Silvopasture Using Indigenous Fodder Trees and Shrubs: The Underexploited Synergy Between Climate Change Adaptation and Mitigation in the Livestock Sector

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1 Introduction

In the dry lands of northern Ethiopia, the frequency of drought has increased greatly in recent decades (Gebrehiwot et al. 2011), albeit, against some predictions of increased rainfall in the Eastern Africa region (Christensen et al. 2007). Future climate predictions for the Sahel and East African region foresee increasingly intensive and erratic rain, exposing farmers and pastoralists to more droughts, floods and other climatic hazards (Giannini 2010). Droughts in arid and semi arid areas (ASALs) are not meteorological per se, but are results of intensive and erratic rainfall which, coupled with land degradation, ineffective land use systems, overgrazing and deforestation, make cultivation difficult and precarious. As a result, even though increased net primary productivity has been observed and predicted for the Sahel and East Africa (Doherty et al. 2010), in the absence of proper management, the increased moisture may not have any positive contribution towards increased productivity. In fact, whatever, the climatic predictions are, a vulnerability study in Ethiopian dry lands indicated that most of the regions, specially the arid and semiarid areas, are highly vulnerable to climate change related hazards and risks (Deressa et al. 2008).

Climate change, usually manifested in the form of extreme climate variability in the ASALs is one of the important constraints to agriculture in general and livestock production in particular, causing decrease in productivity by directly reducing feed availability and increasing the incidence of change induced livestock diseases and parasites (Jones and Thornton 2009). The livestock sector, however, is not only a victim of climate change, but also one of the main contributors. Livestock sector's

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contribution to global green house gases emission is estimated to be 51% (Goodland and Anhang 2009).

Therefore, the future of the livestock sector in the ASALs, both as an adaptable industry to the ensuing climate change, and as politically acceptable production system, from climate politics point of view, is dependent on its future ability to adapt to climate change and to be able to reduce its contribution to it. Within dryland rural settings of Ethiopia, the future of the livestock sector depends on the devising and promotion of climate resilient and adaptable livestock production systems which can maintain and increase livestock productivity under threats of rainfall shortage and variability (climate change).

1.1 Silvopastoralism: A Climate Resilient Alternative Livestock Production System

Silvopastoralism defined as an agroforestry system of livestock production where trees and shrubs, which provide diverse ecosystem services to humans are kept on pasturelands (Rigueiro-Rodríguez et al. 2011). Trees planted or naturally occurring on pasturelands, backyards, wastelands, farm-boundaries are used as a sole source of livestock feed, while at the same time providing other multipurpose ecosystem services and benefits (Gallo 2005).

Silvopastoralism has recently gained prominence as a sustainable and climate resilient livestock production system (Mosquera-Losada et al. 2011), although usually only theoretically (Dagang and Nair 2003). Silvopastoralism, compared to conventional pasture systems, has resulted in better livestock productivity (Schoeneberger 2009), and improved soil fertility (Moreno and Obrador 2007). Most importantly, silvopastoralism, as a tree based livestock production system provides an effective synergy between climate change adaptation and mitigation (Dube et al. 2011; Stavi and Lal 2013), by directly contributing to sequestration of Green House Gases (GHG), while at the same time buffering livelihoods against variability/recurrent drought as trees are less affected by variability in climate than grass pastures (Nair 2012).

Silvopastoralism contributes to climate change mitigation and adaptation in the following ways: first silvopastoralism is more adaptive to drought, than pastures because foliage production from trees and shrubs is less affected by varying precipitation, temperature and other climatic variables thus enabling farmers to sustain livestock production even at extreme weather condition (Papanastasis et al. 2008); second woody fodder species in a silvopastoral system increases the fertility of grazing lands there by providing suitable conditions for grasses, and improving micro-sites for grass growth (Moreno and Obrador 2007); thirdly livestock productivity is higher under a silvopastoral system compared to traditional pasture (Fig. 1) based systems, because fodder trees are of higher quality than many of the herbaceous grasses (Ibrahim et al. 2005), a fact that also enables reduction in the

