapest means of improving his soil fertility, which could effectively reduce or eliminate Strigainfestation, is the use of the *F. albida* tree in an agroforestry practice on his farm. Socio- economically, *F. albida* have served as a fodder for livestock and the source of nectar for honey.

Key words: Agroforestry, *Faidherbia albida*, Parkland, management.

INTRODUCTION

Agroforestry is defined as “a dynamic, ecologically based natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels” (Leakey, 1996). A major reason for practicing agroforestry land use systems is domestication of soil-improving trees for enhancing soil productivity through a combination of selected trees and food crops on the same farm field (ICRAF, 2000). Scattered trees grown in farmlands characterize a large part of the Ethiopian agricultural landscape and it is the most dominant Agroforestry practice in the semi-arid and sub humid zones of the country (Kindeya 2004), while tree species differ depending on their agro-ecological suitability such as rainfall, altitude, and soil and natural distribution patterns. In central Ethiopia, for example, *Faidherbia albida* trees are dominant in tef-wheat zones of central and eastern highlands. The objective of this paper was to highlight the importance of *F. albida* in Parkland Agroforestry and its

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management.

Parkland agroforestry systems

Parklands Agroforestry are characterized by well grown scattered trees on cultivated and recently fallowed land (CTA, 2003). This system is also known as scattered tree. These parklands develop when crop cultivation on a piece of land becomes more permanent. The trees are scattered far apart so that they do not compete with their neighbors. Parkland trees have the following characteristics: They are deep rooting, preferably reaching ground water table (Van Noordwijk et al., 2000). They have capacity to fix nitrogen Produce litter that decomposes well and add as much as possible to soil organic matter. *F. albida* trees fulfill these criteria.

ETHNO BOTANY OF *Faidherbia albida*

F. albida (Delile) A. Chev belongs to a large and economically significant family of flowering plants, Fabaceae (Leguminosae), commonly known as the legume or bean family. Based on the classification by the (Santiago and Lambert, 2010). The genus *Faidherbia* belongs to the Mimosoideae subfamily and is monotypic with *F. albida* as its only member in the tribe Ingeae and subtribe Acacieae. *F. albida* was formerly assigned to the genus *Acacia* as *Acacia albida* Del. *F. albida* grows in a wide range of ecological conditions either scattered or gregarious, in closed canopy woodlands or open savanna (Mokgolodi et al., 2011). It grows on the banks of seasonal and perennial rivers and streams on sandy alluvial soils or on flat land where Vertisoils predominate. It thrives in climates characterized by long summers, or a dry season with long days. It tolerates seasonal waterlogging and salinity but cannot withstand heavy clayey soils (Orwa et al., 2009). The tree has strong and fast growing tap roots that can reach aquifers of up to 80 m below the surface to secure permanent water availability (Le Houérou et al., 1988). Access to groundwater allows *F. albida* to flourish in an otherwise desert or water scarce environment. It grows in areas with mean annual rainfall of 250-1200 mm, mean annual temperature of 18-30°C and altitude of 270-2700 m (Reubens et al., 2011). It is also associated with low rainfall areas. In South-West Africa, it can thrive under desert conditions where the mean annual rainfall is only 20 mm and the mean annual daily temperature16.8°C (Yirgu and Tsega, 2015).

MORPHOLGYOF *Faidherbia albida*

F. albida is one of the largest thorn trees, reaching 30 m in height, with spreading branches and a rounded crown. Mature *F. albida* has spreading branches and a rough, dark brown or greenish-grey bark that is often light grey and smooth when young (Oluwakanyinsola et al., 2010). The bark of the tree is characteristically dull brown to whitish grey, smooth when young, more fissured and flaky and more cork-like in older specimens. The slash is fibrous, pink to light brown. In contrast to all other native "acacias", *F. albida* has a peculiar inverse phenology an unusual habit of retaining its leaves during the dry season and dropping them during the rains. However, this phenology does not occur in seedlings until their tap roots are well into the water table (Fagg, 1995).

In addition to reverse phenology, *F. albida*is also distinguished by its whitish twigs and paired straight thorns. These reddish-brown with white tip thorns are found at the base of the leaves and are about 3 cm long and thickened at their base (Palgrave, 2002). Thorns occur in pairs at the base of the leaves and are modified, spiny stipules. They are straight and robust, thickened at the base and often (particularly when juvenile) orange or brown at the tip and are 0.2-3.2 cm long. They may be distinguished from those of Acacia species with long thorns, such as *Acacia tortilis, Acacia nilotica,* or *Acacia seyal*, by their basal thickening. The leaves are bi-pinnate, blue-green with 3 to 12 pairs of pinnae, carrying 6 to 23 pairs of leaflets that are up to 12 mm long and 5 mm wide and partly overlapping (Oluwakanyinsola et al., 2010).

