Internship thesis

Presented by

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Hedgerows and agroforest practices in the highlands of Kembatta zone, Ethiopia

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ABSTRACT

In a context of high demographic pressure where small farmlands are subject to strong erosion, fodder tree and shrub species can be good alternatives to enhance forage production. For this purpose, Inter Aide introduced five years ago the two fodder species *Chamaecytisus palmensis* and *Sesbania sesban* in the Kembatta highlands. This study aims at assessing the relevance of this project regarding the local agroforestry background and the needs and constraints of farmers.
Woody species are essential in the local farming system. Hedges are above all used as live fences to protect private lands. Trees also provide various products and services, like soil fertility improvement, windbreak or wood supply. However, indigenous fodder species are not traditionally considered for their forage value.
Despite this statement, farmers adopted pretty well *Chamaecytisus palmensis* and *Sesbania sesban*, and testified their concern for these trees regarding their nutrition and environmental benefits. Almost all the interviewees claimed to be willing to plant more of these trees in their farmland. The enthusiasm of farmers shows the relevance of promoting these species in the area. Further support should though be given to farmers to help them to adapt to management practices, especially in terms of germination, care of young seedlings and pruning.

RÉSUMÉ

Dans un contexte agricole soumis à une forte pression démographique, avec une réduction des surfaces arables et une importante érosion, les espèces arborées et arbustives peuvent être considérées comme des solutions intéressantes pour améliorer la production fourragère. C'est pourquoi, depuis cinq ans, Inter Aide a introduit les deux arbustes *Chamaecytisus palmensis* et *Sesbania sesban* dans les hautes terres du Kembatta. Dans cette étude, en tenant compte de l'environnement agroforestier et des attentes des agriculteurs, nous cherchons à apprécier la pertinence de ce projet et à en évaluer les contraintes.
Les espèces ligneuses font partie intégrante du système agricole local. Situées autour des exploitations, ces haies vives marquent les frontières et fournissent en plus des services de fertilisation, protection environnementale ou coupe-vent, et apportent une ressource en bois. Traditionnellement, les arbres endémiques ne sont pas utilisés par les locaux comme ressource fourragère, même ceux dont le feuillage peut être considéré comme intéressant sur le plan nutritionnel.
Cependant, les agriculteurs de la région ont tout de même bien adopté *Chamaecytisus palmensis* et *Sesbania sesban*. Ils ont notamment exprimé leur satisfaction quant aux bénéfices nutritionnels et environnementaux apportés. Presque la totalité des personnes interviewées ont certifié vouloir planter ces arbres de nouveau dans leur ferme. L'enthousiasme des agriculteurs vis-à-vis de ces deux espèces témoigne de la pertinence du projet. Néanmoins, il est important de soutenir les agriculteurs pour les aider à s'accoutumer aux pratiques de gestion comprenant la germination, l'attention portée aux jeunes plants et la taille.

TABLE OF CONTENT

1. INTRODUCTION

Ethiopia is known to have the largest herd in Africa, with more than 60 million heads of cattle in 2017 (FAO, 2019). In this country, where more than 80% of the population still lives in rural areas, livestock production is crucial as it contributes to about 30% to 35% of agricultural gross domestic product, and to more than 85% of farm cash income (Benin *et al.*, 2003). Milk and meat are highly appreciated by Ethiopian people and form an essential part of their diet, although meat is mainly used on special occasions in rural areas. In order to enhance the quantity and quality of dairy products, improved cattle breeds have even been promoted for the last few decades (Hunde, 2018). Nevertheless, in sedentary production farming systems of Ethiopian highlands, livestock is far from being used only as a source of milk or meat production. Farmers actually also highly rely on it for draught power, manure and cash income (Mengistu, 2006). Mixed crop-livestock farming system is thus a widespread model in Ethiopia, and Adugna and Said describe this dominant mode of production for smallholder farmers with close interdependent relationship between crop and livestock production (Adugna & Said, 1992). Feed resources for animals are mainly natural pasture, weeds and crop residues that can be supplemented by agro-industrial buy-products for people who can afford it (Mengistu, 2006).

Kembatta highlands are characterized by this type of farming system. Households of this area usually have no more than one pair of oxen and one or two milking cows, and animal feed relies on a cut and carry system (Barthès & Boquien, 2005 ; Cheveau & Hoornaert, 2011). However, nowadays, a high demographic rate (300 to 600 inhabitants/km²), a diminution of average farmland size (0.5 ha on average), and a high erosion of soils are putting pressure on forage resources (Guyon *et al.*, 2016). The decline of available grazing resources is leading to feed shortage and nutrient deficiencies which are considered as major constraints affecting livestock production (Benin *et al.*, 2003 ; Mengistu, 2006).

In this context, Inter Aide (IA), a French Non Governmental Organization (NGO) specialized in development programs, has been working in these Kembatta highlands since 2005 to help small holder farmers to increase the sustainability of their farms. Above all, it has been specifically working on soil and water conservation integrated with forage production, to increase and diversify fodder sources, protect the environment and cope with climate change (Guyon *et al.*, 2016). For this purpose, the NGO developed, among others, a program of implementation of vegetalized conservative structures in farmlands. Programs are rolled out with the cooperation of some active farmers and traditional social networks of peasants, called *Iddirs*, which can be defined as local associations for social and financial support (Léonard, 2013).

Since 2014, Inter Aide has also started to introduce two legume fodder tree species in order to make an optimization of unproductive spaces and improve soil conservation: *Sesbania sesban* and *Chamaecytisus palmensis*. In fact, trees already seem to have a predominant place in the area. The region is highly wooded and farmlands have the particularity of being surrounded by hedges, which creates a typical bocage landscape. Moreover, in some agroforestry contexts, trees can actually be a good alternative to grass species to produce fodder. They can supply different products and services that can benefit both the farm and the environment (Tengnas, 1994). Especially, incorporation of forage legumes as tree hedgerows may be a relevant approach to improve the sustainability of this area (Adugna & Said, 1992).

However, as this introduction is new, it is very lightly documented and feedbacks from farmers are still very scarce. Two main issues can hence be highlighted. The first one would be to understand more about the agroforest context of Kembatta highlands and the potential of indigenous trees, especially in terms of fodder production; whereas the second one would be to grasp farmers' perception on newly introduced fodder tree species, and evaluate the relevance of IA project in regards with farmers' needs and constraints, in terms of nutrition value, soil conservation, as well as workload and coherence with the traditional system .

This internship thesis will therefore try to answer the following problematic:
What is the agroforestry background in Kembatta highlands, and can fodder tree species be considered as good opportunities to help small holder farmers in this environment?

The development will focus on two specific objectives.
The first objective deals with the traditional hedgerows in farmlands, in order to:

- identify species present in the hedges surrounding farmlands and their use and characteristics for farmers;
- understand the strategy of farmers to plant those species;
- assess the relevance of promoting the use of some indigenous trees as fodder to diversify sources of forage in the area.

The second objective deals with the introduced fodder tree species *Chamaecytisus palmensis* and *Sesbania sesban*, in order to:

- assess the relevance of IA program to promote new fodder tree species in the area;
- consider the perception of farmers on those species as regards to their needs and the challenges for adoption;
- make a documentation on the practices of management of those two species.

2. SITE OF STUDY

The study site is situated in the highlands of the *woredas* (districts) of Kachabira and Doyogena, in Kembatta zone, in the Southern Nations, Nationalities and Peoples' Region (SNNPR). The altitude ranges from 2000 to 2400 metres above sea level.

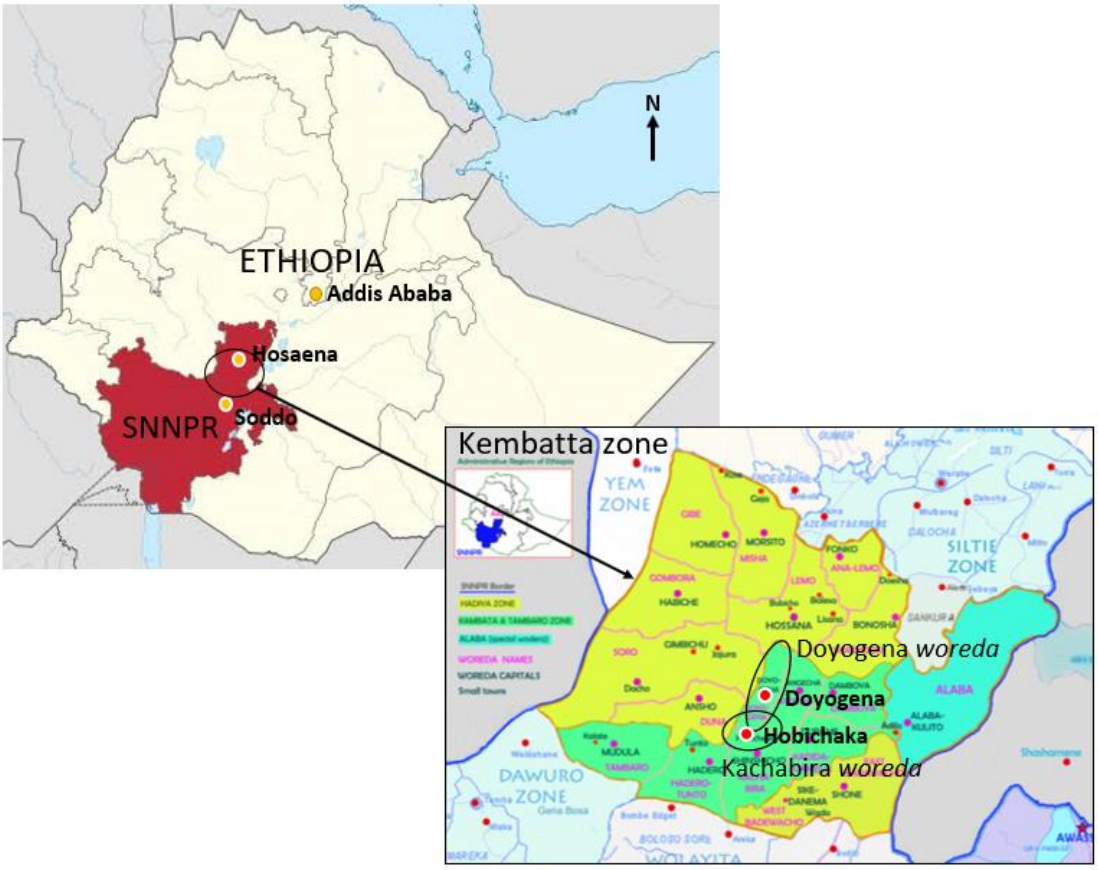

Figure 1: Localisation of the study site

The rainfall pattern is bimodal with a small rainy season from March to May (*belg*), a main rainy season from June to September (*kiremt*) and a dry season from October to February (*baga*). Weather data from the National Meteorological Agency of Ethiopia indicate an annual rainfall of 1300 mm from 2008 to 2010 and an average temperature of 18.4°C in the last three years in the station of Angacha located in Kembatta zone at an altitude of 2317 meters. Cheveau and Hoornaert indicated a higher average annual rainfall (1800 mm) in their agrarian diagnosis of Doyogena *woreda* (Cheveau & Hoornaert, 2011).

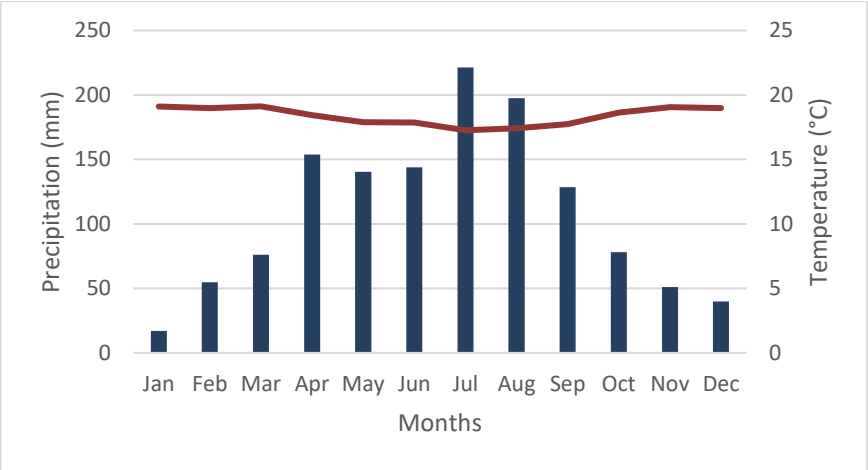

Figure 2: Average of monthly precipitation and temperature in Angacha station from 2008 to 2010
Data purchased from the National Meteorological Agency of Ethiopia in Addis Ababa

The local agroclimatic zone can hence be defined, following the classification given in the Guidelines for Development Agents on Soil and Water Conservation in Ethiopia, as wet *Weyna Dega* to wet *Dega* (Hurni *et al.*, 2016). Those highland areas are characterized by red or dark brown clay soils.

The bimodal rainfall pattern allows to have two distinct crop seasons. Cereals (wheat, barley) and leguminous species (broad beans) are cultivated during the main rainy season and are mostly used as cash crops, whereas products used for self-consumption like maize or potatoes are grown during the small rainy season (Barthès & Boquien, 2005 ; Cheveau & Hoornaert, 2011). Nevertheless, the local agricultural system relies mainly on the cultivation of *enset* or Abyssinian false banana tree (*Ensete ventricosum*). This herbaceous plant from the Musaceae family, indigenous from Ethiopian highlands, forms the basis of local traditional food. Livestock is also essential for the running of farming system as it is a draught power, a source of organic matter for the *enset* plantations and a source of cash flow. It is mainly depending on a cut and carry feeding system (Barthès & Boquien, 2005 ; Cheveau & Hoornaert, 2011).

Figure 3: Plantation of enset

3. LITERATURE REVIEW

3.1. BROWSE TREES AND SHRUBS AS A SOURCE OF FODDER FOR ANIMALS

Multipurpose trees can be defined as "all woody perennials that are purposefully grown to provide more than one significant contribution to the production and/or service functions of a land-use system" (Wood & Burley, 1991). Those trees are hence considered for some of their attributes that can be emphasised in some agroforestry contexts. For instance, in addition to providing fuel and preventing from erosion, multipurpose fodder trees and shrubs can be a good supplement feed to low-quality roughages.

Actually, in southern Ethiopian highlands, farmers are facing feed shortages during the dry season and the short crop-fallow periods, which are considered as one of the major constraints to animal production (Geta *et al.*, 2014a). To cope with these feed scarcities, peasants from the Wolayta area (adjacent area to Kembatta with near agro-ecology context) stated to use indigenous multipurpose trees as feed source to enhance their animal productivity during the feed gap (Adugna & Said, 1992 ; Geta *et al.*, 2014b). This strategy to use available browse trees and shrubs in the diet of animals can also be observed in other agro-ecological context in semi-arid and arid Africa (Shelton, 2000). According to Kindu *et al.*, the wide availability of indigenous tree species, their adaptation to the local environment and their familiarity to farmers make them worthy to be considered as good opportunities to cope with feed shortage (Kindu *et al.*, 2009a). Nevertheless, their utilization depends on the availability of species, their palatability for animals that can change from one area to another, and goals to be obtained after consumption (Geta *et al.*, 2014b).

Besides being an opportunity for seasonal feed, many indigenous multipurpose fodder trees are said to have rather good quality properties and can therefore be seen as potential protein supplements for ruminants with low quality basal diet (Salem *et al.*, 2006 ; Osuga *et al.*, 2008). Especially, the higher crude protein content and lower fibre content of leaves compared to dry grass and cereal crop residues contribute to the fact that these species can be used as strategic supplementation during the dry season (Otsyina *et al.*, 1999 ; Adugna, 2007 ; Deribe *et al.*, 2013 ; Geta *et al.*, 2014b). Their deep root system also enables them to maintain their feeding for a longer period of time. Adugna and Said highlighted the high in vitro dry matter (DM) digestibility values (greater than 50%) of many indigenous fodder trees of Wolayta (Adugna & Said, 1992), whereas high crude protein content (from 10 to more than 25% on DM basis) is often claimed (Adugna & Said, 1992 ; Haile & Tolemariam, 2008 ; Deribe *et al.*, 2013). Moreover, according to El Hassan *et al.*, some indigenous fodder trees have a good nutrient content, particularly in terms of nitrogen (up to 39.5 g available N per kg DM) (El Hassan *et al.*, 2000). N-fixing fodder species could specifically sustain the production of N-rich fodder resources (Kindu *et al.*, 2009a).

However, even if other mineral nutrients in the foliage are often in adequation to the required quantities, Kindu *et al.* found a lower content of Na for many multipurpose fodder tree species, which is essential to regulate osmotic pressure and water balance in animals' body (Kindu *et al.*, 2009a). These trees also often contain antinutritional elements like tannins or phenolic compounds that can be toxic, reduce nitrogen and fibre digestibility, or decrease voluntary feed intake (Otsyina *et al.*, 1999 ; El Hassan *et al.*, 2000 ; Osuga *et al.*,

2008 ; Dubeux *et al.*, 2017). The palatability of leaves can nonetheless be improved by lowering phenolic content by wilting or drying (Otsyina *et al.*, 1999). Because of these anti-nutritional factors, browse trees and shrubs are then often more valuable as a supplement to poor quality roughages than as sole feed.

3.2. TREES AND SHRUBS FOR SOIL PROPERTIES IMPROVEMENT

In agroforestry systems, tree species are interacting with crops for soil fertility improvement but also for competition for growth resources. This soil fertility enhancement can exceed negative interactions in soils where the competition for nutrients is limited (Rao *et al.*, 1998). Tree species mostly improve soil fertility by maintaining soil organic matter level through litterfall and root residues, which improves soil physical properties like soil aggregation, bulk density, resistance to penetration and porosity, and thus influence nutrient availability (Young, 1990 ; Palm *et al.*, 1997 ; Rao *et al.*, 1998 ; Yadessa *et al.*, 2009 ; Manjur *et al.*, 2014). Their deep root system especially allows them to recycle soil nutrients that are not available for crops roots and to concentrate them in the surface soil (Fisher, 1995 ; Rao *et al.*, 1998). Yet, the production rate and nutrient concentration in tree foliage, that depend on climate, soil type and species, determine the amount of nutrients provided by the trees (Palm, 1995). N2-fixating tree species are particularly interesting as they have the ability to add nitrogen input into the system (Fisher, 1995 ; Rao *et al.*, 1998 ; Pan *et al.*, 2015 ; Dubeux *et al.*, 2017), even if the effect on soil N levels is not always obvious, especially for low litter production (Fisher, 1995 ; Tornquist *et al.*, 1999). In addition to that, trees sustain the environment by reducing erosion and leaching of nutrients (Rao *et al.*, 1998 ; Manjur *et al.*, 2014). In the Sidama region (southern Ethiopian highlands), farmers grow consciously specific trees which are thought to improve land properties to cope with the decline of soil fertility (Asfaw & Agren, 2007). In the highlands of central Ethiopia, farmers also consider indigenous tree species like *Hagenia abyssinica* as important for soil fertilization due to their high biomass production, regular leaves shading, fast leaves decomposition and soil erosion protection (Kindu *et al.*, 2009b).

According to Palm *et al.*, the critical value for net mineralisation of nitrogen is 18 to 22 g N kg^{-1} DM. Lignin content should also be lower than 150 g kg^{-1} DM and polyphenol content lower than 30 to 40 g kg^{-1} DM to be considered as high quality green biomass (Palm *et al.*, 1997). Moreover, materials with P content higher than 2.5 g P kg^{-1} DM should result in net P release (Palm *et al.*, 1997). However, even if many organic materials can provide enough nutrients to meet crop demand, there is often a shortage in phosphorus (Palm, 1995). This low P content in tree foliage might be explained by low content of available P in African subsoil, and, as a consequence, the range of many tropical tree and shrub species of P content is reported to be from 1.5 to 2.7 g P kg^{-1} DM (Palm *et al.*, 1997). The average K content is usually from 6 to 43 g K kg^{-1} DM (Palm *et al.*, 1997).

3.3. CHARACTERISTICS OF SOME INDIGENOUS TREES AND SHRUBS OF THE AREA

A literature review has been done on some local multipurpose species which can be particularly valuable in terms of fodder and soil fertility improvement. The family names of the mentioned trees and the vernacular names of each species can be found in the table 1 page 22.

3.3.1. FORAGE VALUE

First of all, it should be noticed that the chemical composition of fodder trees can differ due to the type of species, but also due to plant abilities and soil and environment characteristics (Geta *et al.*, 2014a).

Vernonia amygdalina

This indigenous bushy shrub produces a large mass of forage (Orwa *et al.*, 2009). Some studies indicate that farmers living in Ethiopian highlands have the habit to use it as feed for animals during fodder scarcity and as supplement for enhancing milk production or fattening (Haile & Tolemariam, 2008 ; Geta *et al.*, 2014b). It has rather high crude protein content (more than 20% DM) and so can be considered as a potential feed supply to supplement poor quality roughages (Haile & Tolemariam, 2008 ; Mekoya *et al.*, 2008 ; Deribe *et al.*, 2013 ; Geta *et al.*, 2014a). It has even been shown that the supplementation of this tree fodder on lamb diet had a positive effect on live weight gains (Haile & Tolemariam, 2008). Yet, even if the feed composition is fairly good, the feed intake might be limited because of high neutral and acid detergent fibre (NDF and ADF) contents (Haile & Tolemariam, 2008).

Figure 4: Vernonia amygdalina

Hagenia abyssinica

This tree is described as being highly appreciated by farmers from central Ethiopian highlands as livestock fodder due to its large availability during the dry season and good palatability for animals (Kindu *et al.*, 2009a ; Kindu *et al.*, 2011). The foliage is characterized by a pretty good crude protein content (18% DM) with high in vitro dry matter digestibility (Kindu *et al.*, 2011 ; Deribe *et al.*, 2013). Particularly, leaves have a relatively low content of chemicals that affect palatability and digestibility (NDF, ADF and condensed tannin) (Kindu *et al.*, 2009a ; Kindu *et al.*, 2011 ; Deribe *et al.*, 2013). It can therefore be used as source of supplemental fodder within a proper feeding management scheme (Kindu *et al.*, 2009a).

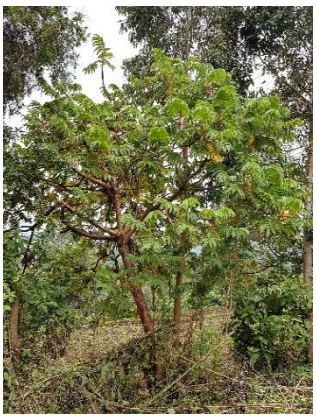

Figure 5: Hagenia abyssinica

Figure 6: Buddleja polystachya

Buddleja polystachya

This species is known to be used for fodder purpose (Bekele-Tesemma *et al.*, 1993). Like *Hagenia abyssinica*, it is specifically utilized by farmers of central highlands (Kindu *et al.*, 2009a). In the Wolayta zone too, farmers are used to feed their cattle with this tree for daily nutrition and improvement of milk production (Geta *et al.*, 2014b). It has adequate mineral nutrients in the foliage, sufficient crude protein content (more than 18% DM) and reasonable in vitro dry matter digestibility (around 45%) which leads to conclude that it can actually represent a potential source of supplement fodder (Haile & Tolemariam, 2008 ; Kindu *et al.*, 2009a).