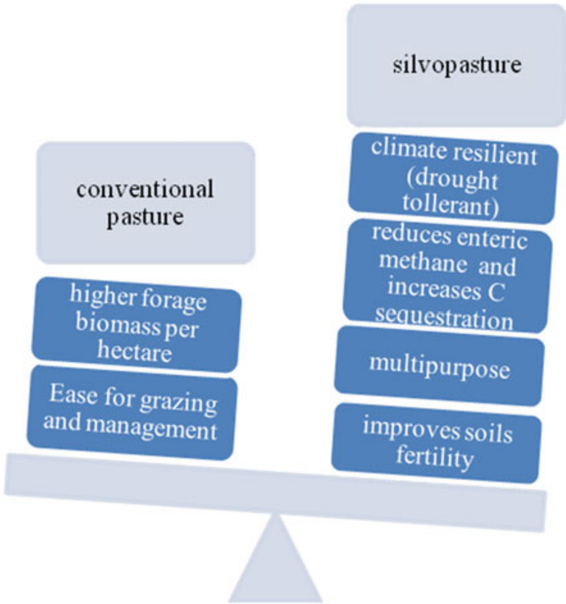

Fig. 1 Conceptual comparison of silvopasture with conventional pasture

amount of enteric methane and other GHG from livestock (Williams et al. 2011); fourth woody biomass increases the ecosystem carbon stock compared to herbaceous covered grazing lands (Mekuria et al. 2011), thereby making the system ecologically sustainable and politically acceptable.

Despite its proved benefits, however, silvopastoralism as a sustainable climate-resilient intensification of livestock sector has been overlooked in many livestock development programs. While work is underway in many places to develop varieties of staple food crops that can adapt to existing climatic changes (Legrève and Duveiller 2010), in contrast there is a serious dearth of information with regard to adaptable fodder trees. For instance, the Clean Development Mechanism (CDM) has spawned over 3000 climate change adaptation and mitigation projects but only 22 afforestation/reforestation projects, with none of those specifically focused on silvopastoralism (Lobovikov et al. 2012). Similarly, the Climate Change National Adaptation Program of Action (NAPA) of Ethiopia fails to mention the term, literally or conceptually (Tadege 2007).

1.2 Current State of Silvopastoral System Practices and the Need for Focusing on Indigenous Species

Traditional free-grazing systems have contributed to the steady degradation of land that has taken place in the highlands of Ethiopia for centuries (Taddese 2001), and has resulted in continuous decline in the availability of livestock feed and other ecosystem services from natural rangelands (Gebremedhin et al. 2004). Free-grazing system did not only result in increased land degradation (Meshesha et al. 2012), but also has limited the effectiveness of human endeavour in degraded areas through the physical destruction of soil and water conservation structures such as terraces, reforestation among others, ultimately causing a vicious circle of land degradation, livestock feed shortage and over all lower productivity of the livestock sector (Yisehak et al. 2013).

Cognizant of the feed challenges and constraints, and associated overgrazing induced land degradation, some strategies have been adopted and launched to alleviate the problems. Common strategies include; introduction of improved forage plants (Gebremedhin et al. 2003), supplementation with high nutritive value concentrates (Mengistu et al. 2006), and implementation of zero grazing (Gebreyohannes and Hailemariam 2011). Moreover, due to the inability of most of the introduced 'improved' species to adapt to local socio-ecological settings and shortage of land and water, the adoption rate of 'improved' introduced forage species was not satisfactory (Sullivan 2001). Higher cost and unavailability of commercial concentrate feeds have also obliterated the possibility of supplementation feeding (Jenkins and Miklyaev 2014). Similarly, due to problems of large numbers of livestock, lack of fodder bank, and cultural limitations, the endeavor to implement zero-grazing system in northern Ethiopia was not successful (Gebreyohannes and Hailemariam 2011).