***Faidherbia albida* USE IN AGROFORESTRY**

F. albida has been promoted in agroforestry as its characteristic reverse phenology allows satisfactory production of crops under a full stand of the species (Ibrahim and Tibin, 2003). Its importance is underscored by a peculiar inverted (reverse) phenology, a phenomenon whereby the tree undergoes a physiological dormancy and sheds its nitrogen rich leaves during the early rainy season – when seeds are being planted and need the nutrients and then regrow its leaves when the dry season begins and the crops are dormant. This makes it highly compatible with food crops since it does not compete with them for nutrients and light (ICRAF, 1989). The leaves are shed at the onset of the rainy season which significantly reduces the shade cast beneath the trees and reduces competition for water, light and nutrients with associated crops grown during the rainy season. Shedding leaves during the rainy season at the time of higher microbial activity in the soil improves the soil structure, permeability while retaining leaves in the dry season provides shade and mulch reducing evaporation thus conserving the available soil moisture (Dangasuk et al., 2006).

ROLE OF *Faidherbia albida* ON SOIL FERTILITY

F. albida is a multipurpose tree grown in addition to its gum production, used in soil fertility improvement as well

Table 1. Soil properties at different distance from *Faidherbia albida* trunk.

Property	Radial distance from the truck (m)				
	1	3	5	12	ANOVA
OC (%)	2.74±0.08 [a]	2.62±0.07[ab]	2.44±0.09[b]	2.35±0.04[b]	*
OM	4.7±0.14 [a]	4.5±0.18 [ab]	4.21±0.15 [b]	4.04±0.08 [b]	**
TN (%)	0.21±0.02 [a]	0.19±0.01 [ab]	0.18±0.00 [b]	0.17±0.00 [b]	**
P(PPM)	17.1±2.02 [a]	16.1±0.66[a]	14.81±0.88[a]	15.16±0.11[a]	ns
C/N	13.49±083	13.72±0.4[b]	13.95±0.4[b]	14.23±0.24[b]	ns
PH	6.18±0.06 [a]	6.15±0.09[a]	6.11±0.07[a]	6.12±0.07[a]	ns
MC (%)	29.53±1.01 [a]	28.75±1.13[a]	28.35±1.45[a]	28.32±1.49[a]	ns
BD(g/cm)	1.12±0.04[b]	1.13±0.03[b]	1.14±0.06[b]	1.15±0.02[b]	ns

Values followed by the same letters in a row are not significantly deferent at P<0.05.

as fuel and fodder production in rural communities. Conservation Agriculture promoters contend that integrating *F. albida* trees into Conservation Agriculture systems based on the three principles of minimum tillage, diversified crop rotations and permanent soil surface cover enhances the soil improving benefits of Conservation Agriculture as not only does *F. albida* fix nitrogen, it also returns other nutrients to the soil and increases Soil Organic Matter content through the shedding of its nutrient-rich leaves and the subsequent decomposition of its leaf litter at the onset of rains. The increased soil organic matter improves soil structure, enhances soil microfauna populations and minimizes excessive evapo-transpiration and soil temperatures (Umar et al., 2012). Soil organic matter improves water holding capacity, increases plant nutrient and moisture availability and reduces soil erosion.

Studies have shown that *F. albida* significantly changes the soil beneath the canopy and that the overall effect of these changes is increased soil fertility (Barnes and Fagg, 2003). The tree cover increases water infiltration and also has a beneficial effect on bulk density, structural stability and chemical and biochemical properties. It is a crucial nutrient source and also helps in cycling of nutrients. *F. albida* has been shown to improve some physical and chemical properties of soils under its canopy; it has been shown to values of total nitrogen and organic carbon while having no effect on soil texture, pH and available phosphorus (Zomer et al., 2009). The trees extensive root systems mine the surface layers of the soil beyond the reaches of its crown and in so doing redistribute the nutrients in the litter that then falls beneath its canopy. In a study of *F. albida* and its effects on Ethiopian Highland Vertisols (Kamara and Haque, 1992) found a significant inverse relationship between SOM, N, P, K concentration and distance from the tree. The *F. albida* did not seem to influence soil reaction (pH) and the exchangeable cations Na, Ca and Mg. The build-up of SOM, N, P and K under the tree canopies was attributed to the litter fall accumulation. They found N and P contents in the fresh leaves and twigs to be 3.85% N and 0.3% P for the leaves and 1.27% N and 0.2% P for twigs (Table 1) (Getahun et al., 2014).