Cordia africana

This tree, mostly growing at medium to low altitude, provides fodder for the dry season (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Geta *et al.*, 2014b ; Alemayehu *et al.*, 2016). The foliage has a rather high crude protein content (about 23% DM) which confirms its property as supplement feed for low-quality diets (Mekoya *et al.*, 2008 ; Deribe *et al.*, 2013). Deribe *et al.* also found NDF and ADF contents lower than 40% on dry matter basis which can be regarded as good quality roughage (Deribe *et al.*, 2013), whereas, on the contrary, other studies show rather high NDF and ADF contents (more than 50% DM) and lignin content (17% DM) compared to other species (Mekoya *et al.*, 2008 ; Geta *et al.*, 2014a).

Figure 7: Cordia africana

Erythrina spp.

The foliage of these native fodder trees is considered as a good protein supplement for ruminants with low quality diets during the dry season (Orwa *et al.*, 2009). Farmers from Wolayta feed their cattle with *E. brucei* for maintenance and to increase milk production (Geta *et al.*, 2014b). Some authors claim a high crude protein content for *E. brucei* and *E. abyssinica* (more than 20% on DM basis) which is sufficient to support animal growth and production (Larbi *et al.*, 1993 ; Deribe *et al.*, 2013 ; Geta *et al.*, 2014a). Larbi *et al.* even recorded linear increase in liveweight gain of sheep and goats with increasing levels of *E. abyssinica* supplement fodder (Larbi *et al.*, 1993). However, it seems that these species have greater NDF and ADF contents than other species, which may lower their palatability and their value as supplement feed (Larbi *et al.*, 1993 ; Geta *et al.*, 2014a). In accordance with this last statement, Shelton suggests the lower quality for forage purpose of *Erythrina spp.* (Shelton, 2000).

Figure 8: Erythrina abyssinica

3.3.2. SOIL FERTILITY IMPROVEMENT

Erythrina spp.

Leaves from these N2-fixing and deciduous trees are said to be traditionally used as source of mulch to maintain soil fertility in Ethiopia (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Wassie, 2012). Muzoora *et al.* highlighted the good litter production of *E. abyssinica* with a satisfying nitrogen content (20.4 g kg^{-1}), and revealed that the soil below the tree canopy tended to increase in macronutrient content as well as pH value compared to the canopy edge (Muzoora *et al.*, 2011). In accordance with this study, Wassie demonstrated that incorporation of *E. brucei* litter as green manure had positive influence on wheat yield, and that it could result in a diminution of applied inorganic fertilizers (Wassie, 2012). However, Negash and Starr didn't find such meaningful results as, in south-eastern Ethiopia, leaves of *E. brucei* didn't have noticeably higher N contents than non N-fixing species (Negash & Starr, 2013).

Croton macrostachyus

Figure 9: Croton macrostachyus

This tree is described as being used for mulch and soil conservation in Ethiopian rural environment (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Alemayehu, 2018). Mostly, its high litter production and high decomposition rate favour a high nutrient recycling potential to improve short-term soil fertility for crops (Gindaba *et al.*, 2005 ; Negash & Starr, 2013 ; Alemayehu, 2018). *C. macrostachyus* seems to have a good quality litterfall compared to other indigenous fodder trees regarding N, P and K contents (Negash & Starr, 2013 ; Getachew *et al.*, 2015). Teklay *et al.* found that this tree had a nitrogen content of 24.7 g kg^{-1}, phosphorus content of 3.5 g kg^{-1} and lignin content of 61.2 g kg^{-1}, that is within the range given by Palm *et al.* to classify trees as high quality green biomass (Palm *et al.*, 1997 ; Teklay *et al.*, 2006). The potassium content was also said to be high in several studies (20 g kg^{-1} on average) (Muzoora *et al.*, 2011 ; Teklay *et al.*, 2006). Different authors brought out the increase in nutrient contents (total N, exchangeable K) and improvement in soil properties under the tree canopy compared to canopy edge (Nyberg & Högberg, 1995 ; Ashagrie *et al.*, 1999 ; Gindaba *et al.*, 2005 ; Muzoora *et al.*, 2011 ; Mamo & Asfaw, 2017). Some of them even detected a build-up of soil in available phosphorus due to the high P concentration in litter (Gindaba *et al.*, 2005 ; Getachew *et al.*, 2015 ; Mamo & Asfaw, 2017). According to Alemayehu, this species could have a high degree of mycorrhizal association which might contribute to the high level of P observed in the tissues (Alemayehu, 2018). The good chemical properties of litter of *Croton macrostachyus* can result in enhancement of crop yield when used as green manure (Teklay *et al.*, 2006 ; Manjur *et al.*, 2014).

Hagenia abyssinica

This species produces a lot of biomass and constantly shed leaves (Orwa *et al.*, 2009). Farmers from central Ethiopian highlands acknowledge to use this tree for different service and product functions, including soil fertility improvement and soil conservation (Kindu *et al.*, 2011). According to Kindu *et al.*, foliage of *H. abyssinica* has good K content (more than 20 g kg^{-1}), P content (more than 3.5 g kg^{-1}) and N content (about 30 g kg^{-1}), and the litter deposition is large which can actually improve soil fertility (Kindu *et al.*, 2006a ; Kindu *et al.*, 2008 ; Kindu *et al.*, 2009b). Soil under the tree canopy is enriched in C, N, P and K due to the efficient power of the tree to recycle nutrients and to the good decomposition rate of leaves (Kindu *et al.*, 2009b ; Kindu *et al.*, 2011). Assefa and Glatzel also demonstrated the enhancement of soil fertility by *H. abyssinica* which leads to higher crop productivity (Assefa & Glatzel, 2010).

Cordia africana

This deciduous species has also high litterfall production that can be used as mulch (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Negash & Starr, 2013 ; Alemayehu *et al.*, 2016). The chemical composition of leaves was found to be sufficient in comparison to the critical values given by Palm *et al.* (Palm *et al.*, 1997 ; Kindu *et al.*, 2006b ; Teklay *et al.*, 2006). Some studies showed the positive influence of *C. africana* on various soil fertility parameters and nutrient accumulation, that could be observed even at young stage (Nyberg & Högberg, 1995 ; Yadessa *et al.*, 2001 ; Gindaba *et al.*, 2005 ; Yadessa *et al.*, 2009). Addition of organic inputs of this species as green manure can generate positive crop yield, even more than some legume tree species (Teklay *et al.*, 2006).

Acacia decurrens

Figure 10: Acacia decurrens

Although this species is not indigenous from Ethiopia, it is worthy to review its fertilisation properties as it is a N-fixing tree (Bekele-Tesemma *et al.*, 1993 ; Kindu *et al.*, 2006a ; El Atta *et al.*, 2013). Khanna specifies that nitrogen fixed by *Acacia spp.* is released into the soil through litterfall, turnover of fine roots and nodule decay (Khanna, 1998). And El Atta *et al.* confirm the role that *Acacia spp.* plays in soil fertility improvement by increasing organic matter content and available nitrogen, phosphorus and potassium contents under their canopy (El Atta *et al.*, 2013).
However, Kindu *et al.* noticed a N depletion in the topsoil layers under this species and a slight improvement in soil N content below 30 cm. They explain this by the poor quantity of grass growing below the dense canopy because of competition for light, leading to high leaching of nutrients (Kindu *et al.*, 2006a). Yet, even if Molla and Linger observed improvement in soil fertility through changes in soil physical properties and nutrient contents, they characterize *A. decurrens* as a shallow root nature tree with roots concentrated up to 30 cm depth, which means that its potential to recycle nutrients from deep soil layers is limited (Molla & Linger, 2017).

Figure 11: Grevillea robusta

Grevillea robusta

This species is also non-native from Ethiopia but can be pointed out for some of its specific qualities. Actually, its deep-rooting system causes little interference with shallow-rooted crops and can thus be planted in intercropping systems (Orwa *et al.*, 2009). Although it seems to have low N, P and K contents in foliage compared to other African species (Palm *et al.*, 1997), its high litter deposition might nonetheless increment nitrogen levels in topsoil layers (Kindu *et al.*, 2006a). As an example, this tree is commonly planted in crop fields in Uganda and Kenya for soil fertility improvement or soil conservation (Muchiri, 2004 ; Muzoora *et al.*, 2011).

3.4. POTENTIAL OF *CHAMAECYTISUS PALMENSIS* AND *SESBANIA SESBAN* AS FODDER SOURCES

3.4.1. ORIGIN AND ECOLOGY

Sesbania sesban is a small fast growing African tree which has been introduced in Ethiopia (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009). It performs well in *Weyna Dega* agroclimatic zones, that is in the Ethiopian highlands (Bekele-Tesemma *et al.*, 1993). This tree can establish easily, even in waterlogging areas, and can survive in seasonally-flooded environments as well as dry soils (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009). Because of its rapid establishment and early growth, this species has a good potential in agroforestry systems (Cook *et al.*, 2017).

Chamaecytisus palmensis, also called Tree Lucerne or Tagasaste, is a small evergreen tree indigenous from Canary Islands and recently introduced in Ethiopia (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009). It is suitable to moist and dry highlands and is thus growing well in *Weyna Dega* and *Dega* agroclimatic zones, up to 3300 m (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009). It tolerates a wide range of temperature and even drought, but seedlings and trees stand with difficulty in very soggy soils (Orwa *et al.*, 2009 ; Esterhuizen, 2012).

Figure 12: Sesbania sesban

Figure 13: Chamaecytisus palmensis

3.4.2. FORAGE VALUE

A study showed that farmers from the northern Ethiopian highlands preferred *Sesbania sesban* as source of feeding compared to other multipurpose trees (Mekoya *et al.*, 2008). This species is actually known to be an excellent supplement feed to poor quality roughages, having a high percentage of foliage nitrogen, good protein content and high dry matter digestibility due to low crude fibre content (Roothaert & Paterson, 1997 ; Orwa *et al.*, 2009 ; Nigussie & Alemayehu, 2013 ; Heering & Gutteridge, 2019). In fact, according to El Hassan *et al.*, this species has high nutritive value with nutrient contents similar to Alfalfa (*Medicago sativa*, legume plant locally used as forage) hay. Its N content is particularly high, reaching more than 36 g available N per kg DM (El Hassan *et al.*, 2000). Other authors also confirm the adequate amount of nutrients for animal production (Karachi & Matata, 2000 ; Etana *et al.*, 2011). The crude protein content reaches 20% to 25% (Kaitho *et al.*, 1998 ; Etana *et al.*, 2011), and the in vitro dry matter digestibility of this tree is higher than 65% (El Hassan *et al.*, 2000 ; Heering & Gutteridge, 2019). The positive impact of *Sesbania sesban* on increasing liveweight of sheep when used as supplementation has also been proved (Kaitho *et al.*, 1998 ; Manaye *et al.*, 2009). The optimum dietary level for supplementation was found to be 25-30% of the ration DM (Kaitho *et al.*, 1998 ; Tessema & Baars, 2004 ; Manaye *et al.*, 2009). When fed with this quantity of supplement Sesbania, the average body weight gain of sheep increases by 103 g/day (Manaye *et al.*, 2009). Last but not least, Mekoya *et al.* assess the positive impact of Sesbania supplementation on milk yield of ewes and growth rate of lambs (Mekoya *et al.*, 2009).

Chamaecytisus palmensis is famous for its good nutritional values as well, and can also be compared to Alfalfa as a supplement feed (El Hassan *et al.*, 2000 ; Armstrong, 2018). Its foliage is said to be particularly free from toxic substances (Otsyina *et al.*, 1999 ; Getnet *et*

al., 2008 ; Orwa *et al.*, 2009), even if NDF and ADF contents are in the range of many other indigenous trees (around 50% and 35% respectively) (Kindu *et al.*, 2009a ; Feleke, 2016). The nutrient concentration is high, with 33g available N per kg DM (El Hassan *et al.*, 2000 ; Kindu *et al.*, 2009a). The crude protein content of the foliage ranges between 18% and 28% DM (Getnet, 1998 ; Getnet *et al.*, 2008 ; Kindu *et al.*, 2009a ; Feleke, 2016), and the digestibility is high with in vitro dry organic matter digestibility of leaves reaching 70% (Getnet, 1998 ; El Hassan *et al.*, 2000 ; Kindu *et al.*, 2009a). This tree can hence be qualified as good quality feed, suitable for protein supplement for ruminant livestock. It was found to be sufficiently high quality forage to be able to substitute concentrates to increase daily weight gain of sheep (Kaitho *et al.*, 1998 ; Getnet *et al.*, 2008). As a supplement, it is recommended to be fed up to 20% to 30% of the ration DM (Kaitho *et al.*, 1998 ; Getnet *et al.*, 2008).

As a matter of fact, both trees can be used as cut and carry supplementary feed in crop-livestock mixed farming systems.

3.4.3. SOIL FERTILITY IMPROVEMENT

Both species are N-fixing legume plants which can improve soil fertility (Orwa *et al.*, 2009 ; Esterhuizen, 2012 ; Scholle, 2017). Kindu *et al.* highlighted their property of soil fertilizer due to their capacity in enhancing total soil N (Kindu *et al.*, 2006b ; Kindu *et al.*, 2006a). Thanks to its deep root system and fast growth, *Sesbania sesban* can specially be used as a short term fallow to maintain soil fertility and prevent land degradation (Roothaert & Paterson, 1997 ; Nigussie & Alemayehu, 2013 ; Scholle, 2017).

3.4.4. OTHER PRODUCTS AND SERVICES

In addition to their fodder and fertiliser properties, *Chamaecytisus palmensis* and *Sesbania sesban* can be considered as good sources of firewood (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009). Sesbania is even described as having a good fuel quality, reaching 4 350 kcal/kg and being relatively smokeless (Orwa *et al.*, 2009 ; Scholle, 2017), and Tree Lucerne is said to burn with intense heat (Orwa *et al.*, 2009).
These species can also serve as shade (for coffee for instance), windbreak, live fence or bee forage (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Cook *et al.*, 2017).

4. AGROFORESTRY BACKGROUND

4.1. METHODOLOGY

4.1.1. DATA COLLECTION

In order to understand about the agroforestry background of the area, two village units from the district of Kachabira were chosen to collect data. The first one is the village of Fidamo, in the *kebele* (lowest administrative unit) of Hoda, where Inter Aide has been working for many years developing specific actions combining soil conservation and biomass production (mainly forage species), and where farmers are particularly active. The second one is the village of Harielcho, in the *kebele* of Ita, in which access to new technologies regarding fodder is still limited, as neither Inter Aide nor the Ministry of Agriculture have developed many programs in this area yet.

Data collection has begun in each village by leading a focus group discussion. These meetings have been organised thanks to the help of Inter Aide's staff and *Iddir* (traditional groups of villagers) committees: twelve farmers were present for each session. The aim of these focus group discussions was to understand the global strategy of farmers to grow hedges around their farmland, to raise a list of the main species that can be found, and to have a first idea about their use. These meetings also helped to select some farmers who have then been interviewed individually afterward.

The second step of data collection has been done by leading individual interviews. Sixteen farmers have been interviewed, eight from each village unit. Most of these farmers have been selected during the group sessions, the others having been suggested by IA staff to fulfil the sample. The volunteer farmers have been chosen on their interest for the study, being attentive to the variety of their social status. The criteria used by *Iddir* committees and Inter Aide to define social status are based on the size of the farmland, the *enset* plantation, the crop and livestock production, and the support given by relatives. The households can be divided in three categories: wealthy, intermediate and poor. Four of the interviewed farmers are wealthy, five are from the intermediate class and seven can be considered as poor. The sample has also been broadened with the point of view of female farmers, two from each village unit being interviewed. Each interview has been led at the farmer's place of residence, lasting between 1 and 3 hours. A grid has been used to help as a directive guideline but the conversations nonetheless remained free, following the speech of the interviewee (Annex 1). The aim of these informal interviews was to collect qualitative information about the farmers' designs concerning hedges and choices of the woody species growing in their farmland. From a forage point of view, the main issue was to identify whether farmers were relying on some trees as a fodder source. The list of the encountered species started during the group discussions has also been completed with direct observations on the field.

In order to supplement the pieces of information gathered during the focus group discussions and informal interviews, some case studies have been carried out for some species considered as particularly interesting in this agroforestry environment. For this purpose, the interviewed farmers have been chosen because of the presence of interesting specimen of the targeted species in their farms. They were asked questions on these specific

trees related to their use, management practices, and sometimes economic valorisation. The historical background of these species and hedges of the area has also been more deeply considered by interviewing senior farmers on the subject.

4.1.2. DATA ANALYSIS

Information collected through the focus group discussions and interviews was analysed thanks to a grid listing the main topics: history of the hedges, reasons to have live fences, species found, use of species, and fodder value. These notes have then been completed with the comments heard during the case studies.

All the main species encountered have also been listed in a table and their uses have been subjectively ranked based on statements of farmers and observations made.

4.2. RESULTS

4.2.1. A LANDSCAPE SHAPED WITH HEDGES

4.2.1.1 Description of the hedges

First of all, here is the typical organization of farms as described in the agrarian diagnoses of the *woredas* of Kachabira and Doyogena (Barthès & Boquien, 2005 ; Cheveau & Hoornaert, 2011). The rectangular-shaped land is oriented down-slope with the house, or *tukul*, which is the living place of the family and the livestock, usually located at the top. A small pasture is often present in front of the house and a backyard can be found just behind the *tukul* with the *enset* plantation which fertility is highly dependent on animal waste. The annual crop fields are located below. Over the last few years, the farmers have well adopted soil and water conservative structures in their fields; this practice is now often encountered in the farmlands.

During the interviews and visits of farms, it appeared that every farmland is surrounded by a hedgerow. Most of the time, some trees and shrubs are planted all around the property, including the plot of grass in front of the house, the backyard, the *enset* plantation and the field part. The live fences may also be strengthened by a built fence made of branches when they are not thick enough, especially around the pasture plot. These hedges surrounding the little farmland of each household create a tight territorial grid in the landscape, creating a sort of bocage typical of the area.

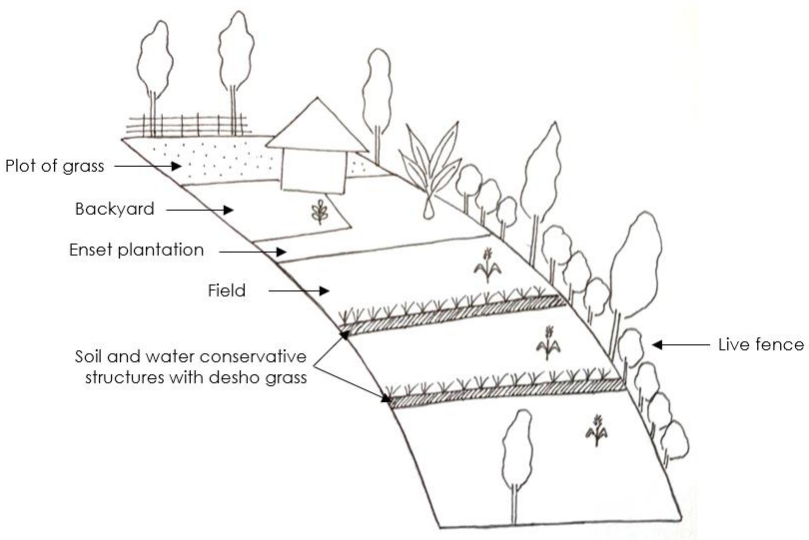

Figure 14: Diagram showing the typical organisation of a farm

The hedges are mostly made of bushy shrubs densely planted in a row, which are 2 to 4 meters high. The most encountered species are indigenous thickets that are well growing in the area, such as *Justicia schimperiana* or *Vernonia spp.* (*V. auriculifera* and *V. amygdalina*). Some higher trees are emerging from these bushy fences, *Erythrina spp.* (*E. abyssinica* and *E. brucei*) being the main local species. The exotic *Eucalyptus spp.* (*E. globulus* and *E. grandis*) and *Cupressus lusitanica* are also essential in the agroforest composition of the farmlands in which they are playing a specific role. Those last species are usually not planted inside the live fence surrounding the fields but in specific plots such as around the pasture in front of the house or as a wood lot at the bottom of the property, that makes these parts of the hedge slightly different from the side part.

Figure 15: Hedge of Justicia schimperiana and Erythrina brucei

Figure 16: Young plantation of Cupressus lusitanica and Eucalyptus species in front of hometsead

No real differences could be determined between the two villages, nor between farmers with different social status. It seemed that hedges had the same composition and organisation, irrespective of farmers' wealth or access to new technologies. In the same way, peasants also all seemed to manage their live fence with the same strategy.

The table 1 lists all the main species recorded during the field work in order of importance in terms of appearance in the hedges. This ranking is valued by expert opinion, based on observations made and the perception of the environment.

Table 1: List of the species encountered in the hedges on the field
The ranking of importance in terms of appearance in the hedge is based on observations.
Key for the mark of importance: 4: most common; 3: common; 2: frequent; 1: rare to very rare

Scientific name	Family	Amharic name	Kambatta name	Origin	Importance
Eucalyptus spp.	Myrtaceae	Barzaf	Barzafa	Exotic	4
Justicia schimperiana	Acanthaceace	Sensel	Gulbana	Indigenous	4
Cupressus lusitanica	Cupressaceae	Farendji Tsid	Homa	Exotic	4
Erythrina spp.	Papilionoideae	Korch	Wella	Indigenous	3
Vernonia auriculifera	Asteraceae		Barawa	Indigenous	3
			Tontona *	Indigenous	3
Vernonia amygdalina	Asteraceae	Grawa	Heba	Indigenous	3
Croton macrostachyus	Euphorbiaceae	Bisana	Massana	Indigenous	2
Acacia decurrens	Mimosoideae	Grar	Odora	Exotic	2
Grevillea robusta	Proteaceae	Gravilla	Gravilla	Exotic	2
Arundinaria alpina	Gramineae	Karkha	Lema	Indigenous	2
Juniperus procera	Cupressaceae	Abasha Tsid	Homa	Indigenous	1
Hagenia abyssinica	Rosaceae	Koso	Tenchuta	Indigenous	1
Cordia africana	Boraginaceae	Wanza	Wanza	Indigenous	1
Euphorbia abyssinica	Euphorbiaceae	Kulkwal	Charichuta	Indigenous	1
Podocarpus falcatus	Podocarpaceae	Zigba	Zagiba	Indigenous	1
Olea europaea	Oleaceae	Weira	Werra	Indigenous	1
Ficus spp.	Moraceae	Shola	Oddeta	Indigenous	1
Buddleja polystachya	Loganiaceae	Anfar	Hanifara	Indigenous	1
Prunus africanus	Rosaceae	Tikur Inchet	Gerba	Indigenous	1
Rhamnus prinoides	Rhamnaceae	Gesho	Gesha	Indigenous	1

* Could not be identified

4.2.1.2 Historical context

It seems that farmlands of this area have been traditionally hedged for a long time. Live fences are even seen as "cultural items" of the Kembatta region, making the landscape particularly verdant. The interviews did not allow to guess the real period from which this cultural practice started, but it seems quite sure that the lands have been surrounded by trees and shrubs for several generations. At least, hedges were already grown during the imperial period according to elder farmers, even if the bocage landscape was less dense than nowadays because of the bigger size of farms. Then, with the land distribution of the agrarian program during the *Derg* regime (1975), every farmer started to plant his own hedgerow around his new plot of land in order to delimit the borders and to protect the garden property (*enset*, cabbage, …) from animals. The main species planted at that time were already the same as nowadays: *Justicia schimperiana*, *Erythrina abyssinica* and *E. brucei*, *Vernonia auriculifera* and *V. amygdalina* and *Croton macrostachyus*. According to a farmer, it was a "cultural practice to plant such species in [their] live fence". In fact, these species are still mainly used nowadays to build new hedgerows or to fill the gaps. However, it appeared that the hedge composition slightly changed through time as some species have been introduced in this last century. This is the case for *Eucalyptus* species and *Cupressus lusitanica* which have been introduced since one or two generations only. Nowadays, they seem to increase in the landscape composition and to become a more and more important stake for

farmers. Recently, the tree *Grevillea robusta* has also been promoted by the Ethiopian government and it can now be distributed by the local offices of the Ministry of Agriculture.