Indigenous Fodder Trees and Shrubs (IFTS) are important part of animal feed and agro biodiversity in developing countries (Le Houèrou 2000). Attempts made to increase knowledge on IFTS have proved that indigenous browse species play a significant role in livestock production primarily by providing animals with feed resources rich in protein, energy, vitamins and minerals at a time when feed is scarce or of low quality (Osakwe and Drochner 2006). Most of the times, indigenous fodder trees and shrubs are appreciated for the higher content of crude protein (CP) they provide (Roothaert and Franzel 2001), and hence have been recommended as supplements, inclusions and replacements to commercial concentrates (Balehegn et al. 2014a).

Unlike many of the 'improved' introduced fodder trees, which are neither locally adaptable nor multipurpose (Balehegn and Eniang 2009a, b), most IFTS are multipurpose and provide benefits and services such as food, fiber, shade, soil improvement and conservation, timber, fire-wood and live fences across all of the agro-ecological zones of Africa. Indigenous browse species are also preferred over the 'improved' forage plants for being of low cost, available and accessible to local communities, adaptable to local environmental conditions, requiring little or no management input, and resistant to diseases and parasites (Inam-ur-Rahim et al. 2011). Therefore, incorporating IFTS into the agro-silvopastoral systems will not only help solve the livestock feed problem, but also contribute to environmental rehabilitation, stability, and improve livelihoods (Murgueitio et al. 2011). Despite their ecological and economic potential, however, there is still very limited research and development attention given to IFTS, compared to introduced 'improved' species (Le Houèrou 2000).

Silvopastoralism, a livestock production system where trees are planted on pasturelands, farmland boundaries and backyards etc., has recently gained prominence as a sustainable livestock production system (Mosquera-Losada et al. 2011), although usually only theoretically (Dagang and Nair 2003). Compared to conventional pasture systems, silvopastoralism, has resulted in better livestock productivity (Ibrahim et al. 2005; Schoeneberger 2009), and improved soil fertility (Moreno and Obrador 2007). It has also provided synergy between climate change adaptation and mitigation (Dube et al. 2011; Stavi and Lal 2013), by directly contributing to sequestration of Green House Gases (GHG), and being climate resilient (McAdam and McEvoy 2008; Nair 2012).

However, while work is underway in many places to develop varieties of staple food crops that can adapt to existing climatic changes (David and Christopher 2007; Legrève and Duveiller 2010), in contrast there is a serious dearth of information with regard to adaptable fodder trees. For instance, the Clean Development Mechanism (CDM) has spawned over 3000 climate change adaptation and mitigation projects but only 22 afforestation/reforestation projects, with none of those specifically focused on silvopastoralism (Lobovikov et al. 2012). Similarly, the Climate Change National Adaptation Program of Action (NAPA) of Ethiopia fails to mention the term, literally or conceptually (Tadege 2007).

It is therefore, based on the appreciation of the positive economic and ecological benefits of agro-silvopastoral system that this paper synthesizes the findings of a seven year study on ecological and livelihoods roles of *Ficus thonningii* (FT) silvopasture common in northern Ethiopia, while at the same time elucidating the ecological and livelihoods and climate change adaptation benefits of the silvopastoral system.

2 Methodology

The study was conducted among indigenous Tigrigna speaking people in Ahferom District central Tigray, Northern Ethiopia. Intensive field ecological and socio-economic survey was carried out using standard field equipment and materials. Individual interviews and focused group discussions were held with different members of the community representing men, women and elders. The interviews and socio-economic surveys focused on understanding the perceptions of the local people on climate change? and role of *Ficus thonningii* silvopasture in climate change adaptation, livelihood improvement and soil and water conservation (Balehegn et al. 2014b). To compare the value of *Ficus thonningii* relative to other local tree species, respondents were asked to rank ten local species according to different local criteria (Table 2). The average number of times a criteria was mentioned by each age category of the respondents is calculated by the number of people who mentioned it for any of the top ten tree species, divided by the 60 (total number of people in each age category). Therefore, if all respondents in a given age category mention the criteria for all the species, then the average number of times a