Mature *F. albida* trees supplied significant amounts of nitrogen, organic carbon and K to the soils under their canopies resulted in a clear fertility gradient for these nutrients. The N, OC and K levels were 42, 31 and 25% respectively higher under the canopies than outside (Umar et al., 2012). The benefit of *F. albida* is its nitrogen-fixing quality, which is the result of protein-rich foliage (pods) that fall from the tree in large quantities during dormancy in the early rainy season and enrich the soil with nitrogen, phosphorus, and exchangeable calcium. It sheds its leaves when ploughing begins and hardly competes for light and water during the growing season of the crop.

THE ROLE OF *Faidherbia albida* ON CROP YIELDS

Several trials have shown the positive effect of *F. albida* on crops. The species has a potential to improve the yield of intercropped plants for instance barley yield was significantly affected by distance from the center of *F. albida* trunk and by the interaction of distance and land use systems. As shown in Figure1 below significantly higher barley yields ($p<0.05$) were found at 1 m distance from the tree compared to yields at 25 and 50 m for land use systems *F. albida* only, and *F. albida* and livestock. In contrast, in the *F. albida* and *Eucalyptus camaldulensis* land use systems barley yields did not change significantly with distance from the tree although average yields were lowest under the tree. *F. albida* is renowned for the so-called 'albida effect', that is crops growing under *F. albida* trees have higher yields than crops growing away from the tree canopy.

This yield increase may result from:(1) light shading early in the cropping season, which results in a decrease in soil surface temperatures (2) nutrient cycling, where nitrogen (N) fixed by the tree and nutrients assimilated

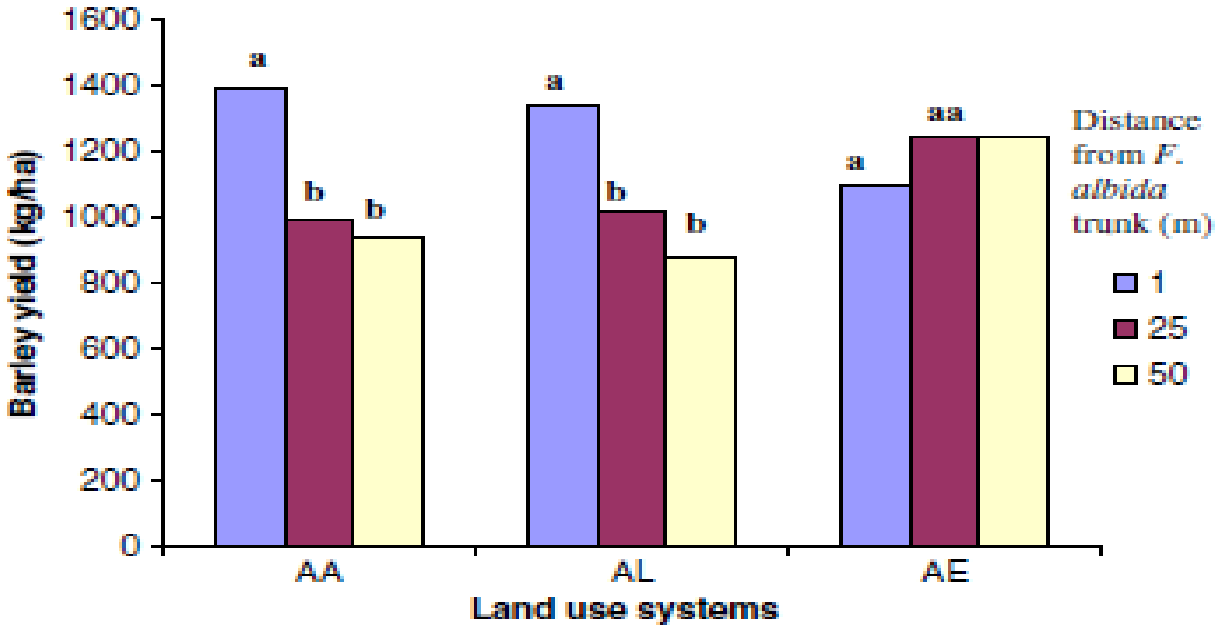

Figure 1. Mean (±SE) barley yield (kg.ha) at increasing distance from the centre of an *F. albida* trunk and for three land use system (*F. albida* only, *F. albida* and livestock, and F. albida and Eucalyptus) for 77 field locations sampled in 2005 in Tigray, Northern Ethiopia.

through the roots are returned to the soil surface through litter fall; and (3) feces and urine deposition by cattle seeking shade and fodder during the dry season (Figure 1) (Hadgu et al., 2009).