4.2.2. THE IMPORTANCE OF PRIVATE OWNERSHIP

Private ownership[1] is a big concern for the inhabitants of this area. Actually, almost all of the interviewed households claimed that the main reason to plant hedgerows around their farmland was to make a live fence that would delimitate boundaries and protect the land from any entry (livestock, wild animals, thieves or even neighbours). It hence appears that, in addition to the purpose of protecting the *enset* and crop plantation from any animal grazing, privacy and intimacy are two main points considered by farmers which explain this "culture of showing the borders".

4.2.2.1 Regulation on trees and shrubs

To have a better understanding about this issue of privacy, the *Iddir* chairman of Fidamo village has been interviewed about regulations existing upon woody species and their use in the area.

As a general rule in the *woreda*, tree or shrub plantation can only be done on someone's property. The owner of the land has then absolute rights on the species that he planted for cutting or use. But what about trees planted on borders? In fact, boundaries are critical places as they are shared by both neighbours. Either they agree on sharing the place, each of them planting their own trees; or only one of them plants on his own land (usually the first one to settle) and he then has all rights on the whole hedge. Conducted interviews showed that conflicts between neighbours because of border purpose occurred quite often. This point is more developed afterwards.
Common lands belong to the *kebele* administration who has therefore every right of property upon the trees which are growing there; it is hence not allowed for farmers to plant or cut on those lands. However, it seems that an exception is done for grasses and shrubs which are naturally grown on those common areas and which can be grazed and used by anyone and even transplanted. Indeed, many farmers conceded that they transplanted these wild species while building their live fence at the beginning, because of their easy access.

These rules of property of trees and shrubs seem to be quite ancient, probably already existing during the imperial period, even if at that time common lands were wider and did not belong to the *kebele* administration but to landlords. As a matter of fact, it appears that the property has been a big issue in this area for many years: the private land is the only place where farmers can cultivate and plant different species for their own use. It is therefore very important to mark boundaries to show the exact limits of someone's property.

4.2.2.2 Boundaries as a critical issue

And these limits are often source of litigation! This assumption was confirmed by the *Iddir* chairman who confessed that his committee and him were "neither surprised nor chocked when [they] hear about such problems". Conflicts can even occur between different members of one family living next to each other.

[1] It should be noticed that private ownership does not exist strictly speaking in Ethiopia as the land is possessed by the government. Farmers officially have a right of use of the land.

The major problem that the *Iddir* committee has to deal with regarding trees issue concerns hedge management. Actually, the owner of the hedgerow has the duty to prune when branches have grown too much and start to damage the neighbour's land. This notion of "damaging" is not well defined but it is commonly accepted that live fences should be cut on average once a year to prevent it from covering paths and fields, especially after the sowing time. Otherwise leaves might overshadow crop plantations, prevent the rain to reach the soil, or even become a shelter for wild animals. This management of the hedge is almost the only one required but it is nonetheless very important, especially for neighbourhood relationships. As the owner of the hedge has absolute rights on his species, he should be the one pruning both sides. Nevertheless, if there is a good relationship between the two neighbours, they can make an agreement in which the owner allows his neighbour to cut the side of the live fence growing on his own land. If there is no agreement between the two farmers and if the owner of the hedge is not fulfilling his duty of pruning, the neighbour may complain about it. This complain should first result in a simple warning to the owner failing in his duty, and, if the situation is not improving after few months, the neighbour may complain directly to the authorities. The traditional commission dealing with this kind of conflict is the *Iddir* committee: they are the ones making the judgement after hearing claims and visiting the site if necessary. Nevertheless, since the *Derg* period, the *kebele* administration rules official decisions, even if they are often supporting the traditional commission. In some cases, people can thus claim directly to the *kebele* committee, if they don't trust the *Iddir* one or if they don't agree with their final decision for example.

Other types of complain upon trees that can be raised are, for instance, regarding soil fertility with *Eucalyptus* species growing next to *enset* plantation, or even cheating in boundary demarcations with the removal of shrubs in order to overtake some land. However, the most serious issue considered in the area is robbery for which is given the worst sentence (high penalty and judgement in the police station if recidivism), this is also true for robbery of trees in live fences (transplantation or cutting of neighbour's trees).

According to the *Iddir* chairman, the number of conflicts tends to increase during the rainy season as it is the tree plantation period. Some problems could indeed occur for instance because of *Eucalyptus* trees plantations, like planting *Eucalyptus* to close to the neighbour's field as it is considered as damaging the soil fertility. Furthermore, tensions have also grown through time. Actually, since the *Derg* regime, the size of farmlands has decreased and the population rate has increased, which is creating much more conflicts between neighbours because of boundary purpose. This is why, even if *Iddir* regulations have existed for many generations, the rules changed a bit and improved those last years to cope with the increasing number of complaints and to adapt to the new societal context.

4.2.2.3 Native species to make a proper live fence

This legislative context offers a better understanding of the importance for farmers to plant live fences around their farmland to show their boundaries and to protect their property. Surely, most of the species which are planted in the hedgerows are not necessarily chosen for any specific purpose but only because "there is not a lot of choice of species growing in this area", according to some interviewed people. The easy and free access to endemic species such as *Justicia schimperiana* or *Vernonia auriculifera* makes them leading species in the hedge composition. Nevertheless, they are still appreciated for their "live fence properties". Indeed, these evergreen species with bushy growth are preferred for their ability to "have

much branches and to cover the whole area" and to be long living. The quick and easy way of propagation by layering, cutting or simple transplantation is also one of the big advantages of the indigenous species planted in the hedges. This is the case, for instance, for the trees *Erythrina abyssinica* and *Erythrina brucei* which are particularly esteemed because of the easy taking of cuttings. Farmers stated that they prefer to let the live fence regenerate by itself without taking too much care about it so to have time to rather focus on species with economic value like *Eucalyptus* and *Cupressus*.

Figure 17: Cuttings of Erythrina abyssinica to make a live fence

4.2.3. INDIGENOUS TREES AND SHRUBS FROM A FODDER POINT OF VIEW

Feeding of livestock mainly consists in a cut and carry system in which women play a major role. They are actually the ones responsible to collect and bring feed supplies in the *tukul* where animals are fed three times a day. Animals are sometimes taken out to graze the private pasture in front of houses. The main fodder sources used in the area during the rainy season are grasses: the natural ones growing in pasture lands or under the *enset* plantation, and the improved ones brought by Inter Aide or the Ministry of Agriculture (like *Pennisetum riparium* or *desho* in Amharic). While during the dry season crop residues are considered as an important source of forage. Nonetheless, a lot of households still rely on their *enset* plantation to feed their cattle, using the leaves and the bark of this Ethiopian false banana, which creates competition with human food as this plant is the base of their traditional diet. It appears that this last feed supply is particularly fundamental for people who do not have a good access to fodder grasses, as for example in the *kebele* of Ita that has been visited and where there are still few interventions of Inter Aide. Anyhow, it seems that for all farmers, having grass resources or not, fodder supplies are still limited, being an everyday challenge for the poorest and a constraint to improve the quality and the quantity of animal products for the wealthiest. Actually, access to fodder is also crucial for farmers to access and maintain cross-breed animals which are requiring more quantity of fodder of good quality. Some people may buy forage if they can afford it, either for the essential needs (grass or *enset* leaves) or for improvement (*frushka* which are by-products from the grain factory).

However, even in this context, it appears that the woody plants are not seen as a reliable source for forage, even for the poorest households or those who do not have a lot of grass. Some species are actually used to feed animals but mainly to face fodder shortage. Among them are *Erythrina* species, *Justicia schimperiana* and *Vernonia amygdalina*. Farmers were unanimous to admit that trees and shrubs were only rarely used for fodder purpose, just to "get through the hunger gap". This is mostly during the dry season, in January and

February, when there is a forage scarcity or sometimes at the end of the rainy season when their own grass is regenerating. Shrubs can nonetheless be browsed directly by the cattle at any time of year and branches of trees are given to feed animals when they are cut for another purpose like firewood or fence building. However, this use as forage seems to be a side effect of the live fence and the species may not be sought for their fodder purpose. Some of the interviewed farmers even admitted that they preferred to buy fodder products on the market or to neighbours rather than relying more on woody species, which leads to believe that the fodder value of shrubs and trees is usually not included in the strategy of planting hedges.

This might be explained by the fact that, in the past, enough common lands were available to let the cattle graze freely and not much forage was therefore needed in addition to this free grazing. Farmers hence did not need to plant, at that time, any additional species in the traditional live fences for specific fodder aims. A second and main reason which can be raised to explain such a behaviour is that the quality of the leaves of indigenous trees and shrubs is not considered by farmers as good enough to be used as fodder. Almost all the interviewees agreed to say that traditional fodder trees were not improving the milk production nor the body performance of animals, unlike *enset* leaves or *desho* grass. Furthermore, for most of these species, the palatability is also regarded by farmers as insufficient; they are browsed by cattle solely when no other green source is available. The only exceptions encountered were for the trees *Buddleja polystachya* and *Vernonia amygdalina* which were said to be rather appreciated by cattle. However, *Vernonia amygdalina* is only rarely specifically used for its fodder value but mostly only given to feed animals when pruned like other species, farmers preferring to rely on grass than on trees as forage. As for *Buddleja polystachya*, before being planted for forage purpose, this species is mainly prized for its good wood quality for construction and fence building (weevil resistant and long living). Its fodder value is hence relegated at the second level in this area, farmers seeking mainly its strong wood proprieties.

4.2.4. OTHER VALUES OF THE HEDGES

4.2.4.1 Soil fertility

Soil fertility is also another argument often raised for selecting some indigenous species, such as *Erythrina spp., Justicia schimperiana* and *Vernonia amygdalina*, to grow in the hedges. Most of the farmers acknowledged the positive impact that these species may have on soil properties, probably due to the high amount of organic matter that is brought through defoliation. Specific interviews have been led upon the leguminous species *Erythrina*. It has been found that environmental benefits provided by these trees have been known for many generations in the area: it is commonly accepted that roots enhance soil fertility and leaves make the soil dark and fertile by shedding down. One interviewed farmer also assessed that this practice of having *Erythrina* trees in the middle of his field and using the leaves as compost before ploughing allowed him to reduce his quantity of fertiliser by half, and so to do some economic profits. This farmer hence confirmed that it was more profitable to use the leaves of these trees to improve the land rather than to feed animals.

Figure 18: Young boy ploughing under Erythrina trees

At least, even if they do not improve the soil fertility strictly speaking, indigenous species are sought for their ability not to drain the land. In fact, the exotic species with high economical value (*Eucalyptus spp.* and *Cupressus lusitanica* mainly) are essential in the strategy of farmers but they are known to have an important negative impact on the soil fertility, making the land very dry. Every farmer recognises the danger that these species can yield on the *enset* and crop plantation and, as a result, tries to plant them far from fields if the size and the organisation of the farmland allow it (mostly in front of the house or as a wood lot at the bottom of the land). One practice also consists in digging a one-metre-deep ditch between the trees and the field to break the root system. On the contrary, the species selected to make the live fence on the side part of the farmland, and mostly those which are next to or inside the *enset* plantation, are chosen with careful attention so that they may not damage the plantation.

In the summary table of the species page 30-31, the soil fertility value has been given according to the opinions recorded during the interviews. There is no scientific value on this ranking nor in the appreciation marks.

4.2.4.2 Windbreak

Some farmers raised the necessity to plant trees in front of their house in order to protect the land from the wind. The best species required for this windbreak effect was said to be *Cupressus lusitanica* (and to a lesser extent the endemic species *Juniperus procera*) which is indeed often planted as a hedge around homestead. One farmer interviewed specifically upon his *Cupressus* trees stated that it was the only species that he knew in the area which can act as a "wall" to protect the land from cold air. Branches can indeed be gathered together to build a powerful windbreak, and the top of the trees can even be cut to strengthen this function of protection by making a well-shaped thick hedge.

Figure 19: Hedge of Cupressus lusitanica protecting the house

One of the farmers also planted a hedgerow over a soil and water conservation structure. In addition to protecting the structure from erosion, this farmer raised the strong windbreak effect of this hedge. It was composed of *Erythrina brucei*, *Justicia schimperiana* and *Vernonia auriculifera* that he chose for their "fertilizer" properties. Even if he is not sure if it is because of the windbreak effect or because of the root system of these species, he nonetheless noticed an improvement in the quality of his soil, particularly in the moisture content. To prevent light competition between trees and crops, he clears the hedge twice a year, in January and in May, and uses the leaves either as compost on the field or to feed his animals.

4.2.4.3 Wood needs

Last but not least, farmers also plant some species in hedgerows for their multipurpose use. The trees present in the hedge are an undeniable source of wood for fuel, for fence building, for cattle's shelter or even for home construction or furniture. As indigenous species, one can name *Erythrina spp.* which are often said to be used to build the stable or doors for example, or *Croton macrostachyus* which is valued as traditional timber tree for furniture or as firewood.

Few trees are also said to have very good wood quality, like *Buddleja polystachya* which is prized to build fences or walls of traditional houses, and *Hagenia abyssinica* which is valuable timber to make furniture. Yet, when *Eucalyptus* species started to spread in the area, about 70 years ago, this new tree replaced the endemic species for timber purpose. According to senior farmers, *Eucalyptus* arrived from the north of the country and spread in the countryside as an answer to the shortage of firewood and wood for construction at that time. Its propriety to grow fast and its good fuel quality are two advantages that made farmers quickly attracted to this species. It hence soon became a leader species for house construction because it could grow easily and reach every kind of size within a short time, unlike indigenous trees which take long time to grow. A business started to develop for *Eucalyptus* products in order to meet the increasing demand of wood for construction and fuel. Farmers then started to not plant indigenous trees like *Buddleja polystachya* or *Hagenia abyssinica* anymore, but rather to replace them in their farmlands with *Eucalyptus* species. As a matter of fact, these endemic trees are becoming rare nowadays and the new generation does not seem to be interested in planting them anymore, willing to focus on trees with better economic values.
According to inhabitants of the area, the exotic species *Cupressus lusitanica* and *Acacia decurrens* have also spread widely since the end of the last century and have now become very common. *Cupressus lusitanica* is appreciated for its good timber to make furniture like beds, chairs or columns for the house, and *Acacia decurrens* for its resistant wood for construction and fencing and for charcoal. Both trees also have the advantage to grow fast, which is a key point for farmers.
Nevertheless, those fast-growing species are mostly not grown directly in live fences, but mainly as woodlots in specific places of the farm. This is generally at the bottom of farmlands or in front of homestead, which makes these parts of the hedge slightly different from the side parts.
The exotic *Grevillea robusta* has also been introduced recently (a couple of decades) in the Ethiopian highlands for its wood value. Yet, farmers said to be less used to utilize this tree and, as for now, it can mainly be observed in public places (towns, schools or administrative compounds) but few farmers actually planted it for private use. Utilities of this tree is still uncertain for farmers and it is often considered solely for its ornamental value.

Some indigenous trees are still planted for wood purpose, to support personal needs, but it is mostly preferred not to plant these trees in the live fence but rather in individual places. This is the case, for instance, for *Podocarpus falcatus*, *Olea europaea* or *Ficus spp*. which are often planted individually in the pasture land in front of homestead and used for own consumption. Wood of *Cordia africana* is also very famous for making all kind of furniture. The presence of these trees allows farmers to produce their own furniture and to build their own house, some of them being thus almost self-sufficient in timber supply.

Figure 21: Podocarpus falcatus in an individual place

Figure 20: Olea europaea in front of homestead

It can thus be concluded that wood functions are not the first reasons raised to plant trees in the live fence. It is nowadays preferred to plant trees for firewood, timber and poles as wood lots (mostly exotic species like *Eucalyptus spp.*, *Cupressus lusitanica* or *Acacia decurrens*) or in individual places (for indigenous species). However, some farmers may not have enough space on their farmland to do so and they may thus rely on the species growing on the hedge to satisfy their basic needs. Anyhow, even if most of the farmers of this area declare to be self-sufficient in terms of firewood, indigenous species growing on hedgerows are, for all of them, still a precious source of fuel that they will not hesitate to use during scarce period or after pruning. This is another advantage of having these permanent species which are easy to cut and to use.

4.2.4.4 Sum up of values

Other specific utilities of the trees were raised during the interviews, like medicine, bee forage, fabrication of some traditional materials, shading or ornamental purpose.

The table 2 sums up all trees and shrubs use identified during the field work. The marks have been estimated based on the perception of the interviewed farmers. The species are presented in the same order than in the table 1 page 22, that is in their order of importance in the hedges.

Table 2: List of the species with their use and mean of propagation
The marks for estimated values have been estimated based on the perception of the interviewed farmers.
Key for estimated values: 4: very valuable; 3: valuable; 2: less valuable; 1: least valuable; 0: no value

Name	Forage	Construction	Furniture	Fuel	Medicine	Income	Soil fertility	Other values	Disadvantages	Propagation	Comments
Eucalyptus spp.	0	4	0	4	2	4	0	Fence building	Soil dryness	Seedlings	Two main species are differentiated: white Eucalyptus (nachi Barzaf, *E. globulus*) and red Eucalyptus (kaï Barzaf, probably *E. grandis*). The white one is growing faster but less resistant for construction than the red one.
Justicia schimperiana	3	0	0	2	0	0	3	Roof for traditional houses	Damaging teeth of animals	Wildings	
Cupressus lusitanica	0	1	4	3	0	4	0	Fence building, windbreak, shade, traditional items, ornamental	Damaging soil fertility	Seedlings	Good for furniture; the wood is weevil resistant
Erythrina spp.	3	0	2	2	0	1	4	Fence building, livestock bed, tools (for *kocho* preparation), coffin, leaves as compost	Taking long time to become dry for fuel purpose	Cuttings	Two species: *E. abyssinica* and *E. brucei*
Vernonia auriculifera	0	0	0	2	3	0	2	Fence building		Wildings	Wound healing
Tontona	2	0	0	0	3	0	4	Repulsive effect on insects (can be used as protection for *enset* plantation)		Wildings	
Vernonia amygdalina	3	0	0	3	3	0	3	Fence building, cultural materials, crop threshing material, bee forage		Wildings	Good palatability forage, medicine for humans and animals (womb and blood pressure, placenta removal for cattle)
Croton macrostachyus	0	0	2	3	2	2	2	Charcoal, coffin, handles		Wildings, seedlings	Medicine for cattle and humans, fast drying of the wood (especially used for *Meskel* feast)
Acacia decurrens	1	3	0	4	0	3	0	Charcoal	Damaging soil fertility, can bend easily when grown with other trees	Seedlings, transplantation of root suckers	
Grevillea robusta	0	1	2	2	0	2	1	Ornamental, shade	Seeds are not easily accessible	Seedlings	
Arundinaria alpina	3	3	3	1	0	4	0	Fence building, tools (for *kocho* extraction), cultural items	Damaging soil properties	Rhizomes	Usually planted in wood lots, not in the live fence
Juniperus procera	0	2	4	3	2	2	0			Seedlings, wildings	Very good quality for timber. Endangered species.

The marks for estimated values have been estimated based on the perception of the interviewed farmers.
Key for estimated values: 4: very valuable; 3: valuable; 2: less valuable; 1: least valuable; 0: no value

Name	Forage	Construction	Furniture	Fuel	Medicine	Income	Soil fertility	Other values	Disadvantages	Propagation	Comments
Hagenia abyssinica	0	1	4	3	3	0	2	Tools (crop threshing, *kocho* preperation), ornamental		Wildings, seedlings	Seeds traditionally used for medicine as dewormer. Very good timber quality. Endangered species.
Cordia africana	3	0	4	3	0	3	3	Leaves as compost, bee forage		Seedlings, wildings	Very good timber quality (best species for furniture)
Euphorbia abyssinica	0	1	1	0	0	0	0	Crop threshing material	Toxic liquid inside branches	Cuttings	
Podocarpus falcatus	0	0	3	2	1	2	0	Ornamental, shade	Slow growth	Seedlings, wildings	Seeds are strong and not growing well, it is usually prefered to be transplanted when naturally grown. Usually not in the live fence but singly
Olea europaea	0	3	0	3	0	0	0	Tools (swing plough), toothbrush, smoking, ornamental, shade		Wildings	Usually not planted in the live fence but singly
Ficus spp.	0	0	3	2	0	2	2			Seedlings	Usually not planted in the live fence but singly
Buddleja polystachya	4	3	0	3	0	0	0	Fence building		Seedlings	Became rare
Prunus africanus	0	1	1	2	0	0	0	Tools		Wildings	
Rhamnus prinoides	0	0	0	0	0	2	0	Traditional drink (*talla*)		Wildings	

4.2.5. MANAGEMENT OF THE HEDGES

As it was raised before, the described live fences do not require a lot of management. A clearing is simply done once or twice a year to avoid overgrowth. At that time, farmers give the leaves for livestock or let them under the trees as compost, and they use the branches as firewood or to build fences. Otherwise, farmers only need to fill the gaps in the hedge from time to time when some species are exploited or disappear.

