Indigenous Fodder Tree Species Composition, Biomass Yield and Socioeconomic Contribution in Sidama South, Ethiopia

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Abstract

Fodder trees are integral components of agroforestry system in the tropics. Indigenous fodder trees (IFT) are grown in Sidama, Ethiopia, for different purposes. However, their composition, biomass yield and socioeconomic importance are inadequately studied. The objective of this study was to assess species composition, biomass yield and socioeconomic contribution of IFT. Three districts and 12 kebeles were purposively selected, from which 273 households were randomly selected for household survey. Sixty households were randomly selected for inventory within nested quadrats of 20 x 20 m. Twenty eight IFT species belonging to 26 genera and 24 families were identified in three agro ecologies. Species richness in lowland (11.08) was significantly higher than highland (9.6) and midland (7.7) ($p < 0.001$). Similarly, lowland (1.5) was significantly more diverse than midland (1.2) and highland (0.8) ($p < 0.001$). *Arundinaria alpine, Hygenia abyssinica* and *Erythrina brucei* were dominant IFT, altogether accounted for 72.35% of the total basal area. In midland, *Cordial africana*, *Ficus sur, Dracaena steudneri* and *Melleitia ferruginea* were dominant species, and *Acacia albida, Acacia tortolis, Balanites aegyptiaca* and *Cordia africana* were dominant in lowland, altogether accounting for 56.1 and 76.72% of the total basal area, respectively. Biomass yield were significantly different ($p < 0.05$) among agro ecologies. *E. brucei*, *D. steudneri* and *C. africana* had the highest biomass yield in highland, midland and lowland, respectively. Farmers with large land size, small family size, practicing agroforestry, having awareness and interest about fodder trees had significantly affected the decision to have IFT. In addition to fodder supply, IFT contribute to soil fertility improvement, income source and timber production. Hence, the dominant IFT are important for maintaining biodiversity and contribute as a feed source. Further research is recommended to evaluate the nutritive value of IFT.

1. Introduction

Ethiopia is believed to have the largest livestock population in Africa. Livestock plays an important role in providing export commodities, such as live animals, hides, and skins to earn foreign exchanges to the country (CSA 2021). Despite of number of livestock, productivity per head is very low (Shenkute et al. 2012). This is mainly caused by feed shortage and poor quality of forage (Gaikwad et al. 2017). To improve the productivity of smallholders' ruminant animals, there is a need to look at ways of extending the availability and quality of feedstuffs produced on small farm holdings. Indigenous fodder trees (IFT) are a viable way to increase the quality and availability of feeds for livestock (Ayenew et al. 2019).

Indigenous fodder trees are recognized as an important component of animal feeds in many parts of the world (Lameso 2021), as they contain high levels of crude protein, mineral and continue to produce well into the dry season because of their deep root systems (Abebe et al. 2008). Moreover, the domestication and integration of IFT into agroforestry system have several benefits (Negash 2010). Similarly, farmers in different parts of Ethiopia, usually integrate diverse IFT species into their farms as their routine practices for different purposes (Robi and Edris 2017). Additionally, when deciding to retain trees, farmers consider the different benefits and ecosystem services of tress as a source of income generation through selling timber, source of food in the form of fruit, source of fuel wood and keep them for other watershed benefits such as soil conservation and soil fertility improvement (Etefa et al. 2014).

Presently, availability of IFT is declining due to agricultural expansion and livestock pressure, resulted in feed shortage (FAO 2010). To minimize such problems, agroforestry is considered as the best solution (Atangana et al. 2014). Agroforestry is expressed as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains smallholder production for increased social, economic and environmental benefits (ICRAF, 2000). In Ethiopia, smallholder farmers carry out various agroforestry practices depending on the socioeconomic and biophysical conditions such as coffee shade based system, scattered trees on farmland, home gardens, woodlots, boundary planting and silvo pastures (Abrham et al. 2016; Iiyama et al. 2017).

Sidama National Regional state of Ethiopia is known for practicing agroforestry systems where farmers integrate IFT with cash crop (enset and coffee) and cereal crops (SNRSAB 2021). Though attempts have been made to introduce and disseminate improved forage grass species, still farmers are facing shortage of animal feed. Thus, the suitable alternative feed resources that fit the existing farming system and adapted to the economic realities of the farmers would be IFT. However, empirical studies on the potential of agroforestry to provide IFT species and influence of socioeconomic factors affecting farmers' decision to integrate IFT in the existing farming system are limited, which has hampered efficient utilization of the potential of agroforestry for fodder supply. Thus, the objective of this study was to assess species composition, diversity, biomass yield and socioeconomic factors determining availability of IFT in Sidama National Region, south-central Ethiopia.