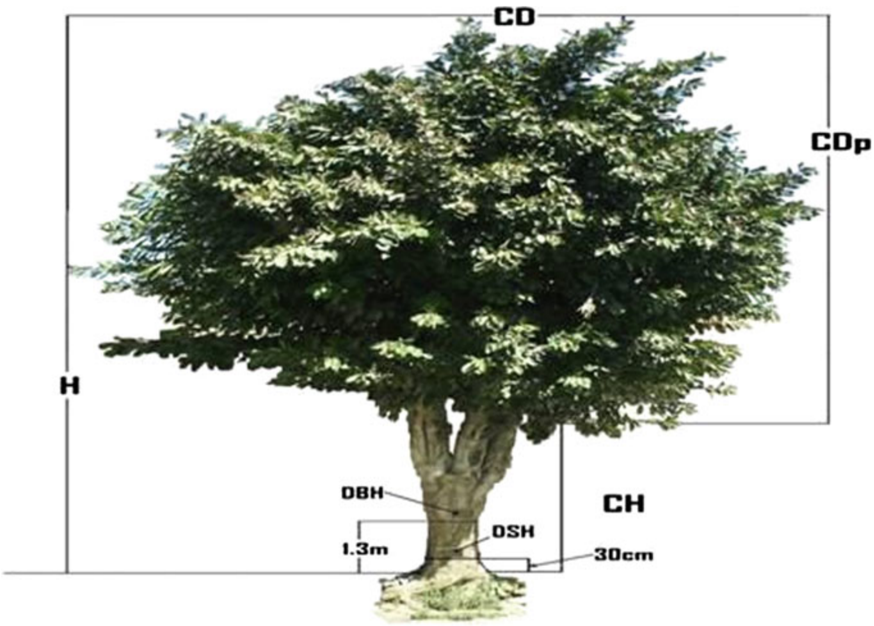

Fig. 2 Pictorial presentation of measured dendrometric parameters of *F. thonningii*

criteria is mentioned is equal to 60 * 10/60 = 10. Therefore, the maximum average number of times a criteria is mentioned by a given age category is 10 (i.e. if 60 of the respondents in a given age category mention it for every one of the 10 species), and the minimum is 0 (i.e. if none of the 60 respondents in a given age category mentioned it for any of the ten species)

To estimate the browse biomass production potential of *Ficus thonningii*, different tree dendrometric parameters, indicated in Fig. 2, were measured from 12 representative trees, four representing each of the three age groups (G1 > 50 years, G2 between 10–20 years, and G3 < 5 years). Measured tree dendrometric parameters including Height (*H*), Crown Height (*CH*) in meters and Diameter at Stump Height (*DSH*) and Diameter at Breast Height (*DBH*) in cm, Crown Diameter and estimated parameters including Crown Depth (*CDp*), Crown Hheight (*CH*), Crown Aarea (*CA*) and Crown Volume (*CV*) were used in a regression analysis to identify the best predictor of browse biomass (Balehegn et al. 2012).

To understand the effect of feeding *F. thonningii* fodder on animals, twenty four weaned central highland male goats of 7 ± 1.5 SD months of age and weighing (15 ± 1.86 SD) kg, were used in complete randomized block design with six goats in four dietary treatments involving partial replacement at different levels of commercial concentrates (Balehegn et al. 2014a).

Table 1 Local communities' perception and manifestation of climate change

S. no	Local manifestation of declining eco-climatic conditions	Percentage of respondents (n = 120)
1	Reduced crop yield	88.6
2	Reduced milk yield	74.3
3	Reduced forage options for livestock	71.75
4	Disappearance of wildlife species	64.2
5	Early drying up of perennial rivers	52.4
6	Increased soil degradation	50.2
7	Increased conflict with neighboring villages	32.4
8	Miscellaneous	12.3

3 Results

3.1 Local Perception of Climate Change and Parameters Used for Selection of Tree Species for the Climate Resilient Silvopasture

Local communities use different bio-physical indicators to express how they perceive climate change and its consequences (Table 1).

Moreover, respondents mentioned twenty local tree selection criteria falling under three categories namely: Animal based, plant based, and multipurpose (Table 2).