4.2.6. TREES IN THE FARMLAND FROM AN ECONOMIC POINT OF VIEW

Most of the trees planted in the farmland are first of all valued for home consumption. It is part of the strategy of every farmer to have enough wood to support his own needs in terms of fuel, construction and furniture. As mentioned above, the indigenous trees traditionally used for construction are *Olea europaea*, *Buddleja polystachya*, *Arundinaria alpina*, *Euphorbia abyssinica*. Whereas one can name the species *Cordia africana, Hagenia abyssinica*, *Juniperus procera*, *Podocarpus falcatus*, *Ficus sur*, *Croton macrostachyus* or even *Erythrina spp*. for their traditional timber purpose for furniture. These species can be located in the live fence or, for some of them which are not suitable in the hedge, they can be planted separately, in front of the house for instance.
Some of these species can be sold when one farmer has extra amount unneeded for personal use. Trees can be sold standing or already prepared as planks or poles. *Cordia africana* and *Podocarpus falcatus* are said to be particularly valued for their good timber quality. One farmer stated to sell 30 years old standing *Podocarpus* for 1000 Etb and 1600 Etb if it was sold as timber.
The endemic bamboo *Arundinaria alpina* was given less attention in this study because of its herbaceous character, and because it is rarely found in hedgerows but mainly grown as specific woodlots. Nonetheless, it can be noticed that farmers are highly relying on it for regular income: its easy propagation, fast growth and multipurpose value are good factors to consider this "tree" as a cash plant. It is specially very prized nowadays to build panels for fence and cultural items.

However, since the arrival of new competitive trees in the area about 70 years ago, the strategy of farmers has changed. In fact, it is now preferred to focus on *Eucalyptus spp*. raised as wood lots to satisfy personal needs for firewood or construction. This fast-growing and drought-resistant tree is hugely appreciated for its multipurpose ability. It can be used at different size for house construction purposes (small poles as *maager*, medium ones as *kwami* and big logs as *girgida*) and it presents good fuel values as it is a dry wood which is not consuming too fast. There is a very good market for its sale and the demand is highly increasing nowadays: merchants even come from towns (Doyogena, Shinshisho, Hosaena) to buy this tree from the countryside. All these characteristics make it a very good saving tree that can be sold from seedlings to huge size. It is thus an interesting source of cash that can be used if the owner is facing any economic need. Some prices were collected in the local market of Doyogena to have a notion of economic benefits that could be done with this species.

Table 3: Prices of Eucalyptus pieces collected in the local market of Doyogena

Name of entity	***Maager***	***Kwami***	***Girgida***
Age of tree	2-3 years old	5 years old	More than 7 years old
Price/unit	10-30 Etb	160-200 Etb	45-50 Etb per log
Pictures			

According to farmers, *Eucalyptus spp.* have nevertheless a very negative effect on soil properties. They often complain about this tree which damages the fertility of the land and they specially take care not to plant it next to the *enset* or crop plantation if possible. But this statement does not restrict the farmers who do not have a big enough land to plant this species anyway, as for them the benefits that these trees can supply far outweigh their environmental costs. Interviewees hence testified that the number of *Eucalyptus* trees is nowadays increasing a lot in the area. One farmer even confessed that "people are working day and night to plant it".

Another species which plays a major economic role for the inhabitants of this area is *Cupressus lusitanica* which arrived in the area, according to senior farmers, a bit after *Eucalyptus*, in the second half of the last century. It is now one of the most common trees after *Eucalyptus*. Even if it is also known to have a negative effect on the soil fertility, this species is particularly appreciated for its easy and fast growth and its good quality timber for furniture and traditional items. Nowadays, a lot of farmers plant it in their hedges or as wood lots, for their own consumption first but also for income purpose if they have extra to sell. The market demand for this species is important and it seems to improve as farmers have witnessed an increase in prices for the last few years. Wood lots are mostly bought as a pack by merchants to be sold in cities or to some furniture firms. One interviewee expected to sell a lot of about fifty 12 years old trees (20 to 40 cm diameter) for no less than 10 000 Etb.

4.3. DISCUSSION

4.3.1. LOW POTENTIAL OF INDIGENOUS FODDER TREES TO DIVERSIFY THE FORAGE PRODUCTION

The focus groups discussions and interviews revealed the existence of a large variety of criteria for selecting tree and shrub species growing in hedges. This is in line with the findings of Mekoya *et al.* who assess that trees are often chosen for their multipurpose properties to achieve different farming objectives (Mekoya *et al.*, 2008).
However, it has been shown that the fodder value of woody plants is not considered as a specific objective for farmers from the Kembatta highlands. A lot of species commonly grown in the live fences are not sought for their products, especially in terms of forage, but rather for the services that they can give to the farming system, mostly for boundary purpose. Hedges are mainly planted in order to protect fields from free grazing and keep private propriety. Most of these species are even specifically appreciated by farmers because of their easy availability and the little management that they require.
Above all, the feed quality of indigenous fodder trees and the palatability of leaves are not very praised in the studied area. The traditional knowledge does not seem to consider these trees as good supplement feed sources for animals. Especially, farmers said to not observe any improvement neither in lactation nor in physical development of cattle. They hence do not rely on tree species production for fodder purpose.

This statement is going against the scientific point of view described in the literature review part. Some indigenous tree species like *Vernonia amygdalina*, *Buddleja polystachya*, *Hagenia abyssinica* and in a lesser extent *Cordia africana* and *Erythrina spp.* can actually be considered for their nutritional value. They are even said to be used by farmers in other parts of Ethiopia for maintenance of cattle or improvement of productivity (Geta *et al.*, 2014b). Yet, in the Kembatta highlands, feeding indigenous trees and shrubs is almost a side effect of hedges as they are very scarcely used during the year (mostly when pruned).

As a matter of fact, no specific indigenous tree or shrub species could have been detected in this study for their local use as fodder source. It can thus be inferred that a program based on the implementation of indigenous woody species does not seem to be a good solution in this area to increase and diversify the feed source.

4.3.2. OTHER BENEFITS FROM INDIGENOUS SPECIES AND RECOMMENDATIONS FOR FURTHER AGROFORESTRY DEVELOPMENT

On another hand, the proprieties of some trees regarding soil fertility seem to be well-known, at least from elder farmers. Species like *Cordia africana*, *Erythrina abyssinica*, *E. brucei*, or *Croton macrostachyus* can even grow in the middle of fields. These local practices are in accordance with the scientific point of view upon those species. Especially, the capacity of *Erythrina spp.* to reduce the quantity of inorganic fertilizer inputs has been scientifically confirmed (Wassie, 2012). In this agroecological context, leaves of indigenous multipurpose trees can hence provide more benefit when used as compost rather than as fodder.
In order to maintain this traditional knowledge and help farmers to increase the economic and environmental sustainability of their farms, more communication could be done about the capacity of some trees to improve soil fertility. In particular, in a country where the

agricultural fertilizer consumption is increasing, trees can be a good alternative for small holder farmers (Buzanakova, 2014). This communication should especially target new generations as they may lose this local knowledge.

Nonetheless, contrary to what can be found in the literature, farmers do not have such a good opinion on *Acacia decurrens*. In spite of being a legume tree, many farmers complain about this species and say that it "dries the soil". This might be due to the shallow root system that can create competition with crops (Molla & Linger, 2017). Another reason which could explain this behaviour is the fact that this fast-growing species is still rather new for farmers. As they still do not have a lot of personal experience about its agronomic characteristics, they might consider it as other exotic fast-growing species which are known to deplete soil fertility.

This is specially the case for *Eucalyptus spp*. which are famous for their "bad effect on soil properties". This assessment was also given by farmers from other regions of Ethiopia, like in the Sidama zone (Asfaw & Agren, 2007). As they are non-leguminous species, *Eucalyptus* trees cannot fix nitrogen, and Michelsen *et al.* demonstrated that soil under *Eucalyptus* plantations have lower nutrient content than in indigenous woodlands. The authors add that the low availability of phosphorus, calcium and potassium in these soils might be the limiting factor for crop growth (Michelsen *et al.*, 1993). Other studies also revealed the negative impact of *Eucalyptus* trees on soil nutrients availability (Chanie *et al.*, 2013). These species are actually supposed to contain many allelochemicals, which are chemicals from leaves or litter that inhibit the germination or growth of other plant species. Indeed, it has been shown that *Eucalyptus spp.* have an allelopathic effect reducing the germination and growth of different Ethiopian crops (Lisanework & Michelsen, 1993). A long-term exposure to allelochemicals may reduce vegetative cover and cause soil erosion. In fact, Abiyu *et al.* found that herbaceous diversity was lower under *Eucalyptus* plantations than in natural regeneration lands, as well as contents of organic carbon and total nitrogen (Abiyu *et al.*, 2011). However, regarding the study of Michelsen *et al.*, no difference in terms of richness and biomass of herbaceous plant species between plantation of *Eucalyptus* and natural forests could have been detected (Michelsen *et al.*, 1996).
In addition to this allelopathic effect, *Eucalyptus spp*. may have a negative impact on crop yields within 20m distance from the tree stand, which is said to be probably due to competition for growth resources and water suction ability of trees (Chanie *et al.*, 2013 ; Alebachew *et al.*, 2015). Yet, according to Davidson, *Eucalyptus* trees need 785 litres of water on average to produce one kilogram of dry biomass compared to 1000 to over 3000 litres for agricultural crops (Davidson, 1995). These results refute the common thought of Eucalyptus consuming a large amount of water and drying the soil.
Though, despite the controversies about the environmental effect of *Eucalyptus spp*., the main problem stays in the fact that those trees are usually mostly raised in monoculture and lead to nutrient losses because of frequent biomass harvest. As an alternative to this monoculture, Khanna suggests that a mixed culture with at least one N-fixing species could improve plant productivity and reduce environmental costs. For instance, *Acacia spp.* incorporated in *Eucalyptus* plantations fix nitrogen in the soil which enhance soil fertility and tree growth (Khanna, 1998).
In the local context of Kembatta highlands, it could hence be relevant to advise farmers to plant legume species next to their *Eucalyptus* trees in order to cope with the depletion of fertility that they express.

Lastly, through this study, some indigenous species appeared to have multi benefits, especially in terms of wood supply, and to be valuable for farmers. In particular, *Cordia*

africana and *Podocarpus falcatus* could be sold for reasonable prices. These indigenous trees, regarding their adaptation to the environment and the experience that farmers have about them, should not be neglected in the strategy of farmers. They can be good supplement wood supply and income to exotic fast-growing species like *Eucalyptus*. Inter Aide could thus assist farmers to propagate these trees in their farmlands.
However, further studies should be led to understand more about the economic value of these species and their way of propagation.

4.3.3. LIMITS OF THE STUDY

This study was based on unformal interviews and thus mostly gather qualitative data in order to understand the overall agroforestry context of the area. Very few quantitative data have been collected which limits the deeper understanding of each species function, mostly from an economic point of view. Only few price data have been recorded to have a global estimation of the potential income value of some specific species considered as worthwhile for farmers. In the same way, the wood needs of households have only been qualitatively assessed. The aim was mainly to have a general idea upon the availability of firewood and timber in the area and appreciate the strategy of farmers regarding those wood supplies growing in their farmlands. Consequently, the quantity of firewood or timber used per household has not been measured.

Even though many farmers declared to be almost self-sufficient in terms of wood supply, investigating further would help to have a better understanding of the socio-agro-economic context of the area and to define more precisely the constraints that inhabitants are facing. Doing more research on economic values of some significant species (like *Eucalyptus spp.*, *Cupressus lusitanica*, *Acacia decurrens, Grevillea robusta, Cordia africana, Podocarpus falcatus, Juniperus procera* and *Ficus spp.*) could also help to appreciate more deeply the strategy of farmers regarding trees in their farmland.

5. INTRODUCED FODDER TREES: TREE LUCERNE (*CHAMAECYTISUS PALMENSIS*) AND SESBANIA (*SESBANIA SESBAN*)

5.1. METHODOLOGY

5.1.1. DATA COLLECTION

5.1.1.1 Questionnaire survey

A questionnaire survey was conducted in order to assess the adoption rate of *Chamaecytisus palmensis* and *Sesbania sesban* by farmers benefitting from Inter Aide in the area. It also aimed to understand the interests of farmers towards those trees by having a global idea about motivations to plant them, as well as benefits and challenges encountered. The total sample population included all the beneficiary farmers of Inter Aide from the Doyogena and Kachabira highlands who already had access to Tree Lucerne and Sesbania, that is about 600 farmers spread in ten different *kebele* (six in Doyogena *woreda* and four in Kachabira *woreda*). Among this population, a sample of 100 farmers was randomly interviewed, ten farmers from each *kebele*. Upon those 100 farmers, 90 knew about the tree *Sesbania sesban* and 62 knew about the tree *Chamaecytisus palmensis*, that is 90 and 62 exploitable answers for each tree respectively. Farmers were interviewed at their place of residence and were asked to answer the survey orally. The questions of the survey were asked for both trees and were about general information on the farmer's status, global knowledge and information about the plants, access for seeds and seedlings, plantation conditions, management of the trees, difficulties encountered, adoption of the trees and future plantations (Annex 2).

5.1.1.2 Individual interviews

In order to go deeper on practices and feedbacks of farmers regarding *Chamaecytisus palmensis* and *Sesbania sesban*, some individual interviews were conducted with some model farmers of the area. These interviews aimed to document more precisely the plantation, management and feeding practices of those farmers in order to learn about the best way of managing the species. An informal discussion also helped to understand more specifically the motivations which led farmers to plant those trees and their perception about them. For this purpose, eleven farmers were selected in the two *woredas*: four farmers were interviewed about Sesbania, five farmers were interviewed about Tree Lucerne, and two farmers were interviewed about both trees. These farmers were chosen with the help of IA staff because of their interesting way of management of the trees and their interest for the project. The informal discussion took place at the place of residence of the interviewee and lasted for about one hour. Direct observations were done on the field and pictures were taken to illustrate the statement. The summarized information sheets of these interviews can be found in the appendix (Annex 5).

5.1.1.3 Focus group discussion

After having completed the questionnaire survey and individual interviews, a focus group discussion took place with all IA staff members of Doyogena and Kachabira offices, and twelve model farmers from the area. The goal of this meeting was to discuss about the findings of the study, and to hear farmers' assessments on the challenges and practices of the two species. It also aimed to discuss more specifically about the bottleneck for the adoption and the diffusion of these fodder tree species. The twelve farmers were chosen and invited by IA project officers because of their interest for the project and their good experience regarding Tree Lucerne or Sesbania management. This focus group discussion took place in a rented room in Kachabira and lasted for 3 hours.

5.1.1.4 Germination test

In order to study the germination of *Chamaecytisus palmensis* and *Sesbania sesban*, a little experience was conducted in the *kebele* of Homa, in Kachabira *woreda*. This experience mainly aimed to determine under which treatment conditions each species grows better.

Study site and preparation of seedbed

The study site is at an altitude of 2100 metres above sea level. The climate characteristics are considered to be the same as the ones described in the introduction.
The seedbed was prepared following local farmers' practices. A plot of 16 m^2 (4mx4m) was dug with the traditional tool *mekofere* (hoe). Then, two samples of soil, about 1 m^3 each, were brought from the Doyogena and Hobichaka nurseries. These brown and red clay loam soil samples are considered to be representative of each type of soil encountered in Doyogena and Kachabira *woreda* respectively. Each sample was spread on half of the seedbed plot, that is, on a 4mx2m strip.

Seeds source and treatments

Seeds of *Sesbania sesban* and *Chamaecytisus palmensis* were obtained from Inter Aide. They were purchased in the market of Soddo, in the Wolayta district, and stocked in the office's store for a few months, but it was not possible to determine their origin more precisely.
Five different treatment techniques were exercised on seeds:

- Treatment 1 (T1 – control): no treatment;
- Treatment 2 (T2): seeds were soaked for 30 minutes in boiled water, the water having been removed from the fire source;
- Treatment 3 (T3): seeds were soaked for 24 hours in cold water;
- Treatment 4 (T4): seeds were soaked for 1 minute in boiling water and then soaked for 24 hours in cold water;
- Treatment 5 (T5): seeds were nicked with a nail clipper and soaked for 24 hours in cold water.

The last treatment is the advised method given by the Lucerne Tree Farm of South Africa for germination of *Chamaecytisus palmensis* (Esterhuizen, 2012). The same treatments were exercised on seeds of *Sesbania sesban* and *Chamaecytisus palmensis* in order to compare which one is the most fitted for each species. Each treatment was applied on 200 seeds of each species, so that 100 treated seeds could be sown in each type of soil.

Plantation

Ten rows were dug in each soil sample, about 30 cm apart and about 1 cm deep. On the 20th of July, the treated seeds were sown in rows with about 1 cm gap in the prepared seedbed and recovered with 1 cm of soil. Each row contained 100 seeds of each species of each specific treatment.

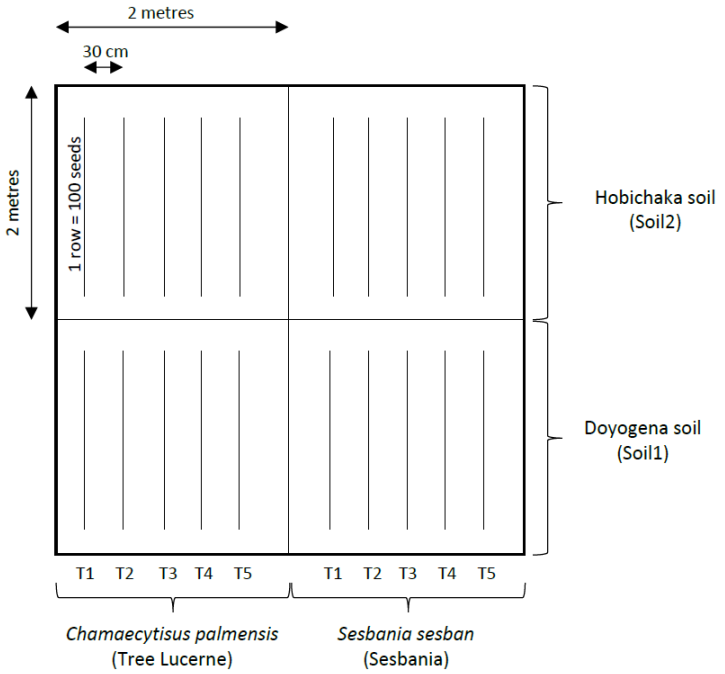

Figure 22: Sketch of the experimental seedbed

The number of growing seeds within each row and the average height of seedlings were collected every week for two months.

5.1.2. DATA ANALYSIS

Some statistical analyses were performed on the datasets of the questionnaire survey. The effect of 2 factors on other variables has been particularly studied: plantation of the tree (Yes/No) and adoption of the tree (Yes/No). In this case, adoption is defined, for farmers who already tried to plant one of the two trees, and still have some plants in their farmland nowadays. On the contrary, farmers are considered as having abandoned the program if they tried to plant Sesbania or Tree Lucerne but don't have these trees anymore.
The first category of questions of the dataset concerns the farmers' status and their farm characteristics. The effects of those variables on plantation and adoption have been analysed in order to see if some factors (age, wealth, household size, education, farmland size or number of animals) could encourage the fact to plant or adopt those new trees. On the one hand, the application conditions to practice an analysis of variance (ANOVA) on qualitative and quantitative variables were not satisfied. These variables have hence been analysed by the non-parametrical test of Kruskal-Wallis. On the other hand, the application condition to practice a Chi2 test on qualitative variables (at least 80% of modalities with more than 5 individuals) was also not satisfied. In order to determine whether there is a

link between two qualitative variables or not, a Fisher's exact test has hence been performed.
Four other factors (year and month of plantation, planting material, and the fact of having some information about the management of the trees) were also thought to have an influence on the adoption of Tree Lucerne or Sesbania. For this purpose, these qualitative variables have been analysed thanks to Fisher's exact test.
Results of the statistical analyses are presented in Annex 3.

Table 4: Statistical tests performed on the questionnaire survey dataset for each tree

Analysed variables	Plantation (Yes /No) *Qualitative*	Adoption (Yes /No) *Qualitative*
Age (30-49 / 50-69 / >70) *Qualitative*	Fisher	Fisher
Wealth (P / I / BO) *Qualitative*	Fisher	Fisher
Household size *Quantitative*	K-W	K-W
Education (No / 1-6 / 7-10 / >11) *Qualitative*	Fisher	Fisher
Farmland size *Quantitative*	K-W	K-W
Number of animals *Quantitative*	K-W	K-W
Year of plantation *Qualitative*		Fisher
Planting material (Seeds / Seedlings) *Qualitative*		Fisher
Month of plantation *Qualitative*		Fisher
Information about management (Yes / No) *Qualitative*		Fisher

Other results from this questionnaire survey are presented through descriptive statistics.

The qualitative statements which were obtained through informal interviews and the focus group discussion were confronted with the general pieces of information obtained from the questionnaire survey. A cross-checking of all information helped to point out the main benefits and difficulties encountered by farmers with *Chamaecytisus palmensis* and *Sesbania sesban* and to gather some management recommendations about those trees. A technical guideline was produced from those findings (Annex 6).

As for the germination test, even if the number of collected data was rather small to conduct a statistical analysis, a Kruskal-Wallis test was nonetheless performed to test whether the differences in germination investigated were statistically significant regarding the type of species or soil. The effect of soil was also tested on each species germination rate individually. Last but not least, a new dataset was created containing the 10 best germinating sets (T1, T3 and T5 for Sesbania seeds and T2 and T4 for Tree Lucerne seeds). The effects of species and soil type were tested on this dataset thanks to analysis of variance (ANOVA). It is obvious that results from these analyses should be carefully interpreted regarding the very small size of data. However, it has nevertheless been chosen to use them in this study to enlighten the relevance of the differences observed in the experimentation.
Results of the statistical analyses are presented in Annex 4.

Table 5: Statistical tests for the germination test

Analysed variables	Germination rate *Quantitative*
For original dataset (20 data)	
Species (Sebania / Tree Lucerne) *Qualitative*	K-W
Soil type (Doyogene / Kachabira) *Qualitative*	K-W
For dataset restricted to each species (10 data)	
Soil type (Doyogene / Kachabira) *Qualitative*	K-W
For new dataset with best treatments (10 data)	
Species (Sebania / Tree Lucerne) *Qualitative*	ANOVA
Soil type (Doyogene / Kachabira) *Qualitative*	ANOVA

5.2. RESULTS

5.2.1. PROFILE OF INTERVIEWEES

5.2.1.1 Characteristics of interviewees and their farm

One hundred farmers of ten different *kebele* of Doyogena and Kachabira *woredas* have been interviewed with the questionnaire survey.
The proportion of interviewed farmers between 30 to 49 years old and 50 to 69 years old is well balanced, whereas much less farmers above 70 years old have been interviewed. There is an effect of the "age" variable on the fact of having planted Tree Lucerne or Sesbania (Fisher, Tree Lucerne P=0.010, Sesbania P=0.0092). Less people who are between 50 and 69 years old have already tried to plant one of the two trees, whereas more young people did. But there is no effect of the age on the adoption of the trees (Annex 3).

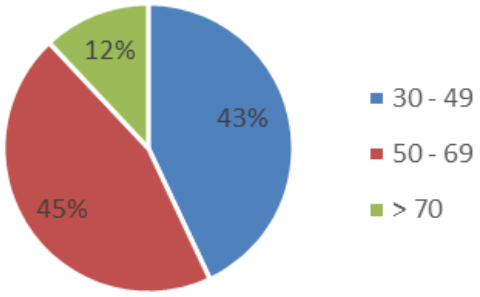

Figure 23: Age range of respondents

The majority of respondents have intermediate wealth status but there is no significant effect of the wealth category on plantation or adoption of the trees (Annex 3).