Faidherbia albida FOR CONTROL OF WEEDS

The food production potential of the semi-arid region of West Africa, especially cereals, for example sorghum (*Sorghum bicolour* (L.) Moench), millet (*Pennisetum glaucum* (L.)) R. Br. and maize (*Zea mays* L.) (Kassa et al., 2010) has seriously been reduced due to the parasitic weed *Strigahermonthica.* Pearl millet is a major food crop grown in the semi-arid region of West Africa.

In areas where there is too little crop rotation, severe cases of *Striga* infestation are more noticeable, often resulting in total crop failure. Great yield losses can occur in cereal crops due to *Striga* infestation; for example, grain yield losses in sorghum mayreach up to 70% as a result of *Striga* infestation (Gworgwor et al., 2001). According to (Sauerborn, 1991), the cultivated areas actually infested by *Striga* in Africa are estimated at 21 million hectares. The overall loss in grain production amounts to 4.1 million tons. The loss of revenue from sorghum, pearl millet and maize due to the parasite infection could total 2.9 billion $ US.

One of the most successful and promising control measures is the adequate application of mineral nitrogenous fertilizers. One of the cheapest means of improving his soil fertility, which could effectively reduce or eliminate *Striga*infestation, is the use of the *F. albida* tree in an agroforestry practice onhis farm. *F. albida* is well spread all over the dried region of West Africa, and East and South Africa where there is a long dry season (Giffard, 1964), which equally favors *Striga* survival.

SOCIO ECONOMIC USE *Faidherbia albida*

The functions of *F. albida* differ widely from one region to another within its vast natural distribution area, which covers the whole of semi-arid Africa, north and south of the equator. There was positive relationship between *F. albida* tree density and bee hives per farm household. Because of its 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 *F. albida* flowers as their main source of forage as most of other plants are dry during the long dry season. Therefore for bee-keepers, it has the advantage of producing flowers at the end of the rains while most of the sahelian species flower just before or during the rains. It therefore becomes the main source of pollen and nectar at this time. In other respects, the seeds, gum, bark, and wood are utilized for many purposes; food, traditional medicine, construction, furniture, canoes, and other domestic uses making *F. albida* the "miracle" tree of the Sahel (Figure 2) (Kessler , 1990). The interest in tree species as a food source for domestic animals lies in the fact that they offer green fodder rich in protein in a period when animal feed is