3.2 Multipurpose Merits of F. thonningii *and Trends in Its Use in a Silvopastoral System*

The proportion of *F. thonningii*, compared to other exotic fodder trees is increasing from time to time (Fig. 3).

3.3 Indigenous Practices of Propagation and Use of Ficus thonningii

Table 3 summarizes indigenous procedures, protocols and nursing practices involved at the different phases of propagation and growth of *F thonningii*.

Table 2 The average number of times fodder tree selection indigenous criteria was mentioned

Category of criteria	Fodder tree selection criteria	Average number of times a criteria was mentioned
Animal based criteria	Rumen fill	8.12[a]
	Health	4.21[b]
	Palatability	8.97[a]
	Milk production	3.21[b]
	Fattening	2.14[b]
Plant based criteria	Drought tolerance	10.00[a]
	Termite resistance	1.36[b]
	Early re-growth	8.76[a]
	Biomass productivity	9.45[a]
Multipurpose criteria	Food	6.23
	Fire wood	8.98[a]
	Charcoal	7.24
	Fencing	8.98[a]
	Timber and construction	3.22[b]
	Farm implements	8.72[a]
	Ethno medicine	8.94[a]
	Shade and shelter	3.24[b]
	Bark for making ropes	1.24[b]
	Sanitation (smoking utensils, tooth brush)	3.22
	Market value (cash)	1.2[b]

Values down the column with different super scripts are significantly different ($P < 0.05$)

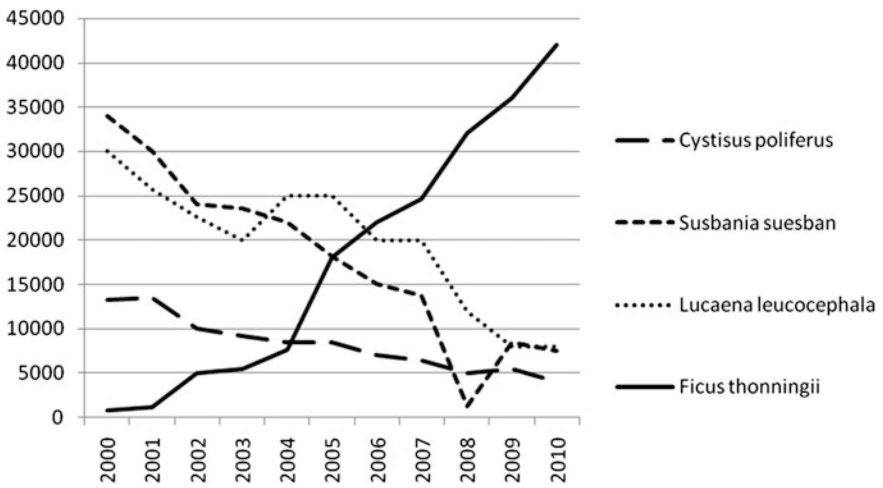

Fig. 3 A decade trend of the number of different fodder trees planted in the backyards of the farmers of Sefeo community (Balehegn et al. 2014b)

Table 3 Indigenous protocol and requirements for successful propagation of *Ficus thonningii*

Requirement	Measurement/indicator	Remark
Age of plant	>2 years	Depends on the size and maturity
Length and width of cutting	Width 10–30 cm, and length <4 m	Long cutting easily shaken by wind thus susceptible to death
Season for cutting	March–May and end of August	Soil should be wet, but not swampy
Care during cutting	Avoid peeling barks and shading cut part	All branches should be cut at once, as shading of cut part causes drying
Incubation time	About 1–2 months for those cut March–May, <1 month for those cut end of August	To make cuttings lose some moisture
Care during Incubation time	Covering the overall cutting with dung, or thorny branches to repel animals	Avoid peeling barks
Depth and width of planting pit	50 cm depth and 20 cm width	Adjusted to fit the dimensions of the cutting.
Special care in planting	Put a flat circular rock at the base of the pit in wet soil	Avoids rotting of new roots due to water logging
Watering	May not need watering	Survive on water stored in the stem watering is not bad though
Care after planting	Complete protection form animals by dipping the whole cutting in dung, attaching cutting to a tree or a stationary peg	Shaking hinders root development and causes subsequent dying of cuttings

This qualitative information on the propagation of *Ficus thonningii* was collected from group discussions and individual interviews (Balehegn et al. 2014b)

3.4 Ficus thonningii *Browse: Production and Its Nutritive Value*

3.4.1 Browse Biomass

The average values of browse biomass in dry matter for three age groups of trees are; 50.36 kg for G1, 5.96 kg for G2, and 0.914 kg for G3 (Table 4).