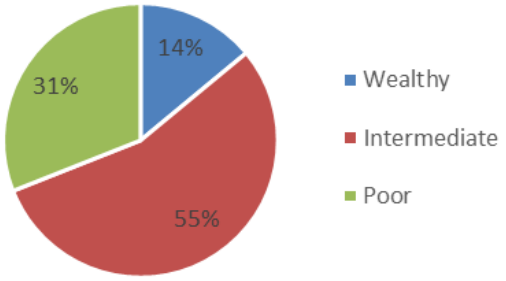

Figure 24: Distribution of the wealth status of respondents

More than half of the respondents did not go to school or stopped their education after a few years. The only significant effect of this variable on plantation or adoption is observed for adoption of Tree Lucerne (Fisher, P=0.047). More people who studied until grade 7 to 10 did not adopt this tree. Results are nonsignificant for plantation of both trees or adoption of Sesbania (Annex 3).

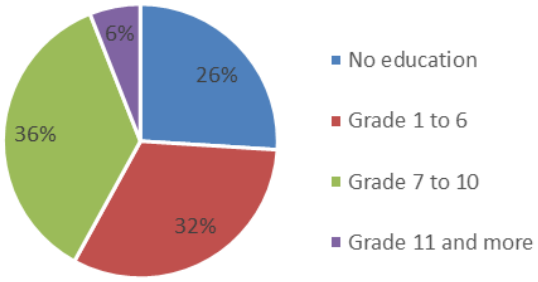

Figure 25: Education level of respondents

The average household size of respondents is 8 family members, with a minimum of 2 and a maximum of 14.
The average farmland size is 2.6 *timad* (local measure equivalent to ¼ ha), with a minimum of 0.5 and a maximum of 8 *timad*.
And the average number of animals is 5.8 with a minimum of 1 and a maximum of 12.
But there is no influence of those three variables on plantation or adoption of Tree Lucerne and Sesbania (Annex 3).

Table 6: Mean of animals owned per household in the Kembatta highlands

	Mean	Minimum	Maximum
Local cattle	1,6	0	7
Hybrid cattle	2,2	0	8
Sheep/Goat	1,2	0	6
Donkey/Horse	0,8	0	3
Total animals	5,8	1	12

Finally, except from the relation between age and plantation of both trees, and the relation between education and adoption of Tree Lucerne, there is no statistical link between the characteristics of the farmers and the fact of planting or adopting the trees. It is thus possible to put forward that all type of farmers can plant or adopt the two studied fodder trees, or that the discriminatory factor has not been taken into account in the description of the farm.

5.2.1.2 Motivations to plant those introduced fodder trees

Upon the 90 farmers who know about *Sesbania sesban*, 68 already tried to plant it. And upon the 62 farmers who know about *Chamaecytisus palmensis*, 50 already tried to plant it.

Table 7: Plantation rate of Sesbania and Tree Lucerne

		Planted	Non planted
Sesbania	Number of farmers	68	22
	Percentage of farmers who knows about the tree	76%	24%
Tree Lucerne	Number of farmers	50	12
	Percentage of farmers who knows about the tree	81%	19%

Except from two farmers who had access to Sesbania 5 years before, both trees really started to spread in the area since 2014. The two species are therefore still rather new for farmers. The variable "year of plantation" does not impact the fact to adopt the trees or not (Annex 3).

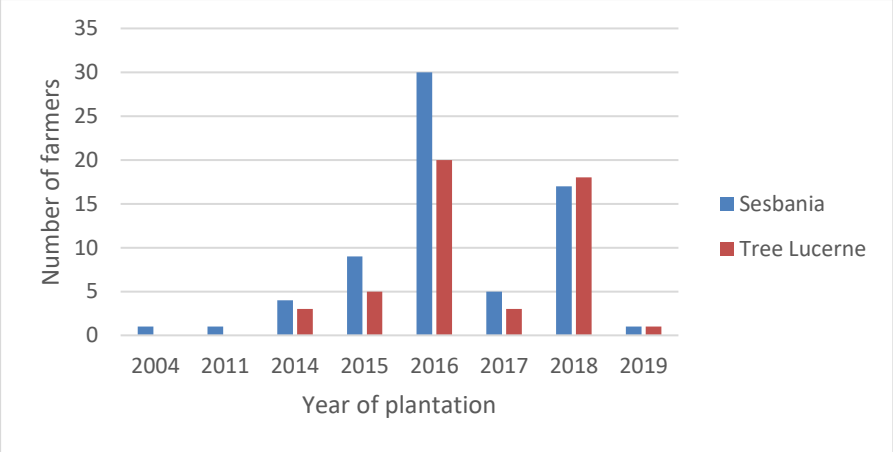

Figure 26: Year of plantation of Sesbania and Tree Lucerne

The main motivation for farmers to plant these trees is for their fodder value (good quality, diversification of fodder source, and increase of forage production) and the second main reason is for soil fertility improvement. Most of them received information about the benefits of these trees from IA and were then interested to test them. Some farmers were also interested in protecting their farm from erosion or in fence and ornamental purpose. Few farmers also had some economic motivations when they planted the trees. But most of them did not already have the opportunity to sell fodder, nor seeds or seedlings. They only wished to be able to do so in the future. One farmer interviewed in the informal way acknowledged to have the experience to sell seeds and seedlings. As for now, his main purchaser is the local agricultural office which is interested in promoting these trees in the area. Another motivation raised is improvement of microclimate.

Table 8: Motivations of farmers to plant Sesbania and Tree Lucerne

		Quality of fodder	Diversify feed source	Increase fodder production	Soil fertility impro-vement	Erosion protection	Fencing	Orna-ment	Eco-nomic purpose	Simple opportu-nity	Other
Sesbania	Number of farmers	62	54	47	48	27	25	20	5	1	2
	Percentage of farmers who planted	91%	79%	69%	71%	40%	37%	29%	7%	1%	3%
Tree Lucerne	Number of farmers	44	41	37	31	17	15	18	5	3	3
	Percentage of farmers who planted	88%	82%	74%	62%	34%	30%	36%	10%	6%	6%

Most of the people who did not plant said that it was because they did not have access to the planting material (seeds or seedlings). Some other farmers also suggested that they did not know enough about the trees. But only few of them raised some physical constraints (no place to plant in the farmland or no time to manage).
However, all these farmers who did not plant the trees answered that they would like to try in the future. This means that they are not reluctant to the idea of introducing this new technology in their farm.

Table 9: Reasons of farmers to not have planted Sesbania and Tree Lucerne

		Unaccess to planting material	Lack of awareness	No place	No time	Other
Sesbania	Number of farmers	21	3	2	2	1
	Percentage of farmers who didn't plant	95%	14%	9%	9%	5%
Tree Lucerne	Number of farmers	10	1	1	1	2
	Percentage of farmers who didn't plant	83%	8%	8%	8%	17%

5.2.2. MANAGEMENT OF THE TREES

5.2.2.1 Germination of seeds and management in seedbed

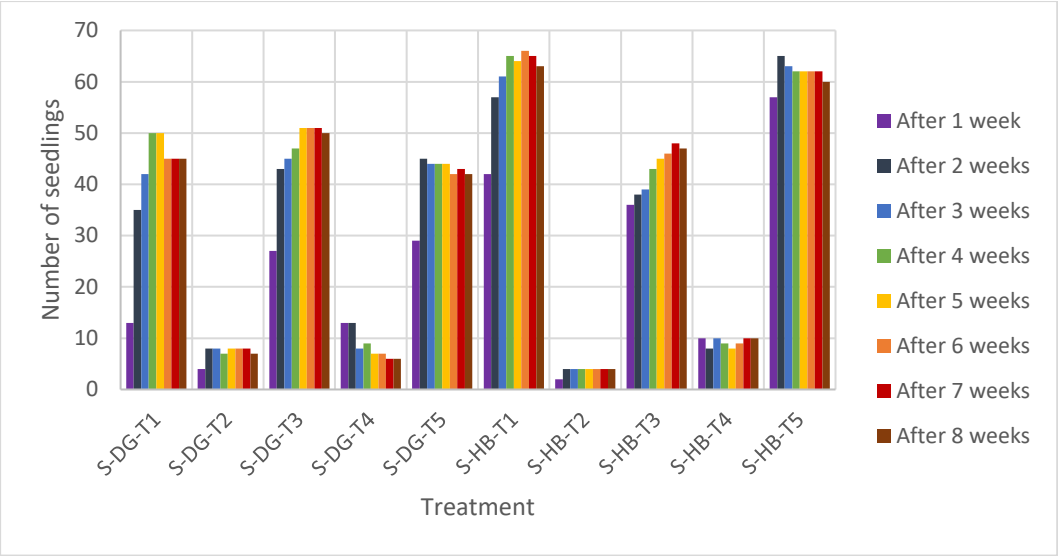

Figure 27: Number of seedlings of Sesbania per treatment

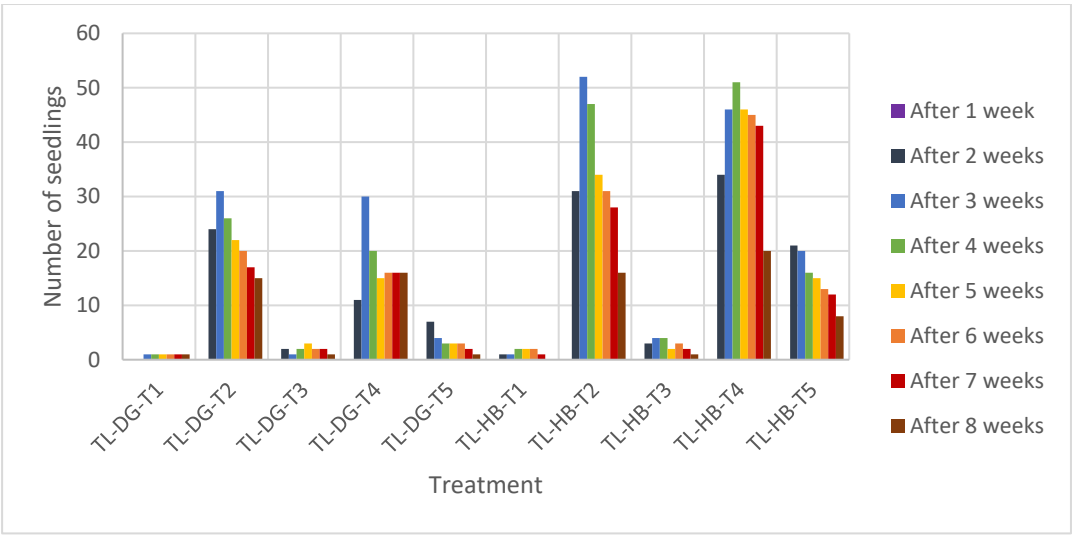

Figure 28: Number of seedlings of Tree Lucerne per treatment

The percentage of germinated seeds is significantly higher for *Sesbania sesban* than for *Chamaecytisus palmensis* (KW, P=0.019). The difference is even more significant for the dataset containing only the best treatments: T1, T3 and T5 for Sesbania and T2 and T4 for Tree Lucerne (Anova, P=5.23e-05). Best treatments reach 60% of germination rate for Sesbania whereas the maximum is 20% for Tree Lucerne after eight weeks of experiment. A strong mortality rate was particularly observed for sprouts of Tree Lucerne after the third week of experiment. There is no significant effect of the soil type on the germination rate of the trees after eight weeks for none of both datasets (Annex 4).

The low germination and strong mortality rate observed for Tree Lucerne might be explained by the weather conditions. Actually, August was characterised by a heavy daily rain and, according to the inhabitants of the area, it seemed that this summer was a particularly wet season this year. But *Chamaecytisus palmensis* is a species which needs

moderate moisture to germinate well and it is even advised to sow it on a well-drained soil (Esterhuizen, 2012). It is hence possible that this tree did not tolerate well the weather conditions during the peak of the rainy season. Sesbania, however, seemed to resist better to very moist and cold climate.

Even if the collected data are not big enough to do proper statistical analyses to compare the treatment effect, it can nonetheless be noticed that some treatments are leading to better germination rate than others. On the one hand, treatments 1, 3 and 5 are better than treatments 2 and 4 for *Sesbania sesban* and the mean of sprouting of these three treatments is 51% after eight weeks of experiment. On the other hand, the contrary can be pointed out for *Chamaecytisus palmensis*. The average of germination of treatments 2 and 4 for this tree is only 17% after two months whereas it reached 40% on the third week of the experiment at the highest sprouting peak, before some seedlings disappeared. The results obtained for the treatment 5 for Tree Lucerne are particularly surprising, as it was expected, according to Lucerne Tree Farm, that it would have had the best germination rate (Esterhuizen, 2012). However, this treatment reached only an average germination rate of 14% at its best, after two weeks of experiment, and only 4,5% after eight weeks. This result shows that manual scarification is not the best suited treatment for Tree Lucerne seeds in this site.
The soil type does not influence significantly the germination of seeds of Sesbania nor Tree Lucerne (Annex 4).
It was observed that both of the species still have a rather low growth rate after two months, reaching between 2 cm and 4.5 cm for Sesbania and between 1 cm and 5 cm for Tree Lucerne in average. This might also be explained by the weather conditions during the experiment which were not optimal for young sprouts growth with heavy rainfalls and few sunny phases.

Therefore, this experiment enlightened that seeds of *Sesbania sesban* can grow equally if they do not suffer any treatment, if they are soaked 24 hours in cold water or if they are manually scarified and soaked in cold water, whereas hot water seems to inhibit the germination. It is then advisable for farmers, as easiest practice, to sow directly seeds of Sesbania in their seedbed, without any treatment, as it is already prescribed and applied by Inter Aide staff. On the contrary, it should be advised against soaking seeds of Sesbania in hot water as it was proven that this practice leads to poor results.
Contrariwise, it can be assessed that seeds of *Chamaecytisus palmensis* germinate better when having sustained treatment with hot water, either soaked for 30 minutes or 1 minute and then soaked in cold water. This result is also in line with Inter Aide policy, as the staff already treats seeds for 30 minutes in hot water before sowing.

Results from the questionnaire survey show that most of the farmers who already had seeds of Sesbania actually sowed without any treatment. The others treated with hot water, mainly for 30 minutes, but they did not specifically complain about bad germination rate (only 2 farmers did out of the 10 who treated with hot water). However, it is nevertheless likely that they could have even better plants production had they sown directly without any treatment. As for Tree Lucerne, most of the farmers who had seeds sowed after having treated the seeds with hot water. In fact, they were taught by IA staff members to do so when they received the planting material.

Table 10: Treatments exercised by farmers on seeds of Sesbania and Tree Lucerne

		Seeds	Treatment		
			30 min hot water	Other*	No treatment
Sesbania	Number of farmers	35	5	5	25
	Percentage of farmers who planted	51%			
	Percentage of farmers with seeds		14%	14%	71%
Tree Lucerne	Number of farmers	23	10	8	5
	Percentage of farmers who planted	46%			
	Percentage of farmers with seeds		43%	35%	22%

*All the farmers who practiced another treatment did soak seeds in hot water but for more or less time than 30 minutes

Through the survey, it has been recorded that most of the farmers sowed during the small rainy season, *belg* (from March to May). This statement was confirmed during the focus group discussion by the present farmers. As experienced in the germination experiment, heavy rainy months do not seem to be the best period to plant Tree Lucerne as young seedlings are particularly susceptible to soil moisture. Therefore, it might be recommended to follow farmers practices and to advise all of them during training to sow when the rain is still not too heavy and the sun still shines.

Table 11: Period of sowing for Sesbania and Tree Lucerne

		Belg	*Kiremt*	*Baga*
Sesbania	Number of farmers	24	10	1
	Percentage of farmers who had seeds	69%	29%	3%
Tree Lucerne	Number of farmers	14	8	1
	Percentage of farmers who had seeds	61%	35%	4%

Last but not least, farmers let seeds grow for an average of 3 months in seedbed (2.8 for Sesbania and 3.1 for Tree Lucerne). However, this issue of time that seedlings should spent in seedbed is still not very clear. During informal interviews, some farmers expressed about their practice of letting the trees for at least one year in seedbed before transplanting. They argued that this practice was better for survival of seedlings after transplantation. However, when the issue was raised during the focus group discussion, farmers did not agree: some assessed that a long time in seedbed is necessary and some confirmed that a few months are enough.

5.2.2.2 Plantation of seedlings

The majority of the interviewed farmers planted the seedlings in their farm during the big rainy season, *kiremt* (from June to September). During the focus group discussion, farmers generally acknowledged that the best months for planting or transplanting seedlings were from April to June or in August, but not in July because the amount of rain is too high during this month. However, the month of plantation has no significant effect on the fact of adopting or not the trees (Annex 3).

Table 12: Period of plantation of Sesbania and Tree Lucerne

		Belg	*Kiremt*	*Baga*
Sesbania	Number of farmers	9	48	1
	Percentage of farmers who planted	13%	71%	1%
Tree Lucerne	Number of farmers	11	37	0
	Percentage of farmers who planted	22%	74%	0%

Farmers usually plant Tree Lucerne or Sesbania on the soil and water conservative structures in the middle of their field or as a hedge around homestead (Figure 29). Only a few people planted in other places like in their backyard, or around their field, or at the bottom of the farm. Two farmers did not use Tree Lucerne and Sesbania as a hedge but as an improved fallow on an unfertile plot of land.
During the informal interviews, it was also noticed that both species were mostly planted in a row on conservative structures or in front of the house. Two main plantation strategies could be described: either to plant trees with a certain gap between each of them (50 cm to 1 m), or to plant trees very close one from the other (less than 50 cm) to make a fence. The first strategy is mostly observed on the conservative structures whereas the second one is usually used near the house.

Table 13: Place of plantation in the farm of Sesbania and Tree Lucerne

		Conservative structure	Hedge around homestead	Backyard	Around field	Bottom of farm	Other
Sesbania	Number of farmers	48	31	3	1	0	2
	Percentage of farmers who planted	71%	46%	4%	1%	0%	3%
Tree Lucerne	Number of farmers	28	25	4	1	1	1
	Percentage of farmers who planted	56%	50%	8%	2%	2%	2%

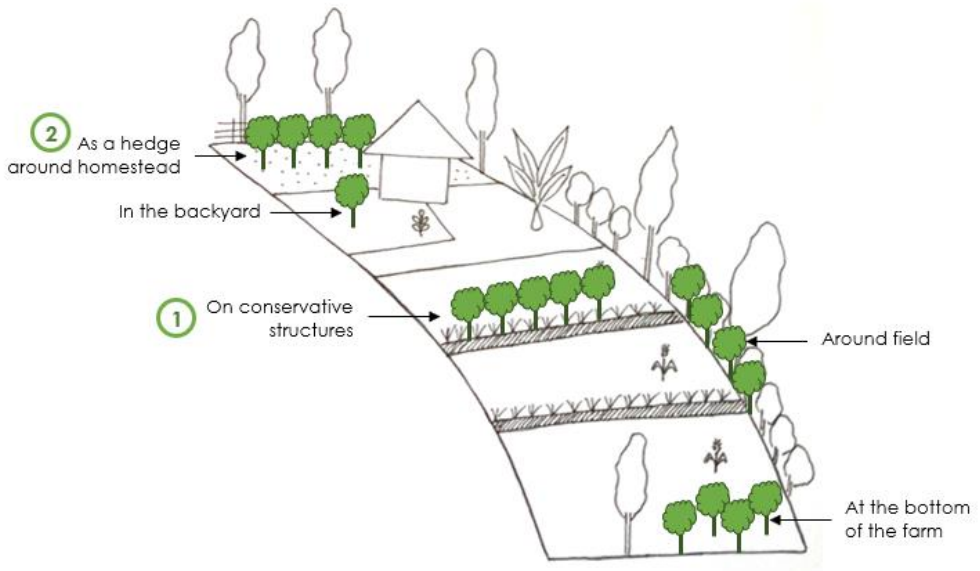

Figure 29: Location of Sesbania and Tree Lucerne in the farmland

Figure 30: Hedge of Sesbania around homestead

Figure 31: Hedge of Tree Lucerne on a soil and water conservative structure

5.2.2.3 Practices of pruning

The informal interviews allowed to gather some practical information about management practiced by farmers. Some points were specifically discussed afterward during the focus group discussion.

Size of cutting: farmers usually prune Sesbania and Tree Lucerne between 1m and 1m50 height. Some exceptions were nonetheless encountered for some farmers who chose to cut their trees higher. For instance, one farmer decided to make a live fence of Sesbania which could protect his backyard from cattle browsing, and for this purpose he pruned his trees at 2m height. On the contrary, farmers who tried to cut their trees at less than 50 cm height complained that they died soon.

Figure 32: Farmer pruning his hedge at 1m height

Figure 33: Hedge of Sesbania pruned at 2m high

Frequency of pruning: it varies from 1 to 4 months. When the issue was mentioned during the focus group discussion, it was raised that waiting for 3 or 4 months until trees became mature enough (change of leaves colour for Tree Lucerne and flowering for Sesbania) was improving the quality and palatability of the forage.

A specific recommendation was given by some farmers during the focus group discussion to take particularly good care not to damage the branches when pruning the trees. They added that tools used for this purpose and the way of cutting twigs were very important and needed to be done properly. Branches need to be cut at a certain distance from the stem (10 to 20 cm) so that new shoots can grow.

5.2.2.4 Practices of feeding

According to the farmers interviewed by survey, it is common to feed the cattle with fresh twigs or to let them dry for few minutes only in the sun before giving to the animals, but rarely more. It is also usually preferred to give fodder from *Sesbania sesban* or *Chamaecytisus palmensis* mixed with another source of forage.
During the focus group discussion, farmers confirmed that it was very good to give those trees mixed with another fodder source (mainly grass but it can also be *enset*), even if they can be given alone when cattle is already adapted to them. They also confirmed that they usually have the experience to feed fresh. An exception is done during the rainy season because of the high moisture content of leaves. When harvested at that time, it is better to wait for some time (up to one day) before giving to animals until the forage loses some moisture. An idea was also suggested during this meeting to keep forage in store like crop residues to feed animals during the feed shortage period, but none of the farmers already experienced this practice.

Figure 34: Tree Lucerne fed to cattle in the stable

Even if the pruning frequency of these trees is pretty low compared to other fodder sources, farmers testified that they were nonetheless very important source of feed for their animals. They use them as *fushka* (local pelleted feed) occasionally, in order to improve the milk production of cows or the body performance of cattle.

5.2.3. BENEFITS AND CHALLENGES ENCOUNTERED BY FARMERS

Almost half of the farmers who planted *Sesbania sesban* did not meet any difficulty at all with this tree and said that it was very easy to manage. This is less true for *Chamaecytisus palmensis* as only a quarter of the farmers who planted it acknowledged that there was no difficulty with this tree.