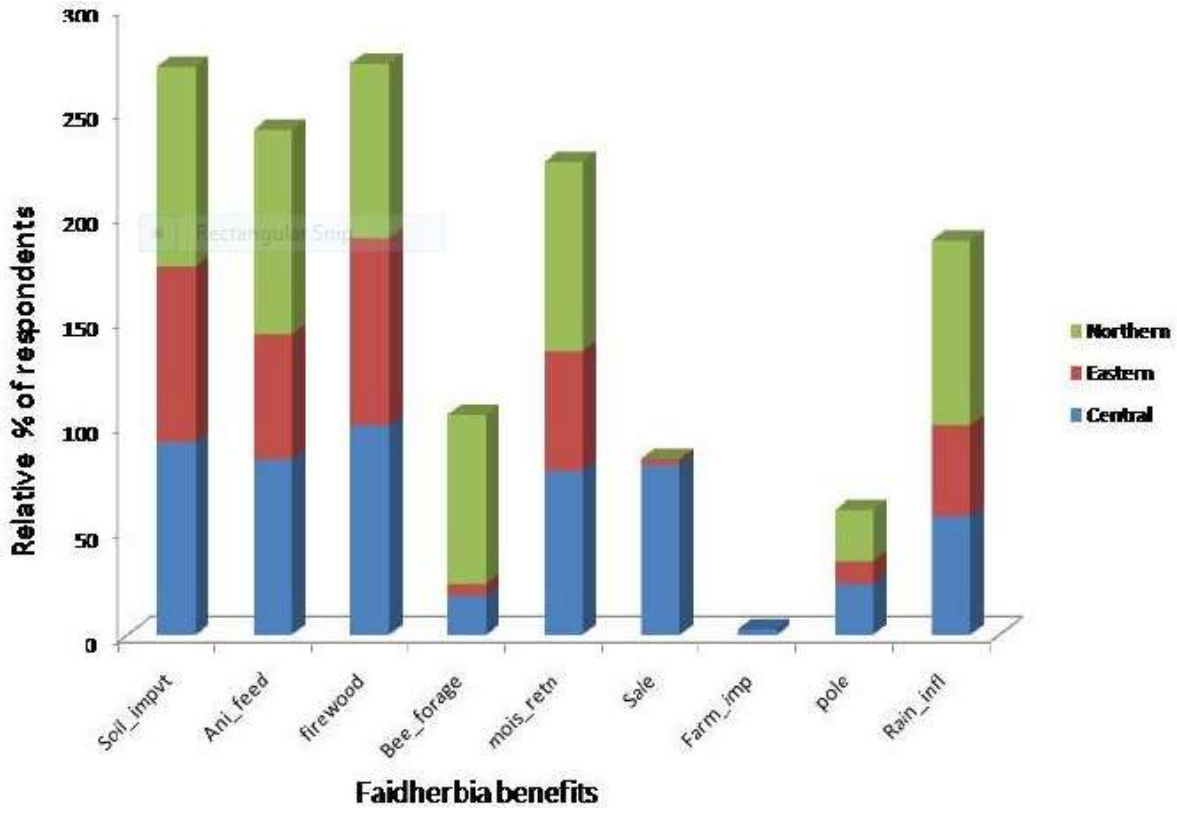

Figure 2. Benefits of *F. albida* according to the respondent farmers in 2010 in Ethiopia.

scarce; (Hadgu et al., 2009).

Faidherbia albida PROPAGATION AND TREE MANAGEMENT

The hard coated *F. albida* seeds store well under dry conditions and are usually extracted by pounding the pods in a mortar. Pretreatment is often needed for rapid uniform germination. Various methods used include; mechanical scarification, dipping in concentrated sulphuric acid for 5-15 min and dipping in boiling water. Early seed collection is recommended to avoid heavy infestation by bruchid beetles. Seed storage behavior is orthodox; there is no loss after one year in hermetic storage at 4°C; viability maintained for several years in hermitic storage at 10°C with 6-10% mc. When treated with insecticides and kept in simple closed containers, seed can be stored for several years.

Seedlings and direct sowing at site may be used for propagation of *F. albida*. Pruning in the second year to about half the tree height may be needed to control low branching. Repeated pruning during periods of average biomass production stimulates leaf production. It can be pruned twice a year. Resulting re-growth is especially vigorous in the first year but decreases as exploitation continues; trees show stress at the end of the sixth year. Regular lopping (once every 3 - 4 years) removing 0.4 - 0.5 m³ of foliage (or 35% of the total volume) at the start of the growing season is recommended (Maundu and Tengnas, 2005). However, care should be taken as improper methods of lopping have been observed to cause wounds, predisposing the tree to attack by pathogens. This tree responds well to coppicing.

Natural stands of *F. albida* in Ethiopia are generally managed in two ways, depending on the type of farming system and area where it grows. In the coffee growing region of Hararghe (eastern Ethiopia), particularly in the Gelemso area, farmers usually maintain and protect *F. albida* in their coffee plantations for shade. Pods of the trees are collected and fed to livestock. On the other hand, mature trees found in cereal-based farming systems (southeastern Shewa region and the Fedis area of Hararghe) are regularly pollarded at intervals of 3-4 years. Whole canopies are cut right back to the trunk, leaving the trees completely bare. Farmers use the branches for fuelwood and for fencing their compounds and barns.

CONCLUSION

F. albida can simultaneously store significant quantities of

carbon in aboveground biomass and increase crop yields. The unusual phenology and the ability to fix nitrogen makes it excellent in agroforestry systems. The mulch created by falling leaf litter and the canopy shade at planting time favors crop production beneath its canopy. It has positive effect on crops yield. Litter drop combined with high microbiological activity in the soil (especially during the rainy season) apparently constitute its main soil improving effect. The deep-rooting capabilities of the trees play a particularly important role in enriching surface soil horizons by drawing up mineral elements from lower horizons. Its reverse phenology of contributes much to crop fertilization, since its litter fall occurs in the rainy season. Other beneficial effects of *F. albida,* such as nodulation and the attraction it holds for cattle resulting in manuring of the site are important as well.

F. 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, and serves as shade for livestock. This agroforestry tree species are not only an effective tool for smallholders to increase cereal yields and short-term food security, the long-term soil fertility and available soil moisture increases hold promise for making cropping systems more resilient under increasing climate variability. In addition, these species provide multiple benefits, developing carbon stocks that may be converted into offsets, providing on-farm fuelwood, as well as fodder, food and medicinal products.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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