3.4.2 Nutritive Value of *Ficus thonningii* Foliage

The proximate nutritional value of *F. thonningii* foliage for this study is given in Table 5.

Table 4 Average predicted biomass for sampled trees of *F. thonningii* in Sefeo, Central Tigray, northern Ethiopia (Balehegn et al. 2012)

No	Age group	DSH (Giannini et al. 2008)	CV (m^3)	Average predicted DW (kg)tree^{-1}year^{-1}
1	G1 (20–100+ years)	62.098	77.404	50.356
2	G2 (5–20 years)	33.595	17.58	5.9611
3	G3 (<5 years)	12.65	6.1755	0.9136

Prediction formula: DW = 0.8470 * CV − 0.2202 * DSH − 1.5315

3.4.3 Effect of Feeding *Ficus thonningii* on Productivity of Animals

Replacement of local commercial concentrate by *F. thonningii* leaf meal at 50% level weight based has resulted in higher body weight gain compared to lower levels of replacements (Table 6) (Balehegn et al. 2014a).

4 Discussions

4.1 Local Perception of Climate Change and Parameters Used for Selection of Tree Species for Climate Resilient Silvopasture

Local communities' observations and perceptions of climate change are similar in principle to those observed in Kenya and Ethiopia (Ifejika Speranza et al. 2010; Balehegn and Tafere 2013), which also reflect people's focus on observable bio-physical changes when describing climate change focusing on drought. Similarly, answering to question on how they select forage plants in the study areas, 67% of respondents (Table 2) emphasized importance of characteristics of the plant to tolerate drought (plant based characteristics) than the ability of the plant to maintain animal productivity (animal based characteristics) (Balehegn et al. 2014b). The emphasis on drought tolerance imply that drought has become unavoidable part of the agrarian life in northern Ethiopia as noted by Gebrehiwot et al. (2011).

4.2 Multipurpose Merits of Ficus thonningii *and Trend in Its Use in a Silvopastoral System*

Ficus thonningii produces a large amount of nutritious foliage, which exceeds that of many conventional fodder trees (Berhe and Tanga 2013; Balehegn et al. 2012). Other ecological merits such as ability to withstand lopping; absence of allelopathic

Table 5 Nutritional value of *Ficus thonningii* foliage compared to common feed ingredients (Balehegn et al. 2014a)

Feed ingredients	DM	CP	Ash	OM	NDF	ADF	ADL	Tannin
Cotton seed cake	90.00 ± 12.3	28.00 ± 9	7.20 ± 3.0	94.23 ± 32.1	38.48 ± 15.0	39.00 ± 9.1	18.00 ± 3.4	–
Wheat bran	85 ± 12.4	11.00 ± 2.2	47.25 ± 13.0	96.24 ± 42.1	11.00 ± 2.2	50.20 ± 8.2	25.29 ± 18.2	–
Maize	85.40 ± 13.4	10.00 ± 3.4	13.00 ± 8.4	98.26 ± 42.2	12.00 ± 7.3	3.00 ± 0.5	1.00 ± 0.01	–
FT leaf	90.00 ± 9.4	18.00 ± 9.0	14.28 ± 9.0	88.00 ± 15.0	42.12 ± 7.3	36.00 ± 5.1	16.05 ± 2.3	0.06 ± 0.03
Wheat straw	90.00 ± 10.4	4.00 ± 2.0	7.10 ± 3.0	89.00 ± 32.1	81.00 ± 8.4	51.00 ± 7.3	8.42 ± 4.0	–