The main difficulty raised for both trees is mortality of young seedlings. Some reasons hypothesized by farmers are browsing of wild animals or sheep at young stage, moles, weather conditions (too dry or too much rain), lack of fertility of the place, or competition with grass. When the question was raised during the focus group discussion, farmers said that a proper management for plantation should be able to decrease the number of dead seedlings. Above all, a proper place should be chosen (fertile soil and no competition with bigger trees), and holes should be dug and prepared some days before planting so that the soil moisture could be good enough. Browsing was also recognised as being a problem for survival of young trees: one farmer even said that he was "sharing these fodder trees with wild animals".
There is an important decrease between the number of trees effectively planted by farmers interviewed by survey method and the number of trees that they still have in their farmland nowadays. This statement does not seem to come from the will of farmers to remove the trees from their farm, but rather to be the result of a high mortality rate of trees.

Table 14: Number of trees planted by farmers and current number of trees in farms

		Mean
Sesbania	Number of planted trees by farmer	88,3
	Number of trees nowadays	41,2
Tree Lucerne	Number of planted trees by farmer	56,6
	Number of trees nowadays	27,9

The low germination rate of seeds was also given as being a main issue. This was also confirmed by the experiment which was led in Homa. Seeds provided to farmers mostly come from the market of Soddo, in Wolayta district, and their time spent in store is uncertain but might be for several months. As a result, the quality of the seeds may have been loosened and the properties of the material may not be totally adapted to the local environment as it comes from another area. During the informal interviews and the focus group discussion, farmers assessed that it was better to keep some trees unpruned to collect their own fresh seeds to be sure about the quality of the planting material.

Another major difficulty raised for *Sesbania sesban* deals with its short lifespan. Actually, even if the tree is rather new in the area, many farmers reported the death of their trees after 3 or 4 years. One farmer who has been individually interviewed and who planted Sesbania in his farm since 2006 confirmed that this tree was not long living and that it was not producing enough fodder anymore after 5 years. Because of this, he already had to replant Sesbania 3 times in his farm. During the meeting with model farmers, it has been hypothesized that some proper management could potentially improve the lifespan of

Sesbania, like covering the roots with some amount of soil and taking care to not damage branches when pruning. Farmers nevertheless recognised that the fodder production of this tree was decreasing after few years, but, according to them this is not a problem to replant trees regularly to replace the old ones.

Feeding animals with fodder produced by Sesbania and Tree Lucerne is also a difficulty for a few farmers. One farmer confessed to have removed all his trees because his animals did not eat their leaves, even after trying to feed by a lot of different ways. The issue of palatability of these fodder trees has been particularly debated during the focus group discussion to hear farmers' opinion on this subject. Model farmers recognized that it is a big deal at the beginning, when animals are not already adapted to those two trees. Yet, they said that cattle can easily adapt after some time. To enhance the palatability, they advised to mix with other forage. The moisture content of leaves during the rainy season was also seen as a criterion which was depleting palatability for animals and which could be resolved by letting the forage dry for some time before feeding.

Other farmers complained that cattle and wild animals damaged the trees, that moles could damage the roots and one said that it dried up the land.

Table 15: Difficulties encountered by farmers regarding Sesbania and Tree Lucerne

		Survival of seedlings	Germination of seeds	Mana-gement	Feed of animals	Other	No difficulties
Sesbania	Number of farmers	20	11	3	1	14*	29
	Percentage of farmers who planted	29%	16%	4%	1%	21%	43%
Tree Lucerne	Number of farmers	24	10	3	3	9	14
	Percentage of farmers who planted	48%	20%	6%	6%	18%	28%

* 7 out of those 14 farmers encountered problem of mortality of Sesbania trees after few years

The farmers who adopted the species, that means who planted one of the trees and still have some plants, were asked if they observed concrete benefits from them or disadvantages.

A lot of farmers observed real improvement of soil fertility next to the trees, and improvement of milk production and body performance of their cattle when feeding their animals with this forage. Some farmers also agreed to say that the trees have a pretty good production, or at least satisfying enough regarding their expectations. Other benefits raised concern protection from erosion, live fence, ornament and also bee forage. The majority of farmers are hence satisfied with the benefits that Sesbania and Tree Lucerne afford.
However, some farmers also claimed that they could not observe any real benefit from it, either from a feeding or environmental point of view. But most of these farmers answered that they would like to plant the trees again anyway in the future as they are aware about the benefits that the trees should be able to afford.

Table 16: Benefits observed by farmers regarding Sesbania and Tree Lucerne

		Forage quality	Forage quantity	Soil fertility improvement	Other	No benefit
Sesbania	Number of farmers	40	21	40	14	9
	Percentage of farmers who still have some trees	73%	38%	73%	25%	16%
Tree Lucerne	Number of farmers	21	11	26	8	11
	Percentage of farmers who still have some trees	54%	28%	67%	21%	28%

As for disadvantages, the majority of the respondents said they did not see any. Other farmers answered that the biomass production was not high, that the growth was slow, or that it did not have a good palatability for animals. Few farmers raised the fact that the trees were depleting soil fertility.

Table 17: Disadvantages observed by farmers regarding Sesbania and Tree Lucerne

		Poor biomass production	Slow growth	Low palatability	Poor fodder quality	Other	No disadvantages
Sesbania	Number of farmers	11	7	6	1	3	33
	Percentage of farmers who still have some trees	20%	13%	11%	2%	5%	60%
Tree Lucerne	Number of farmers	10	9	6	0	3	19
	Percentage of farmers who still have some trees	26%	23%	15%	0%	8%	49%

5.2.4. ESTIMATION OF ADOPTION RATE

In this survey, farmers are considered as having abandoned the program if they already tried to plant *Sesbania sesban* or *Chamaecytisus palmensis* but do not have the species anymore in their farm nowadays. The others are considered as having adopted the program.

Table 18: Adopted rate of Sesbania and Tree Lucerne

		Adopted	Abandon
Sesbania	Number of farmers	55	13
	Percentage of farmers who planted	81%	19%
Tree Lucerne	Number of farmers	39	11
	Percentage of farmers who planted	78%	22%

Reasons for abandon are mainly regarding non-germination of seeds or death of young seedlings after few months. Few farmers pointed out the low biomass production of Sesbania which they replaced with another fodder source (grasses), or its bad effect on soil fertility. As described above, the short lifespan of *Sesbania sesban* also contributed to the disappearance of this tree after few years. As a matter of fact, some farmers had to remove their trees after 4 or 5 years because they did not produce enough forage anymore, or died.

Table 19: Reasons raised by farmers for abandon of Sesbania and Tree Lucerne

		Non-germination	Death of seedlings	Poor production	Damage soil	Poor management	Other
Sesbania	Number of farmers	4	3	3	1	1	6
	Percentage of farmers who abandoned	31%	23%	23%	8%	8%	46%
Tree Lucerne	Number of farmers	3	5	0	0	0	4
	Percentage of farmers who abandoned	27%	45%	0%	0%	0%	36%

There is no effect of the year or month of plantation, nor the planting material (seeds / seedlings) on the fact to adopt or not Sesbania and Tree Lucerne. Having any information about how to manage the fodder tree does not impact either the adoption (Annex 3).

Ultimately, a good way to estimate the adoption of the project of introducing *Sesbania sesban* and *Chamaecytisus palmensis* in the area is to observe the proportion of respondents who expressed their willingness to plant those trees in the future. That is the great majority of the interviewed farmers. Even all the farmers who have abandoned the trees nowadays expressed their wish to try again to plant in the future.
Making their own seedbed does not seem to be a constraint either for farmers as almost all of them answered that they could do it, even if a treatment is necessary before sowing Tree Lucerne seeds. The benefits that farmers expect from the two fodder species are therefore important enough to justify the labour work that is needed upstream.
However, it is important to notice that a lot of respondents admitted that they expected to have the planting material (seeds or seedlings) from Inter Aide. Actually, non-access to planting material was also the main explanation for farmers who had not already tried to plant the two trees. This means that farmers are still not completely self-sufficient regarding the collection of seeds and production of seedlings of Tree Lucerne and Sesbania, and that it is still not used to spread these species in the villages from neighbour to neighbour. Even if they understand a lot of their benefits, farmers are still not totally used to these species and they are still relying on Inter Aide to initiate their production.

Table 20: Expectations of farmers for future plantation of Sesbania and Tree Lucerne

		Willingness of future plantation	Can make own seedbed	Expect seeds/seedlings from IA
Sesbania	Number of farmers	84	76	60
	Percentage of farmers who knows about the tree	93%	84%	67%
Tree Lucerne	Number of farmers	59	55	40
	Percentage of farmers who knows about the tree	95%	89%	65%

This issue of adoption and diffusion has been specifically discussed during the focus group discussion to get IA staff and farmers' assessment on the point. From a general point of view, it has emerged that farmers have a good feedback on both species. Many farmers who got information about the trees from Inter Aide effectively tried to plant them in their farm and observed real benefits in terms of nutrition or environment. And people are also eager to plant Tree Lucerne and Sesbania again in the future. This statement is comforting, and model farmers and IA staff members are quite confident in the success of the project. However, as the project started rather recently, the key point for diffusion concerns communication. Active farmers acknowledged that they had a great role to play in terms of sharing information and experience, so that the project could spread more easily. The

follow-up of farmers is also fundamental as those species are still new technologies. The difficulties encountered by farmers regarding high mortality rate of young trees show that it is still difficult for farmers to have a clear idea about how to manage and use these trees and that some mentoring would be necessary. Last but not least, three outlines have been mentioned to satisfy the need for planting material in order to facilitate the diffusion of the trees. First of all, it seems essential to sensitize farmers to keep few trees for their own seeds collection. Besides the fact that they would be self-sufficient, this would also probably increase seeds quality and decrease bad germination and mortality rate. Then, active farmers could produce seedlings to distribute to their neighbours as some of them already do. And finally, Inter Aide and the Farmers Training Centres (FTC) are used to cooperate to distribute some planting material to farmers and they plan to do so for *Sesbania sesban* and *Chamaecytisus palmensis*.

5.3. DISCUSSION

5.3.1. CHALLENGES FOR ESTABLISHMENT OF TREE LUCERNE AND SESBANIA

5.3.1.1 Germination of seeds

Results for the germination of seeds of *Sesbania sesban* are in accordance with what is usually prescribed for this tree, that is to be sown directly without any treatment (Bekele-Tesemma *et al.*, 1993). Cook *et al.*, also point out that treating seeds with hot water could lead to non-viability of seeds, which confirms the statement made during the experiment (Cook *et al.*, 2017). As for germination of *Chamaecytisus palmensis*, authors usually advise to pre-treat seeds with hot water as they are very hard-shelled, which is also in accordance with the findings (Bekele-Tesemma *et al.*, 1993 ; Orwa *et al.*, 2009 ; Getnet *et al.*, 2012). The result obtained regarding the fifth treatment with manual scarification goes against the technical prescriptions done by the Lucerne Tree Farm of South Africa (Esterhuizen, 2012), but this is rather a good finding as this practice is quite laborious and time-consuming. In order to improve the germination rate, it should hence be advised to farmers to not treat seeds of Sesbania and to soak seeds of Tree Lucerne in hot water.

Recommended studies:
It is still uncertain if the time of soaking for Tree Lucerne seeds could have any impact on the germination rate. Further investigations should be done to determine if this parameter could improve germination of seeds or contribute to better establishment of seedlings.
It could also be relevant to redo the nursery trials during a more appropriate period of the year to verify the seasonal effect on germination and see if a better rate could be obtained during the *belg* season.

5.3.1.2 Survival of seedlings

Sesbania is known for its easy establishment, even in waterlogged and dry eroded soil (Bekele-Tesemma *et al.*, 1993), whereas Tree Lucerne stands with difficulties very soggy soils (Esterhuizen, 2012 ; Feleke, 2016). Yet, in this study, the high mortality rate of young trees appears to be a critical point for the establishment of both trees. This statement was also done by Kindu *et al.* in four different Ethiopian highland sites, suggesting that the young stage was the most challenging phase for survival of trees on farm (Kindu *et al.*, 2017). Many authors report browsing of young seedlings as being a main issue for Sesbania

and Tree Lucerne (Orwa *et al.*, 2009 ; Esterhuizen, 2012 ; Feleke, 2016 ; Kindu *et al.*, 2017). Young trees should hence be carefully protected from grazing to improve the survival rate, as it has been demonstrated in different studies (Feleke, 2016 ; Kindu *et al.*, 2017). According to Kindu *et al.*, farmers even have the experience to plant trees in strategic places like backyard for better protection and management purposes (Kindu *et al.*, 2017). Weeding and mulching during dry periods have also positive effect on survival of trees (Feleke, 2016 ; Kindu *et al.*, 2017).

5.3.1.3 Pruning

On the one hand, the pruning frequency of Sesbania could reach up to 5 times per year, whereas more frequent coppicing is suspected to reduce the lifespan of plants (Scholle, 2017 ; Cook *et al.*, 2017). Heering demonstrated the bad effect of repeated pruning on yield of six different accessions of *Sesbania sesban* (Heering, 1995). On the other hand, it has been shown that *Chamaecytisus palmensis* has higher biomass production when pruned every six months as the development of new buds is rather slow (Getnet, 1998 ; Getnet *et al.*, 2012 ; Feleke, 2016). The forage production of farmers may thus be enhanced if the trees were pruned a bit less often than they already are.
Cutting the tip of trees when they reach 1m or 1m50 high enables to develop more side shoots (Orwa *et al.*, 2009 ; Esterhuizen, 2012), but no significant difference in biomass yield could be established for different cutting heights for Tree Lucerne (Feleke, 2016). However, pruning Sesbania above 4m high or below 50cm could results in the plant death, which is in line with the observation of farmers (Scholle, 2017 ; Cook *et al.*, 2017). The actual cutting management of farmers from Kachabira and Doyogena highlands is already in accordance with those points.

Recommended studies:
Further studies on the coppicing frequency and the proper space between plants for improved yield could be carried out in order to assist farmers in management practices.

5.3.1.4 Short lifespan of Sesbania

According to Mekoya *et al.*, farmers of Lay-Armachuho and Sidama districts raised the same issue of Sesbania being short-lived compared to other multipurpose fodder trees (Mekoya *et al.*, 2008). This short lifespan seems to be undeniable and *Sesbania sesban* is said to be able to persist for up to 5 years with an appropriate cutting management (Karachi & Matata, 1997 ; Roothaert & Paterson, 1997 ; Cook *et al.*, 2017). It is hence particularly important to inform farmers about this point when they are given the planting material so that they could anticipate by collecting their own seeds and produce regularly seedlings to replace their fodder trees. Model farmers of the area assured to be ready to replant Sesbania on a regular basis, but this constraint could be a drag for several reluctant peasants. This assumption should be clarified after some years to see if the plantation trend stays positive.

5.3.2. POTENTIAL OPPORTUNITIES AND RECOMMENDATIONS FOR FURTHER DIFFUSION

Even if some disadvantages have been pointed out by few farmers for *Sesbania sesban* and *Chamaecytisus palmensis*, like poor biomass production or slow growth, these reasons were not the ones spotlighted for abandon. Farmers who abandoned the trees nowadays did not express their will to remove them from the farmland, but explained their difficulties for germination or survival instead. A lot of peasants already observe concrete benefits from

Sesbania and Tree Lucerne in their farm, mostly in terms of nutrition for cattle or soil fertility and they are eager to plant more of these trees if they have the opportunity. These assertions and the rather high adoption rate witness the relevance of the project in this area. Furthermore, Sesbania and Tree Lucerne have good potential to add value to the soil and water conservative structures. As it is already well practiced, trees can be planted on the top of the structures, next to *desho* grass, to strengthen the maintenance of soil and increase the forage production, while restricting competition between sources. Direct browsing is nonetheless a key focus that should not be neglected, which means that the proper place to plant the trees should be easy to look after (homestead, backyard, or field with strict control of cattle).
As a matter of fact, both trees have a good potential to answer feeding needs as supplement qualitative food for cattle, and it seems that they can be easily anchored in the agricultural system of this context. The restricting factors appear to be technical (production and establishment of trees mostly) and practical (access for planting material).

Actually, the number of planted trees in the farms is still rather low, and a lot of farmers rely on Inter Aide to have access to planting material and to diffuse the trees in the area. In the previous study upon traditional hedges, it has been shown that local farmers are not really used to use trees for fodder purpose. Planting and raising trees for this specific goal is not a common practice in the area and this can explain the fact that farmers are still not totally used to this new technology. They nevertheless understand the benefits that Sesbania and Tree Lucerne can afford and are hence motivated to plant them. However, a lot of communication should still be done on the way to produce and manage the trees to make best profit.
Farmers should also be warned on the fact that germination can be difficult and the mortality rate of young trees can be high. This should be taken into consideration in the planting strategy of farmers and so they should be encouraged to produce more plants than needed in order to fill the gaps in the hedges. A close follow-up by IA staff should be done to help farmers to get used to the management practices and to help them to add plants if needed.
The quality of seeds and their origin is a critical point as well. Farmers should be particularly advised to collect their own seeds as much as possible to enhance the quality of semen and improve the germination rate. It is also preferable that IA staff and FTC development agents purchase the seeds from the area so that plants could be more suitable to the environmental context.

5.3.3. LIMITS OF THE STUDY

The study was conducted with beneficiary farmers from Inter Aide in order to assess the adoption rate of the program within the targeted population. Results showed a pretty good adoption rate and good feedbacks from farmers. However, this sample population gathered people who used to work with Inter Aide for many years. Furthermore, these farmers were mainly chosen originally to implement the program because of their motivation for the project and their temerity to test new ideas. Even if some farmers who did not adopt the project or saw disadvantages regarding the trees were interviewed, they remained a minority. This population was hence a bit biased compared to the total population of the area, which can explain the fact that no particular group of farmers could have been detected with statistical tools. However, Inter Aide has been working in the area for a long time and it already initiated some projects which propagated widely, like the establishment of soil and water conservative structures. Those projects were originally implemented by model farmers and have then been promoted in the area with their help. This is why, the

real motivation of those active farmers regarding Tree Lucerne and Sesbania is a good omen for future diffusion. Their approval of the project and their enthusiasm is an essential prerequisite for further spreading of both trees.

It may be wondered, though, whether some answers of farmers were not a bit biased because of the interviewer. In fact, some people may have answered what they thought was expected from them because they understood the importance of the trees as a study was conducted on this subject. For instance, the result concerning future plantation provokes particular questioning as 95% of interviewees answered they wished to plant again Sesbania and Tree Lucerne in the future. Is this figure really reliable or did farmers answer this to please the NGO? Even if farmers seemed very enthusiastic, it is still doubtful that they will all really take the opportunity to plant the trees in the future.

Lastly, this study shows some limits because it includes mostly qualitative data (on motivations to plant the trees and feedbacks perceived by farmers who tried to plant them). However, very few quantitative data (like exact number of trees or biomass production) were taken into consideration. This choice was made because of the quite recent character of the project which did not allow to conduct a real impact assessment. But it would be very relevant to do one after few years to have a proper assumption on the planting trend and to collect more quantitative data in order to provide better guidance to farmers in terms of management of *Sesbania sesban* and *Chamaecytisus palmensis*.

6. CONCLUSION

Hedgerows are commonly integrated in the farming system of the Kembatta highlands. Farmers use to plant live fences around their farmland to mark boundaries and keep their property from free grazing or any passage. For this purpose, native species with bushy growth, easy access and propagation with few management requirements are particularly appreciated. Even though farmers do not rely on indigenous woody plants as fodder sources, these species can supply other products or services. *Erythrina spp.*, *Cordia africana* or *Croton macrostachyus* are well-fitting in the agroforestry system thanks to their capacity to enhance soil properties and fertility, and hedges provide other environmental services like windbreak. Moreover, trees and shrubs are essential to meet farmers' needs in terms of fuel and timber, even though species grown for timber purpose are usually not planted inside the hedges but as wood lots or in individual places. Some species with economic value are particularly significant as sources of income. Yet, some exotic trees introduced in the last century, like *Eucalyptus spp.*, seem to become increasingly important in the strategy of farmers who replace some endemic species with these highly valuable ones. However, further investigations should be led on economic potential of these plants and to quantify wood needs of households in order to understand more precisely the constraints and potentials for improvement for farmers.

On another hand, although trees are not really considered for their fodder value in the traditional system, the two introduced species *Chamaecytisus palmensis* and *Sesbania sesban* seem to be a relevant option to diversify and increase sources of forage in the area. Thanks to their good nutrition value, these species can be used as supplement qualitative feed for livestock. Their ability to fix nitrogen and improve soil fertility are also assets which make these trees suitable for the considered agroecological context. They can play a role in the erosion control, while increasing forage production. Farmers testified the double-benefit of these species. The good adoption rate of Tree Lucerne and Sesbania and the willingness of farmers to plant these trees again in the future are two evidences of their good appreciation.
Some technical challenges, like germination of seeds or survival of young seedlings, still hinder a good propagation of these species. The other main limit for diffusion appears to be access to planting material. In fact, planting and raising trees for specific fodder purpose is not a common practice in the area, which can explain the fact that farmers are still not totally used to this new technology. A good communication and a proper support upon management practices would hence help farmers to cope with these difficulties.
Anyhow, it can be concluded that, as for now, farmers have a good perception of *Chameacytisus palmensis* and *Sesbania sesban* and that those species are well adapted to meet their needs. It would though be relevant to redo the study after some years to appreciate the plantation trend of those species in the area and assess the impact upon the socio-agro-economic system.

7. REFERENCES

Abiyu A., Lemenih M., Gratzer G., Aerts R., Teketay D., and Glatzel G. 2011. Status of native woody species diversity and soil characteristics in an exclosure and in plantations of Eucalyptus globulus and Cupressus lusitanica in Northern Ethiopia. *Mountain Research and Development*. 31(2), p. 144-152.

Adugna T. and Said A.N. 1992. Prospects for integrating food and feed production in Welayita Sodo, Ethiopia. In: Stares J. E. S., Said A. N. and Kategile J. A. (eds), *The complementary of feed resources for animal production in Africa. Proceedings of the joint feed resources networks workshop*. Gaborone: African Feeds Research Network, International Livestock Centre for Africa, p. 309-318.

Adugna T. 2007. *Feed resources for producing export quality meat and livestock in Ethiopia. Examples from selected Woredas in Oromia and SSNP regional states*. PhD. Addis Ababa: Hawassa University, 77 p.

Alebachew M., Amare T., and Wendie M. 2015. Investigation of the effects of Eucalyptus camaldulensis on performance of neighbouring crop productivity in western Amhara, Ethiopia. *Open Access Library Journal*. 2(e992).

Alemayehu G., Asfaw Z., and Kelbessa E. 2016. Cordia africana (Boraginaceae) in Ethiopia: a review on its taxonomy, distribution, ethnobotany and conservation status. *International Journal of Botany Studies*. 1(2), p. 38-46.

Alemayehu G. 2018. Ethnobotanical profile of Croton macrostachyus (Euphorbiaceae) in Ethiopia: Review of the literature. *International Journal of Research in Pharmacy and Pharmaceutical Sciences*. 3(1), p. 209-222.

Armstrong L. 2018. Our seedlings. In: *Damara Farm* [Online]. Available at: < http://damarafarm.com/our-seedlings/ > (Accessed: 10 July 2019).

Asfaw Z. and Agren G.I. 2007. Farmers' local knowledge and topsoil properties of agroforestry practices in Sidama, Southern Ethiopia. *Agroforestry Systems*. 71, p. 35-48.

Ashagrie Y., Mamo T., and Olsson M. 1999. Changes in some soil chemical properties under scattered Croton macrostachyus trees in the traditional agroforestry system in North-Western Ethiopia. *Ethiopian Journal of Natural Ressources*. 1(2), p. 215-233.

Assefa B. and Glatzel G. 2010. Measuring soil fertility under Hagenia abyssinica (Bruce) J.F. Gmel by the biotest method. *International Journal of Agronomy*. 2010, p. 1-5.

Barthès V. and Boquien N. 2005. *Analyse diagnostic d'une petite région agricole du sud de l'Ethiopie (Kambatta, Kebele de Homa)*. Pour l'obtention du Diplôme d'Ingénieur Agronome. Paris: Institut National Agronomique Paris-Grignon, 160 p.

Bekele-Tesemma A., Birnie A., and Tengnäs B. 1993. *Useful trees and shrubs for Ethiopia. Identification, Propaation and Management for Agricultural and Pastoral Communities*. Addis Ababa, Nairobi: Regional Soil Conservation Unit, Swedish International Development Authority, 472 p. (Technical Handbooks Series, 5)

Benin S., Ehui S., and Pender J. 2003. Policies for livestock development in the Ethiopian highlands. *Environment, Development and Sustainability*. 5, p. 491-510.

Buzanakova A. 2014. Ethiopia FAO STAT - Land use and Agricultural Inputs. In: *Ethiopia data portal* [Online]. Available at: < ethiopia.opendataforafrica.org/howisde/ethiopia-fao-stat-land-use-and-agricultural-inputs > (Accessed: 5 October 2019).

Chanie T., Collick A.S., Adgo E., Lehmann C.J., and Steenhuis T.S. 2013. Eco-hydrological impacts of Eucalyptus in the semi humid Ethiopian highlands: the lake Tana plain. *Journal of Hydrology and Hydromechanics*. 61(1), p. 21-29.

Cheveau A. and Hoornaert C. 2011. *Development perspectives for an Ethiopian agrarian system sinking into crisis. Agrarian diagnosis carried out from March to October 2011, Doyogena Woreda, Kambatta, Southern Ethiopia*. Master degree thesis, Agronomics. Paris: AgroParisTech, 47 p.

Cook B.G., Pengelly B.C., Brown S.D., Donnelly J.L., Eagles D.A., Franco M.A., Hanson J., Mullen B.F., Partridge I.J., Peters M., and Schultze-Kraft R. 2017. Fact sheet: Sesbania sesban. In: *Tropical Forages: an interactive selection tool* [Online]. Available at: < http://www.tropicalforages.info/key/forages/Media/Html/entities/sesbania_sesban.htm > (Accessed: 17 September 2019).

Davidson J. 1995. Ecological aspects of Eucalyptus plantations. In: White, K., Ball, J. and Kashio, M., Eds., *Proceedings: Regional expert consultation on Eucalyptus*. FAO Regional Office for Asia and the Pacific, Bangkok: Rapa Publication, p. 202.

Deribe G., Abubeker H., Tsedeke K., Tekleyohannes B., Zekarias B., and Addisu J. 2013. Chemical composition and digestibility of major feed resources in mixed farming system of Southern Ethiopia. *World Applied Sciences Journal*. 26(2), p. 267-275.

Dubeux J.C.B. Jr., Muir J.P., Apolinario V.X.O., Nair P.K.R., Lira M.A., and Sollenberger L.E. 2017. Tree legumes: an underexploited resource in warm-climate silvopastures. *Revista Brasileira de Zootecnia*. 46(8), p. 689-703.

El Atta H., Aref I., and Ahmed A. 2013. Effect of Acacia spp. on soil properties in the highlands of Saudi Arabia. *Life Science Journal*. 10(4), p. 100-105.

El Hassan S.M., Lahlou Kassi A., Newbold C.J., and Wallace R.J. 2000. Chemical composition and degradation characteristics of foliage of some African multipurpose trees. *Animal Feed Science and Technology*. 86, p. 27-37.

Esterhuizen M. 2012. Planting trees. In: *Lucerne Tree Farm. Food that grows on trees* [Online]. Available at: < https://lucernetreefarm.wordpress.com/planting-trees/ > (Accessed: 10 July 2019).

Etana D., Adugna T., Eik L.O., and Salte R. 2011. Nutritive value of morphological fractions of Sesbania sesban and Desmodium intortum. *Tropical and Subtropical Agroecosystems*. 14, p. 793-805.

FAO. 2019. FAO STAT Live Animals. In: *Food and Agriculture Organization of the United Nations* [Online]. Available at: < fao.org/faostat/en/#data/QA > (Accessed: 26 September 2019).

Feleke T. 2016. *Growth performance and nutritive quality of tree lucerne (Chamaecytisus palmensis) fodder under different management conditions in the highlands of Ethiopia*. Degree of Master of Science in Animal and Range Sciences. Hawassa: Hawassa University, 91 p.

Fisher R.F. 1995. Amelioration of degraded rain forest soils by plantations of native trees. *Soil Science Society of America Journal.* 59, p. 544-549.

Geta T., Nigatu L., and Animut G. 2014a. Evaluation of potential yield and chemical composition of selected indigenous multi-purpose fodder trees in three districts of Wolayta zone, Southern Ethiopia. *World Applied Sciences Journal.* 31(3), p. 399-405.

Geta T., Nigatu L., and Animut G. 2014b. Ecological and socio-economic importance of indigenous multiputpose fodder trees in three districts of Wolayta zone, southern Ethiopia. *Journal of Biodiversity and Endangered Species.* 2(4), p. 136.

Getachew K., Itanna F., and Mahari A. 2015. Evaluation of locally available fertilizer tree/shrub species in Gozamin Woreda, North Central Ethiopia. *Research Journal of Agriculture and Environmental Management.* 4(3), p. 164-168.

Getnet A. 1998. Biomass yield, botanical fractions and quality of tagasaste (Chamaecytisus palmensis) as affected by harvesting interval in the highlands of Ethiopia. *Agroforestry Systems.* 42, p. 13-23.

Getnet A., Kijora C., Kehaliew A., Bediye S., and Peters K.J. 2008. Evaluation of tagasaste (Chamaecytisus palmensis) forage as a substitue for concentrate in diets of sheep. *Livestock Science.* 114, p. 296-304.

Getnet A., Peters K.J., Kijora C., and Muluneh M. 2012. Field performance of Tagasaste (Chamaecytisus palmensis) under different harvesting management in a tropical highland area of Ethiopia. *Ethiopian Journal of Agricultural Science.* 22, p. 143-158.

Gindaba J., Rozanov A., and Negash L. 2005. Trees on farms and their contribution to soil fertility parameters in Badessa, eastern Ethiopia. *Biol Fertil Soils.* 42, p. 66-71.

Guyon L., Demeke G., Redon P., Bourgois F., du Portal D., Mega T., Tilahun A., and Desalegn M. 2016. *Combining soil conservation and fodder production for an adaptation to climate change.* Southern Region, Ethiopie: Inter Aide, 17 p.

Haile A. and Tolemariam T. 2008. The feed values of indigenous multipurpose trees for sheep in Ethiopia: the case of Vernonia amygdalina, Buddleja polystachya and Maesa lanceolata. *Livestock Research for Rural Development.* 20(3), p. 1-7.

Heering J.H. 1995. The effect of cutting height and frequency on the forage, wood and seed production of six Sesbania sesban accessions. *Agroforestry Systems.* 30, p. 341-350.

Heering J.H. and Gutteridge R.C. 2019. Sesbania sesban (PROSEA). In: *Plant Use* [Online]. Available at: < https://uses.plantnet-project.org/en/Sesbania_sesban_(PROSEA) > (Accessed: 17 September 2019).

Hunde D. 2018. Dairy cattle breeding program in Ethiopia: lesson learned from case studies in the tropical countries. *Academic Research Journal of Agricultural Science and Research.* 6(2), p. 97-104.

Hurni H., Berhe W., Chadhokar P., Daniel D., Gete Z., Grunder M., and Kassaye G. 2016. *Soil and Water Conservation in Ethiopia: Guidelines for Development Agents.* Second revised edition. Bern: Centre for Development and Environment (CDE), University of Bern, with Bern Open Publishing (BOP), 134 p.

Kaitho R.J., Umunna N.N., Nsahlai I.V., Tamminga S., and Van Bruchem J. 1998. Effect of feeding graded levels of Leucaena leucocephala, Leucaena pallida, Sesbania sesban and Chamaecytisus palmensis supplements to teff straw given to Ethiopian highland sheep. *Animal Feed Science and Technology*. 72, p. 355-366.

Karachi M. and Matata Z. 1997. Effect of age of cutting on the productivity and forage quality of fourteen Sesbania accessions in wester Tanzania. *Tropical Grasslands*. 31, p. 543-548.

Karachi M. and Matata Z. 2000. Forage and seed yields, mortality and nutritive value of Sesbania sesban under unimodal rainfall in Tanzania. *Journal of Tropical Forest Science*. 12(2), p. 238-246.

Khanna P.K. 1998. Nutrient cycling under mixed-species tree systems in southeast Asia. *Agroforestry Systems*. 38, p. 99-120.

Kindu M., Glatzel G., Tadesse Y., and Yosef A. 2006a. Tree species screened on Nitisols of Central Ethiopia: biomass production, nutrient contents and effect on soil nitrogen. *Journal of Tropical Forest Science*. 18(3), p. 173-180.

Kindu M., Tadesse Y., Glatzel G., and Yosef A. 2006b. Performance of eight tree species in the highland Vertisols of central Ethiopia: growth, foliage nutrient concentration and effect on soil chemical properties. *New Forests*. 32, p. 285-298.

Kindu M., Glatzel G., Sieghardt M., Birhane K., and Taye B. 2008. Chemical composition of the green biomass of indigenous trees and shrubs in the highlands of Central Ethiopia: implications for soil fertility. *Journal of Tropical Forest Science*. 20(3), p. 167-174.

Kindu M., Glatzel G., and Sieghardt M. 2009a. Assessments of fodder value of 3 indigenous and 1 exotic woody plant species in the highlands of central Ethiopia. *Mountain Research and Development*. 29(2), p. 135-142.

Kindu M., Glatzel G., Sieghardt M., and Ottner F. 2009b. Soil properties under selected homestead grown indigenous tree and shrub species in the highland areas of central Ethiopia. *East African Journal of Sciences*. 3(1), p. 9-17.

Kindu M., Glatzel G., and Sieghardt M. 2011. Hagenia abyssinica (Bruce) J.F. Gmel: a preferred tree for fodder and soil fertility improvement in Galessa watershed, central Ethiopia. *Ethiopian Journal of Natural Ressources*. 11(2), p. 277-291.

Kindu M., Jogo W., Melkamu B., Mulema A., and Thorne P. 2017. Determinants of survival and growth of tree lucerne (Chamaecytisus palmensis) in the crop-livestock farming systems of the Ethiopian highlands. *Agroforestry Systems*.

Larbi A., Thomas D., and Hanson J. 1993. Forage potential of Erythrina abyssinica: intake, digestibility and growth rates for stall-fed sheep and goats in southern Ethiopia. *Agroforestry Systems*. 21, p. 263-270.

Léonard T. 2013. *Ethiopian Iddirs mechanisms. Case study in pastoral communities in Kembata and Wolaita*. Ethiopie: Inter Aide, 104 p.

Lisanework N. and Michelsen A. 1993. Allelopathy in agroforestry systems: the effects of leaf extracts of Cupressus lusitanica and three Eucalyptus spp. on four Ethiopian crops. *Agroforestry Systems*. 21, p. 63-74.

Mamo D. and Asfaw Z. 2017. Status of selected soil properties under Croton macrostachyus tree at Gemechis district, west Hararghe zone, Oromia, Ethiopia. *Journal of Biology, Agriculture and Healthcare*. 7(8), p. 36-43.

Manaye T., Adugna T., and Tessema Z. 2009. Feed intake, digestibility and body weight gain of sheep fed Napier grass mixed with different levels of Sesbania sesban. *Livestock Science*. 122, p. 24-29.

Manjur B., Abebe T., and Abdulkadir A. 2014. Effects of scattered F. albida (Del) and C. macrostachyus (Lam) tree species on key soil physicochemical properties and grain yield of Maize (Zea Mays): a case study at umbulo Wacho watershed, southern Ethiopia. *Wudpecker Journal of Agricultural Research*. 3(3), p. 63-73.

Mekoya A., Oosting S.J., Fernandez-Rivera S., and Van der Zijpp A.J. 2008. Multipurpose fodder trees in the Ethiopian highlands: farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators. *Agricultural Systems*. 96, p. 184-194.

Mekoya A., Oosting S.J., Fernandez-Rivera S., Tamminga S., and Van der Zijpp A.J. 2009. Effect of supplementation of Sesbania sesban to lactating ewes on milk yield and growth rate of lambs. *Livestock Science*. 121, p. 126-131.

Mengistu A. 2006. *Country pasture/forage resource profiles*. Addis Ababa: Food and Agriculture Organization of the United Nations, 36 p.

Michelsen A., Lisanework N., and Friis I. 1993. Impacts of tree plantations in the Ethiopian highland on soil fertility, shoot and root growth, nutrient utilisation and mycorrhizal colonisation. *Forest Ecology and Management*. 61, p. 299-324.

Michelsen A., Lisanework N., Friis I., and Holst N. 1996. Comparisions of understorey vegetation and soil fertility in plantations and adjacent natural forests in the Ethiopian highlands. *Journal of Applied Ecology*. 33, p. 627-642.

Molla A. and Linger E. 2017. Effects of Acacia decurrens (Green wattle) tree on selected soil physico-chemical properties North-western Ethiopia. *Research Journal of Agriculture and Environmental Management*. 6(5), p. 95-103.

Muchiri M.N. 2004. Grevillea robusta in agroforestry systems in Kenya. *Journal of Tropical Forest Science*. 16(4), p. 396-401.

Muzoora A.K., Turyahabwe N., and Majaliwa J.G.M. 2011. Validation of farmer perceived soil fertility improving tree species in agropastoral communities of Bushenyi District. *International Journal of Agronomy*. 2011, p. 1-10.

Negash M. and Starr M. 2013. Litterfall production and associated carbon and nitrogen fluxes of seven woody species grown in indigenous agroforestry systems in the south-eastern Rift Valley escarpment of Ethiopia. *Nutrient Cycling in Agroecosystems*. 97, p. 29-41.

Nigussie Z. and Alemayehu G. 2013. Sesbania sesban (L.) Merrill: Potential uses of an underutilized multipurpose tree in Ethiopia. *African Journal of Plant Science*. 7(10), p. 468-475.

Nyberg G. and Högberg P. 1995. Effects of young agroforestry trees on soils in on-farm situations in western Kenya. *Agroforestry Systems*. 32, p. 45-52.

Orwa C., Mutua A., Kindt R., Jamnadass R., and Simons A. 2009. *Agroforestree Database: a tree reference and selection guide version 4.0*. Nairobi: World Agroforestry Centre

Osuga I.M., Wambui C.C., Abdulrazak S.A., Ichinohe T., and Fujihara T. 2008. Evaluation of nutritive value and palatability by goats and sheep of selected browse foliages from semiarid area of Kenya. *Animal Science Journal*. 79, p. 582-589.

Otsyina R.M., Norton B.W., and Djimdé M. 1999. Fodder trees and shrubs in arid and semi-arid livestock production systems. In: *XVIII International Grassland Congress, Winnepeg and Saskatoon, Canada, 8-17 June 1997*. Calgary: Association Management Centre, 10 p.

Palm C.A. 1995. Contribution of agroforestry trees to nutrient requirements of intercropped plants. *Agroforestry Systems*. 30, p. 105-124.

Palm C.A., Myers R.J.K., and Nandwa S.M. 1997. Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In: Buresh R.J., Sanchez P.A. and Calhoun F. (ed.), *Replenishing Soil Fertility in Africa*. Madison: American Society of Agronomy and Soil Science Society of America, p. 193-218 (SSSA Special Publication 51)

Pan F., Zhang W., Liu S., Li D., and Wang K. 2015. Leaf N:P stoichiometry across plant functional groups in the karst region of southwestern China. *Trees*. 29, p. 883-892.

Rao M.R., Nair P.K.R., and Ong C.K. 1998. Biophysical interactions in tropical agroforestry systems. *Agroforestry Systems*. 38, p. 3-50.

Roothaert R.L. and Paterson R.T. 1997. Recent work on the production and utilization of tree fodder in East Africa. *Animal Feed Science and Technology*. 69, p. 39-51.

Salem A.Z.M., Salem M.Z.M., E-Adawy M.M., and Robinson P.H. 2006. Nutritive evaluations of some browse tree foliages during the dry season: secondary compounds, feed intake and in vivo digestibility in sheep and goats. *Animal Feed Science and Technology*. 127, p. 251-267.

Scholle J. 2017. *Agroecological and agroforestry practices in tropical wet zones. Technical guide*. France: Gret, 302 p.

Shelton H.M. 2000. Tropical forage tree legumes in agroforestry systems. *Unasylva 2000*. 51, p. 25-32.

Teklay T., Nyberg G., and Malmer A. 2006. Effect of organic inputs from agroforestry species and urea on crop yield and soil properties at Wondo Genet, Ethiopia. *Nutrient Cycling in Agroecosystems*. 75, p. 163-173.

Tengnas B. 1994. *Agroforestry extension manual for Kenya*. Nairobi: International Centre for Research in Agroforestry, 188 p.

Tessema Z. and Baars R.M.T. 2004. Chemical composition, in vitro dry matter digestibility and ruminal degradation of Napier grass (Pennisetum purpureum (L.) Schumach.) mixed with different levels of Sesbania sesban (L.) Merr. *Animal Feed Science and Technology*. 117, p. 29-41.

Tornquist C.G., Hons F.M., Feagley S.E., and Haggar J. 1999. Agroforestry system effects on soil characteristics of the Sarapiquì region of Costa Rica. *Agriculture, Ecosystems and Environment*. 73, p. 19-28.

Wassie H. 2012. Appraisal of Erythrina bruci as a source for soil nutrition on nitisols of South Ethiopia. *International Journal of Agriculture and Biology*. 14(3), p. 371-376.

Wood P.J. and Burley J. 1991. *A tree for all reasons: the introduction and evaluation of multipurpose trees for agroforestry*. Nairobi: International Centre for Research in Agroforestry, 167 p. (Science and Practice of Agroforestry, 5)

Yadessa A., Itanna F., and Olsson M. 2001. Contribution of indigenous trees to soil properties: the case of scattered trees of Cordia africana Lam. in croplands of western Oromia. *Ethiopian Journal of Natural Ressources*. 3(2), p. 245-270.

Yadessa A., Itanna F., and Olsson M. 2009. Scattered trees as modifiers of agricultural landscapes: the role of waddeessa (Cordia africana Lam.) trees in Bako area, Oromia, Ethiopia. *African Journal of Ecology*. 47(1), p. 78-83.

Young A. 1990. *Agroforestry for soil conservation*. 2e éd. Wallingford: CAB International and ICRAF, 276 p.

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8. LISTE OF ACRONYMS

ADF	Acid Detergent Fibre
C	Carbon
DF	Degree of Freedom
DM	Dry Matter
Etb	Ethiopian Birr
Fisher	Fisher's exact test
FTC	Farmers Training Centre
IA	Inter Aide
K	Potassium
K-W	Kruskal-Wallis test
N	Nitrogen
NDF	Neutral Detergent Fibre
NGO	Non Governmental Organisation
P	Phosphorus
SNNPR	Southern Nations, Nationalities and Peoples' Region

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APPENDIX TABLE

ANNEX 1: INTERVIEW GRID ABOUT HEDGEROWS IN THE FARMLAND

Kebele:
Village Unit:
Name of the interviewee:
Household size:
Farmland size:
Number of cattle owned (cow, ox, calf, sheep, goat, donkey,…):

The following questions are covered thematic, but the discussion remained free.
A visit of the farm with personal observations completed the pieces of information.

- Where is situated the live fence?

- When was the life fence established? Why?
  Did the composition change through time?

- Are you selecting the species which are growing in it?

- Which species of trees or shrubs are present in the composition of the life fence?
  What are their uses?
  Are there some negative effects?

➔ Use this table to answer

Species name	*Importance of the species in the composition*	*Apart from protection of the farm what are other benefits?*						*Negative effects*
		Forage value	*Construction value*	*Fuel value*	*Income value*	*Soil fertility value*	*Other values*	

- Do you use some indigenous species as fodder?
  When do you browse or feed those fodder species? How often? And why?
  Make a ranking of the species based on appreciation for fodder value.

ANNEX 2: FORMAL SURVEY ON TREE LUCERNE AND SESBANIA IN DOYOGENA AND KACHABIRA *WOREDAS*

General information on the farmer's status:

1) Name:
2) Sex:
3) Age:
4) Wealth category (to determine with Iddir leaders or IA staff)
5) Household size:
6) Education level (grade):
7) Land size (*timad*):
8) Number of local cattle:
9) Number of hybrid cattle:
10) Number of sheep or goats:
11) Number of donkey or horse:
12) Village unit:
13) Kebele:

The questions will be asked for one tree and then for the other.

Knowledge and information about the plants

14) Do you know Tree Lucerne or Sesbania?
    a) Yes b) No
15) If yes, how do you understand the benefit of this plant?
    a) As animal forage
    b) As soil fertility plant
    c) As fence or ornamental tree
    d) Other
    e) Don't know the benefit
16) For the first time, from whom did you get information about Tree Lucerne or Sesbania?
    a) From Inter Aide through peer educators or field workers
    b) From a neighbour farmer
    c) From Kebele MoA
    d) Other
17) If from IA, how did you get the information
    a) During a meeting or training
    b) During the visit to a farmer's field
    c) While distribution of seeds/seedlings from PE or IA field workers
    d) Other

Access for seeds or seedlings

18) Did you already plant Tree Lucerne or Sesbania?
    a) Yes b) No
19) If no, what were the reasons? (then jump to question 42)
    a) No access to planting material
    b) Too expansive costs
    c) No available place in the farm
    d) No time to manage it
    e) No good perception upon this tree
    f) Don't know the use
    g) Other

If yes,

Plantation conditions:

20) When did you plant it?
21) What were your motivations to plant?
    a) To diversify fodder production
    b) To increase fodder production
    c) To sell fodder or seeds
    d) Because of its good fodder quality
    e) For soil fertility
    f) To protect from erosion
    g) For fencing purpose
    h) For ornamental purpose
    i) Because there was an opportunity to get seeds/seedlings
    j) Other
22) Which planting material did you get the first time?
    a) Seeds b) Seedlings
23) From whom?
    a) Inter Aide d) Market
    b) Kebele MoA e) Other
    c) Neighbour

If you got seedlings:

24) How old were the seedlings (months)?
25) How did you get the seedlings?
    a) Bare root b) Polybag c) Other
26) Did you plant them directly?
    a) Yes b) No

If you got seeds:

27) Did you treat them before planting?
    a) Yes b) No
28) If yes, how?
    a) Soaking in hot water for 30 minutes
    b) Soaking in cold water for 24 hours
    c) Other
29) In which month did you sow?
30) How long did the seeds stay in the seedbed?