Values are Mean ± Std Dev, DM dry matter, *CP* crude protein, *OM* organic matter, *NDF* neutral detergent fiber, *ADF* acid detergent fiber, *ADL* acid detergent lignin, *FT Ficus thonningii*

Table 6 Body weight gain and feed conversion efficiency of experimental goats

	Treatments				SEM
	T1	T2	T3	T4	
Body weight gain					
Average initial body weight	14.50	14.08	15.00	15.00	2.00
Average final body weight	17.06[a]	16.23[b]	19.12[ac]	17.00[b]	2.10
Live weight gain (kg)	3.00[a]	2.15[b]	5.00[ac]	2.25[b]	1.60
ADG (g day^{-1})	29.00[a]	24.00[b]	50.37[ac]	25.00[b]	19.16
Feed conversion efficiency					
g ADG/g DM	11.00[a]	8.00[b]	13.03[c]	6.37[d]	5.41
g ADG/g CP	90.00[a]	56.41[b]	94.00[a]	48.36[c]	52.00

[a–d]Values across rows with different superscripts are significantly different ($P < 0.05$)

effects to other plants mainly to the economically important shrub, *Ruhamnus prinoides* or '*Gesho*',[1] which grows underneath *F. thonningii*; easiness for propagation, and positive effect of soil fertility (Balehegn 2011; Berhe et al. 2013; Balehegn and Eniang 2009a; Tegegne 2008). All these ecological and livelihoods benefits make it a very opportune choice as a silvopastural fodder tree. As a result intensive use of *F. thonningii* for animal feeding, and thus its steady planting in silvopastoral system practices started following severe feed scarcity problems in the area caused by repeated droughts and over grazing which reached alarming levels between the years 1985 and 1991 (Balehegn and Eniang 2009a).

Appreciating its extensive benefits for livelihoods and adaptation to reoccurring drought, people have been extensively planting FT on a variety of land types, that the proportion of FT compared to other 'improved' introduced forage species (mainly *Cystisus proliferus*, *Sesbania sesban* and *Leucaena leucaocephala*) has been increasing from time to time, despite the orchestrated push by governmental and non-governmental agricultural and environmental agencies to introduce the latter (Fig. 2). Multipurpose drought tolerant plants such as *Ficus thonningii* and Bamboo will dominate the future of species for climate change adaptation, as they simultaneously help poor communities economically, while enabling them to adapt to climate change (Lobovikov et al. 2012). This tendency of people to develop a locally relevant system than just accepting what is recommended by outsiders is also a case confirming that local species are more adapted to local socio-ecological settings (German et al. 2006).

[1]A common local shrubby plant used by indigenous people to produce "*Swa*" or a traditional alcoholic beverage that yields considerable income to small scale producers. Owing to the economic value of *Ruhamnus prinoides* or '*Gesho*', the indigenous community would have preferred *F. thonningii* eliminated, if its existence had any negative impacts on the former.

4.3 *Indigenous Practices of Propagation and Use of* Ficus thonningii

Through experience, local communities in northern Ethiopia have developed and perfected indigenous procedures and protocols for successful propagation of the plant (Table 3). It takes between 2 and 5 years for a newly planted cutting to reach the stage of a matured tree ready for harvest of both cuttings and leaves. Time at first harvest seems to depend on the original size of the cutting used for propagation as it takes longer time for small cuttings to reach harvest size than it does to larger cuttings (Balehegn 2011). However, large cuttings are susceptible to damage by wind shaking and animals (Balehegn 2011; Balehegn and Eniang 2009a). Moreover, since the barks are usually watery at the cutting stage, they are highly relished by animals which nibble and harm the cuttings, thus farmers usually use either protective thorny fencing or rub cow dung on the young cuttings to protect them from animals (Balehegn and Eniang 2009a). Some of the local practices in the use and propagation of *F. thonningii* are also given in Fig. 4.