For all:

31) How many trees did you plant in your farmland?
32) Where did you plant these trees?
    a) As a hedge around homestead d) On conservative structures
    b) As a hedge around fields e) In the backyard
    c) At the bottom of the farm f) Other
33) In which month did you plant these trees?
34) What specific management did you do when planting?
    a) Pollarding b) Pruning c) Nothing d) Other

Management:

35) Did you have any information about managing the tree before planting it?
   a) Yes b) No
   If yes, from whom?
36) Do you (or did you) feed your animals with it?
   a) Yes b) No
   If yes, what are the practices: dry/fresh, mix/alone, chopped/direct

Difficulties encountered:

37) What kind of difficulties did you go through?
   a) Getting the planting material
   b) Germination of seeds
   c) Seedlings' survival
   d) Management
   e) Feed for animals
   f) No difficulties
   g) Other

Adoption:

38) How many trees do you have now?
39) If you don't have anymore, what is (are) the reason(s)? (then jump to question 42)
   a) Seeds didn't grow
   b) Young trees died (at what age)
   c) Not enough production
   d) Not good fodder quality
   e) Bad effect on soil fertility
   f) Bad management
   g) Other
40) If you still have, what are the benefits?
   a) Good fodder quality (precise)
   b) Good fodder quantity
   c) Increase soil fertility
   d) No benefit
   e) Other
41) What are the disadvantages?
   a) Difficult access for seeds
   b) Slow growth
   c) Management takes time
   d) No satisfactory biomass production
   e) Fodder is not improving meat or milk production
   f) Fodder doesn't have good palatability
   g) No disadvantage
   h) Other

Future plantations:

42) Do you plan to plant (again) this tree in the future?
   a) Yes b) No
43) From where do you think access seeds/seedlings?
   a) Collecting my own seeds
   b) From another farmer who produce seeds
   c) From IA or MoA
   d) Other
44) Do you plan to make your own seedbed?
   a) Yes b) No

ANNEX 3: STATISTICAL RESULTS FOR THE QUESTIONNAIRE SURVEY

Results 1: Non-parametrical test of Kruskal-Wallis for *Sesbania sesban*

	Plantation (Yes / No) *Qualitative*			Adoption (Yes / No) *Qualitative*		
	Chi-squared	DF	P-value	Chi-squared	DF	P-value
Household size *Quantitative*	0.11725	1	0.73	0.090286	1	0.76
Farmland size *Quantitative*	1.0596	1	0.30	1.2851	1	0.26
Number of animals *Quantitative*	0.00035939	1	0.98	1.2113	1	0.27

Results 2: Non-parametrical test of Kruskal-Wallis for *Chamaecytisus palmensis*

	Plantation (Yes / No) *Qualitative*			Adoption (Yes / No) *Qualitative*		
	Chi-squared	DF	P-value	Chi-squared	DF	P-value
Household size *Quantitative*	0.11222	1	0.74	0.011522	1	0.91
Farmland size *Quantitative*	0.5175	1	0.47	0.32791	1	0.57
Number of animals *Quantitative*	0.1363	1	0.71	0.33682	1	0.56

Results 3: Fisher's exact test for *Sesbania sesban*

	Plantation (Yes / No) *Qualitative*	Adoption (Yes / No) *Qualitative*
	P-value	P-value
Age (30-49 / 50-69 / >70) *Qualitative*	0.0092 *	0.43
Wealth (P / I / BO) *Qualitative*	0.081	0.81
Education (No / 1-6 / 7-10 / >11) *Qualitative*	0.20	0.67
Year of plantation *Qualitative*		0.064
Planting material (Seeds / Seedlings) *Qualitative*		0.54
Month of plantation *Qualitative*		0.99
Information about management (Yes / No) *Qualitative*		1

* Significant result

Results 4: Fisher's exact test for *Chamaecytisus palmensis*

	Plantation (Yes / No) *Qualitative*	Adoption (Yes / No) *Qualitative*
	P-value	P-value
Age (30-49 / 50-69 / >70) *Qualitative*	0.010 *	0.78
Wealth (P / I / BO) *Qualitative*	0.17	0.90
Education (No / 1-6 / 7-10 / >11) *Qualitative*	0.054	0.047 *
Year of plantation *Qualitative*		0.059
Planting material (Seeds / Seedlings) *Qualitative*		0.73
Month of plantation *Qualitative*		0.23
Information about management (Yes / No) *Qualitative*		1

* Significant result

ANNEX 4: STATISTICAL RESULTS FOR THE GERMINATION TEST

Results 1: Non-parametrical test of Kruskal-Wallis for the original dataset (20 data)

	Germination rate *Quantitative*		
	Chi-squared	DF	P-value
Species (Sebania / Tree Lucerne) *Qualitative*	5.5372	1	0.019 *
Soil type (Doyogene / Kachabira) *Qualitative*	0.28234	1	0.60

* Significant result

Results 2: Analysis of variance (ANOVA) for the dataset with best treatments (10 data)

	Germination rate *Quantitative*		
	F-value	DF	P-value
Species (Sebania / Tree Lucerne) *Qualitative*	60.88	1	5.23e-05 *
Soil type (Doyogene / Kachabira) *Qualitative*	0.376	1	0.56

* Significant result

Results 3: Non-parametrical test of Kruskal-Wallis for datasets restricted to each species (10 data)

	Germination rate *Quantitative*		
	Chi-squared	DF	P-value
For Sesbania			
Soil type (Doyogene / Kachabira) *Qualitative*	0.53455	1	0.46
For Tree Lucerne			
Soil type (Doyogene / Kachabira) *Qualitative*	0.10519	1	0.75

ANNEX 5: SUMMARY SHEETS OF THE INDIVIDUALLY INTERVIEWED FARMERS ABOUT SESBANIA AND TREE LUCERNE

SPECIES: **SESBANIA**

NAME OF THE FARMER: **SIYUM DELKASO**
KEBELE: **LEMISUTICHO**
VILLAGE UNIT: **TULLA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 10 minutes in boiled water
Month of sowing: May
Time in seedbed: 12 months
Germination rate: good
Keep one tree for seed collection

MANAGEMENT

Place of plants:
- Conservative structure (1)

Quantity: about 60 trees
Space between plants: 50cm
Height of cut: 1m
Cutting frequency: 15 days

BENEFITS

- Good fodder quality, improves body performance
- Gives a good taste for milk
- Soil fertility improvement

DIFFICULTIES

- Don't have a good production.

FEED

Every 2 weeks.
Usually mixed with crop residues or grass.
Can be given fresh.

Comparison with Tree lucerne:

- Sesbania is better for body performance improvement and milk production
- Sesbania has better palatability
- Tree lucerne has better quantity, fast growing and has a lot of branches

Trees are better than grass because they are long living and can be used as fence.

SPECIES: **SESBANIA**

NAME OF THE FARMER: **YOHANES AMADO**
KEBELE: **BURCHANA**
VILLAGE UNIT: **TUBUKO**
YEAR OF PLANTATION: **2017**

PLANTATION

Seed treatment: No
Month of sowing: February
Time in seedbed: 4 to 6 months
Germination rate: good
Keep trees for seed collection

MANAGEMENT

Place of plants:
- Backyard (some mixed with Tree Lucerne)

Quantity: about 30 trees
Space between plants: 0,5 to 1m
Height of cut: 1m20 (cut after 1 year)
Cutting frequency: 3-4 months. Prune when it starts flowering.

BENEFITS

- Good quality fodder: milk production and body performance
- Good palatability
- Soil fertility improvement
- Ornamental

DIFFICULTIES

No

FEED

Dry for 2 hours in the sun.
Mix with *desho* or natural grass.

Comparison with Tree Lucerne:

- Sesbania has better palatability
- Tree Lucerne has better biomass production
- Both have good quality

SPECIES: **SESBANIA**

NAME OF THE FARMER: **ALAMU ARFICHO**
KEBELE: **HOBICHAKA**
VILLAGE UNIT: **YAYAMA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: Before: 30min in HW + 24h in CW. Now: no treatment
Month of sowing: June
Time in seedbed: 2 months
Germination rate: very good
Own-seeds collection
Made a lot of seedbeds already to distribute to his neighbours

MANAGEMENT

Place of plants:
- At the bottom of conservative structure (1)
- Hedge around homestead (10m)

Quantity: about 100 trees
Space between plants: 60cm on CS, 20cm in the hedge
Height of cut: 1m50 (but for those at the bottom of the structure, only 50cm overpass the bank)
Cutting frequency: 2 months in rainy season, 3-4 months in dry season
Production measurement: 4kg fresh weight (length: 10m, height: 1m50, n° of trees: 16) (low production probably because planted under the conservative structure)

BENEFITS

- Fast growth
- Good biomass production if good care: allowed him to change his local cattle with hybrid one
- Good quality fodder: milk production and body performance (now has enough milk for home consumption and can sell animals at good price)
- Good palatability, mostly for hybrid cattle
- Soil fertility improvement
- Live fence
- Ornamental

Replanted 3 times in his farmland

DIFFICULTIES

- Short lifespan, need to replace every 5 years
- Browsing of wild animals, damages

FEED

Gives every day until he has.
Mixed with *desho* grass.

Comparison with Tree Lucerne:

- Sesbania has better quantity, quality and palatability (more experience about this tree)
- Tree lucerne has low germination rate

SPECIES: **SESBANIA**

NAME: **AMANUEL HEGENA**
KEBELE: **DOREBA**
VILLAGE UNIT: **MATANA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: No
Month of sowing: May
Time in seedbed: 2 months
Germination rate: good

MANAGEMENT

Place of plants:
- Conservative structures (4)
- Scattered in field
- Hedge around homestead (less than 10m)
- Old seedbed

Quantity: about 600 trees
Space between plants: 20cm on CS
Height of cut: 1m20 on CS
Cutting frequency: 2 months (rainy season), 4 months (dry season)
Production measurement: 19,5kg fresh weight (length: 10m, height: 1m20, n° of trees: 40)

BENEFITS

- Good quality fodder: milk production and body performance. Sesbania is even better quality than *frushka* and other fodder.
- Good palatability
- Soil fertility improvement
- Ornamental

DIFFICULTIES

- One row became dry after having cutting the tips at 20cm high after 2 years
- Medium quantity, but still enough to be useful and important

FEED

Dry for 30min before giving during the rainy season.
Mixed when another source of fodder is available, otherwise alone.

SPECIES: **SESBANIA**

NAME: **MOJAMO SOSAMO**
KEBELE: **BEGEDAMO**
VILLAGE UNIT: **GETAME**
YEAR OF PLANTATION: **2015**

PLANTATION

Seed treatment: No
Month of sowing: March
Time in seedbed: 3 months
Germination rate: good

MANAGEMENT

Place of plants:
- Hedge around homestead (30m)

Quantity: about 120 trees
Space between plants: 30cm
Height of cut: 2m
Cutting frequency: 1 or 2 months
Specific management: branches are linked together
Production measurement: 32kg fresh weight (length: 10m, height: 2m, n° of trees: 37)

BENEFITS

- Fence
- Ornamental
- Good quality fodder: used as *frushka* to improve milk production and body performance
- Good palatability
- Soil fertility improvement
- Shadow for crops when planted in the field

DIFFICULTIES

No

FEED

Make dry for some hours.
Not mixed.
Give 'as a desert', try to give every 4 days.

SPECIES: **SESBANIA**

NAME OF THE FARMER: **TADELE GATISO**
KEBELE: **DOREBA**
VILLAGE UNIT: **MATANA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 30 minutes in boiled water
Month of sowing: March
Time in seedbed: 3 months
Germination rate: very good
Plan to collect his own seeds

MANAGEMENT

Place of plants:
- Conservative structures (2)
- Hedge around homestead (about 15m)

Quantity: about 60 trees
Space between plants: 1m on CS
Height of cut: 0m80 – 1m on CS
Cutting frequency: 1 month

BENEFITS

- Soil fertility improvement, increase crop production
- Diversified fodder source for cattle
- Good palatability
- Good quality fodder: milk production and body performance
- Live fence
- Ornamental

DIFFICULTIES

- Seedlings' survival: some dried 2 weeks after replanting
- Browsing of wild animals

FEED

Gives for one week every month.
Mixed with ¾ other fodder.

Comparison with Tree Lucerne:

- Tree lucerne had low germination rate
- Tree lucerne has poor production (tip uncut)
- Same palatability

SPECIES: **TREE LUCERNE**

NAME OF THE FARMER: **SIYUM DELKASO**
KEBELE: **LEMISUTICHO**
VILLAGE UNIT: **TULLA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 5 minutes in boiled water
Month of sowing: June
Time in seedbed: 11 months
Germination rate: good
Specific management in seedbed: cut the tip one week before replanting

MANAGEMENT

Place of plants:
- Hedge around fields (newly planted)
- Hedge in front of the house (about 20m)

Quantity: about 120 trees
Space between plants: 50cm
Height of cut: 1m; or 1m70 when at reach from the cattle
Cutting frequency: 2 or 3 months

BENEFITS

- Very helpful fodder
- Good fodder quality
- Soil fertility improvement
- Live fence around the field and backyard
- Strong wood for tools

DIFFICULTIES

No

FEED

Every 2 weeks, mostly during the dry season. Usually mixed with crop residues or grass. Better to give dried.

Comparison with Sesbania:

- Sesbania is better for body performance improvement and milk production
- Sesbania has better palatability
- Tree lucerne has better quantity, fast growing and has a lot of branches

Trees are better than grass because they are long living and can be used as fence.

SPECIES: **TREE LUCERNE**

NAME OF THE FARMER: **YOHANES AMADO**
KEBELE: **BURCHANA**
VILLAGE UNIT: **TUBUKO**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 30 minutes in boiled water
Month of sowing: February
Time in seedbed: 4 to 6 months
Germination rate: good
Keep trees for seed collection

MANAGEMENT

Place of plants:
- Backyard (some are mixed with Sesbania)
- Hedge around homestead (about 15m)

Quantity: about 60 mature trees + about 100 new seedlings
Space between plants: 0,5 to 1m
Height of cut: 1m20 (cut after 1 year)
Cutting frequency: 3-4 months

BENEFITS

- Live fence: shadow and protection from wind
- Ornamental
- Good quality fodder: milk production and body performance, can be used to fatten
- Good palatability
- Soil fertility improvement

DIFFICULTIES

No

FEED

Dry for 2 hours in the sun.
Mix with *desho* or natural grass.

Comparison with Sesbania:

- Sesbania has better palatability
- Tree Lucerne has better biomass production
- Both have good quality

SPECIES: **TREE LUCERNE**

NAME OF THE FARMER: **LAPISO GIRMISO**
KEBELE: **LEMISUTICHO**
VILLAGE UNIT: **TULLA**
YEAR OF PLANTATION: **2015**

PLANTATION

Seedlings: from IA and neighbour
Month of plantation: June, May

Seed treatment: 30 minutes in hot water
Month of sowing:
Now is producing his own seeds

MANAGEMENT

Place of plants:
- Row inside the enset plantation
- In the fence in front of the house (newly planted)

Quantity: about 30 trees and 50 newly planted
Space between plants: 50cm in the fence, 1m in the enset plantation
Height of cut: 1m60
Cutting frequency: 1 or 2 months

BENEFITS

- Soil fertility improvement
- Fodder quality which improves milk production and body performance of cattle. Even a small quantity is enough to have a good impact.
- Ornamental
- Strong wood to make fence or tools
- Good fuel quality when dry

DIFFICULTIES

- Seeds require treatment
- Can't be transplanted at a too early stage, needs to stay for a long time in seedbed

FEED

Once or twice a week, especially during the dry season.
Usually mixed with other food.
Good palatability.

SPECIFIC MANAGEMENT

He pruned the totality of the trees which are inside the enset plantation because they were too high and hence competing with the enset. He expects the trunk to produce new sprouts. He collected the seeds, used the leaves as fodder and the branches to build a fence.

SPECIES: **TREE LUCERNE**

NAME: **TASHOME TEKATEL**
KEBELE: **GOMORA**
VILLAGE UNIT: **JANA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 10 minutes in boiled water
Month of sowing: April
Time in seedbed: 5 months
Germination rate: good
Keep trees for seed collection (better to collect seeds in March-April)

MANAGEMENT

Place of plants:
- In the fence around homestead (about 30m)
- Conservative structures (unknown)

Quantity: about 50 in the fence
Space between plants: 0,5-1m in the fence
Height of cut: 1m50
Cutting frequency: 3 months

BENEFITS

- Very good quality fodder: milk production, body performance, health (lot of protein content)
- Firewood
- Strong wood to make ploughing material
- Soil fertility improvement: source of N
- Soil conservation: erosion protection
- Ornamental and shadow
- Economic benefits: sale of seeds and seedlings

DIFFICULTIES

- Wild animal damage

FEED

Dry for 30 min in the sun.
Mix with crop residues.

Comparison with Sesbania:

- Sesbania has better quality, especially for milk production
- Tree Lucerne has better biomass production
- Sesbania died after 2 years, during the rainy season: maybe it didn't adapt well to the cold weather

SPECIES: **TREE LUCERNE**

NAME OF THE FARMER: **TEREFA TEMAMO**
KEBELE: **HODA**
VILLAGE UNIT: **HODA**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 30 minutes in boiled water
Month of sowing: July
Time in seedbed: 2 or 3 months
Germination rate: good

MANAGEMENT

Place of plants:
- Conservative structures (3)
- Hedge in front of the house (mixed with Sesbania)

Quantity: more than 150 trees
Space between plants: 40 cm
Height of cut: 1m10 in average
Cutting frequency: 1 or 2 months
Production measurement: 22kg fresh weight (length: 10m, height: 1m10, n° of trees: 23)

BENEFITS

- Fodder diversity
- Fodder quality which improves milk production and body performance of cattle
- Good quantity
- Live fence around the field
- Ornamental

DIFFICULTIES

No

Comparison with Sesbania:

- Both have good palatability and good quality
- Tree lucerne has better quantity

SPECIES: **TREE LUCERNE**

NAME OF THE FARMER: **TESEMA YANORE**
KEBELE: **LEMISUTICHO**
VILLAGE UNIT: **SUTICHO**
YEAR OF PLANTATION: **2016**

PLANTATION

Seed treatment: 2 min in hot water
Month of sowing: March
Time in seedbed: 3 months
Germination rate: good
Keep some trees for seed collection

MANAGEMENT

Place of plants:
- Hedge in front of the house (2x10m)

Quantity: about 100 trees
Space between plants: 20 cm
Height: 1m for one hedge, 1m60 for the other
Not all the tips are cut but they are bended
Cutting frequency: 3 or 4 months
Specific management: branches are linked together to make a fence
Production measurement: 16,5kg fresh weight (length: 10m, height: 1m60, number of trees: about 40)

BENEFITS

- Live fence
- Ornamental
- Good fodder quality, for milk production and body performance
- Improvement of soil fertility

DIFFICULTIES

No

FEED

Cut one row for 1 or 2 meals.
Give mixed with 2/3 of other food.

SPECIES: **TREE LUCERNE**

NAME: **TESFAYE DUBUSHA**
KEBELE: **GOMORA**
VILLAGE UNIT: **CHOLOLA**
YEAR OF PLANTATION: **2016 AND 2018**

PLANTATION

Seed treatment: Don't know, got seeds from IA
Month of sowing: July
Time in seedbed: planted directly as a row next to *enset*
Germination rate: medium

MANAGEMENT

Place of plants:
- Hedge next to *enset* plantation (newly planted)
- Hedge around homestead

Quantity: about 100 trees
Space between plants: 1 foot
Height of cut: 1m to 1m50
Cutting frequency: 3-4 months

BENEFITS

- Live fence: protection of *enset* from animals and wind (replace traditional live fence)
- Soil fertility improvement
- Good quality fodder: milk production and body performance
- Good palatability, especially for hybrid cattle

DIFFICULTIES

- Germination

FEED

Dry for 1 hour on the sun.
Mix with *desho* or natural grass.

Comparison with Sesbania:

- Both are good for soil fertility
- Both have good palatability
- Tree lucerne has better biomass production

Sesbania, Tree Lucerne and grass are complementary food, they need to be mix to have a better nutrition quality.

In the future, wants to replace the totality of his live fence with Tree Lucerne and Sesbania.

ANNEX 6: TECHNICAL GUIDELINES FOR MANAGING SESBANIA AND TREE LUCERNE

Germination of seeds

Treatment:

- Sesbania: NO
- Tree Lucerne: treatment with hot water

> *Recommendation: do further tests on germination of Tree Lucerne to see if the time of soaking has an impact on the germination rate.*

Sowing

Period of sowing: *belg* season
Preparation of seedbed: some days before plantation, chose a fertile place
Taking care of seedbed: weed, protection from browsing and heavy rain
Time in seedbed: unclear if the time in seedbed has an impact on survival of seedlings (can be some months or 1 year)

> *Literature: Sesbania and Tree Lucerne can be transplanted 6 to 10 weeks after sowing (20 cm in height) and establishment of Tree Lucerne is even better for small seedlings of 20 cm than for larger plants.*
> *It is also better not to put seedlings of Tree Lucerne in polybag.*

Plantation of seedlings

Period of plantation: rainy season (April, May, June or August) but not in July
Preparation: dig holes some days before plantation to improve moisture
Place of plantation: fertile place like top of conservative structures, backyard, around homestead, … The bottom of conservative structures doesn't seem to be a proper place (less fertile so less production). Tree Lucerne doesn't establish well on water logged areas.
Space between plants:

- 1m for rows on conservative structures
- 25 to 50 cm if used as a fence

Taking care: protection from browsing specially at young stage, cover and keep the roots with some amount of soil

Pruning

Do not prune at early stage of development, wait for 1 year before first cutting.
Cutting height: 1m to 1m50
Frequency: every 3 or 4 months

- when tree start to flower for Sesbania
- when leaves start to change colour for Tree Lucerne (become white)

Literature:

- *Until 5 coppicing cycle/year for Sesbania (more frequent cutting will decrease the lifespan of the plants)*
- *2 coppicing cycle/year for Tree Lucerne to have a better biomass production (every 6 months)*

Take good care of not damaging branches: use proper tool, cut twigs 10 cm far from the starting point, no direct browsing

Feeding

Use as supplement forage.
Mixing with other source of fodder: 1/3 tree fodder – 2/3 other source
This is especially important at the beginning to adapt animals to it.
Can be used fresh or dry. During the rainy season, let the leaves dry some time to lose their moisture content (half day).

Literature: Cattle prefer to eat dry leaves of Tree Lucerne rather than fresh or wilted

Long-term

Sesbania has short lifespan: need to be replanted every 5 years.
When dry, can be used for firewood.
Importance of keeping some trees to **produce own seeds**.

Model farmers

Sesbania on conservative structures:
Amanuel Hegena (Doreba)

Sesbania as a fence:
Mojamo Sosamo (Begedamo-Getame)

Tree Lucerne on conservative structures:
Terefa Temamo (Hoda)