Fig. 4 Preparation, incubation and planting of *Ficus thonningii* cuttings (*upper row*), *Ficus thonningii* leaves used for animal feeding (*lower row*)

4.4 *Browse Production and Nutritive Value of* Ficus thonningii

4.4.1 Browse Production

The average values of dry matter biomass for each age group in (Table 4) translates into 222.2 ton/ha, 26.48 ton/ha and 4.05 ton/ha for G1, G2, and G3 respectively (Balehegn et al. 2012). These results indicate that *F. thonningii* produces by far higher biomass annually as compared to the average 31–87 Mg DM ha^{-1} for 26 native and exotic fodder species in similar non tropical drylands in west Africa (Larbi et al. 2009). This higher browse biomass production capacity of *F. thonningii* is also appreciated by farmers in the study area and other areas (Balehegn and Eniang 2009a; Mekoya et al. 2008).

4.5 *Nutritive Value of* Ficus thonningii *Foliage*

The reasonably higher nutritional values of the foliage of *F. thonningii* compared to the other common feed ingredients (Table 5) is the main reason for the higher palatability of *F. thonningii* by all species of livestock (Balehegn et al. 2014a). The crude protein (CP) of *F. thonningii* is similar to CP values of 21.5 (Bamikole and Ikhatua 2010). Moreover, unlike common fodder trees and shrubs, *FT* has very low tannin content of only 0.06% (Balehegn et al. 2014b). This value is comparable to the value of 0.04% reported by (Mekoya et al. 2008). This low tannin content coupled with reasonably higher protein content, could be a reason for its higher palatability to all farm animals reported in the silvopastoral system in northern Ethiopia (Tegegne 2008; Balehegn and Eniang 2009a; Berhe and Tanga 2013). Similarly, the NDF and ADF contents of FT reported in this study are also lower than the threshold safe level recommended by NRC (2007), again contributing to its nutritive value and subsequent acceptability by animals.

4.6 *Effect of Feeding* Ficus thonningii *on Productivity of Animals*

The higher body weight gain at the 50% level of replacement (Balehegn et al. 2014a) is comparable to the values of 37.6–54 g day^{-1} for naturally grazing and concentrate supplemented goats observed by Zewdu and Taye (2013). The larger body weight gain in the combined diets than concentrate only diet indicate that *F. thonningii* affected digestibility and assimilation of diets, as also observed in (Bamikole and Ikhatua 2010).

Increased body weight gain in the goats fed 50% *F. thonningii* leaf meal was also reflected in improved carcass components. Higher values in proximal thoracic limb, lumbar and abdominal region and the proportion of neck to hot carcass weight observed in goats fed treatments with 50 and 75% level of replacement of commercial concentrates by *F. thonningii* leaf meal (Balehegn et al. 2014a). This is expected because these two commercial cuts (proximal thoracic limb and lumbar and abdominal regions) are where initial growth in growing animals takes place (Mahgoub and Lu 1998). Aside from feed, nutritive and afore-listed multipurpose values of *F. thonningii* silvopasture has also resulted in improved habitat for wildlife species including *Cercopithecine* monkeys, frugivorous birds and insects the most significant of which is the endangered White billed starling (Balehegn and Eniang 2009b).

5 Conclusions and Implications

This review revealed an indigenous innovation for recurrent drought and climate change adaptation using *F. thonningii*—a drought resistant multipurpose indigenous fodder tree as a key species in an emerging silvopastoral system. This indigenous innovation silvopastoral system enabled herders in the dryland areas of northern Ethiopia to adapt to recurrent drought, while improving their livelihoods through contribution to much sought after nutritious animal fodder, improvement of soil fertility and maintenance of ecological integrity.

Looking at the potential of *Ficus thonningii* towards adapting and sustaining livelihoods of farmers living in fragile ecosystems, it should be adopted in future adaptation programs. Being indigenous to 33 other Sub-saharan African countries with similar agro-ecological settings with northern Ethiopia, *F. thonningii* silvopasture has a potential for similar use in these other countries, but most importantly these studies provide an insight for the use of indigenous tree species in the agro-silvopastoral system in future local climate-change adaptation and mitigation programs.

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