2. Materials and methods

2.1. Description of study area

Sidama National Regional state is located in south-central Ethiopia, 275 km from the Addis Abeba (Fig. 1). This region has highland (2,500-3,700 m), midland (1500-2,300 m) and lowland (< 1500 m) agro ecologies. Total annual rainfall of highland, midland and highland are ranging from 1,600 to 2000 mm, 1,200 to 1,599 mm and 400 to 800 mm, respectively. Mean monthly temperature for highland, midland and highland are 12 to 14.5°C, 15 to 19.9°C and 20 to 24.9°C, respectively (SNRSAB 2022).

2.2. Sampling techniques

Multi-stage sampling technique was applied to select the study sites. First, one district was selected from each agro ecology purposively based on the availability of IFT and road accessibility. Accordingly, Hulla, Aletachuko, and Boricha districts in the highland, midland and lowland were selected, respectively. Then, 9 kebeles (3 from each district, the lowest administrative unit in Ethiopia) were randomly selected (Fig. 1). Then, 273 sample households were randomly selected using Yamane (1967) formula at 96% confidence level. The size of sample households from each kebele was determined in proportion of total household (Table 1).

Table 1
Sample households selected across agro ecologies in the study area

Agro ecology	District	Kebele	Total household	Sample household
Highland		Adola kure	1519	29
	Hulla	Gasse	1612	31
		Chalbesa	1667	31
		Sub Total	4798	91
Midland	Aleta chuko	Chuko lamala	2115	38
		Guurre	1894	36
		Galma	1733	33
		Sub Total	5671	107
Lowland	Boricha	Hariro badalicha	1643	31
		Gasara kuwe	1225	23
		Dilanole	1103	21
		Sub Total	3971	75
Total			14400	273

2.3. Data Collection

Semi structured questionnaires were used to collect primary information on demographic characteristics, landholding, land use system, availability of IFT and livestock size. Key informants (KI) interview was conducted to obtain general information about socio economic importance and availability of IFT to farmers. Thirty-six (4 from each kebeles) KI were selected purposively based on experiences on planting IFT, use for different purposes like feeding to animals. Accordingly, elders, women and model farmers which have experience about IFT were included as KI. Secondary data were collected from regional agricultural office about location, rainfall, temperature, types of crops, livestock size and total number of household.

2.4. Indigenous fodder tree inventory

In total 60 plots (one plot per farm), 20 plots from each district, were randomly laid down and the nested quadrats (20 × 20m) were used for the inventory of fodder tree species. To locate the central position of a quadrat on the farm, ocular estimation was first used to divide the farm into ten equal parts. Then, a number was assigned to each part and the sample plot was selected using random numbers (Negash et al., 2012). All individual IFT species within the quadrats were measured and recorded (Magurran, 2004). Name of species, abundance, diameter at breast height (DBH) and total height were recorded. The tree species were identified at the site, using identification keys (Tesemma 2007), and local informants.

2.5. Data analysis

To analyze the data, SPSS and SAS Version 19.0 (SAS, 2008) software were used. Descriptive statistics were used to calculate plot frequency, relative abundance, mean DBH, height and basal area for each species. A binary logistic regression was carried out to assess the effect of gender, age, family size, land size, land use types, awareness about IFT, access to seed and seedlings and interest to plant IFT on the likelihood of having IFT in the farm. ANOVA was used for continues variable, whereas Chi-square (χ2) test was used for categorical variables to assess a statistical significance of a particular comparison. The Duncan multiple comparison tests was used for mean separation at 5% uncertainty. The statistical model used was:

Yi = μ + Ai + ei.

Where: Yi is dependent variable; μ is the overall mean; Ai is independent variables and ei is the error.

The model for Binary logistic regression was formulated as follows (O'Connell, 2006):

$$\mathbf{Li} = Ln\left[\frac{Yi}{1-Yi}\right] = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \epsilon i$$

Where;

Dependent Variable, $Y = Ln\left[\frac{Yi}{1-Yi}\right] = \begin{cases} 1, if farmers having IMPFT, p\left(Y=1\right) = Yi \\ 0, otherwise, p\left(Y=0\right) = 1 - Yi \end{cases}$

Where, α = intercept of regression; β1, β2 and β3 = the regression coefficients of the independent variables; £ = Error term

2.6. Species richness and diversity analysis

Common species diversity indices including richness (S’) and Shannon diversity (H’) of IFT in different AE were conducted. H’ was used for each plot which is widely used index for comparing diversity between various habitats (Kent and Coker, 1992). The H’ was preferred, due to its sensitivity to sample size and because it gives more weight to rare species. The H’ was calculated as:

$$H\prime = -\sum_{i=1}^{s} pi * lnpi$$

Where, H ' = Shannon-Wiener index of species diversity; s = number of species in community; pi = proportion of total abundance represented by i^{th} species

2.7. Stand structure

The structure of IFT in agroforestry was characterized in terms of density, basal area, frequency and importance value index (IVI) (Leul et al., 2010). The DBH and height class distribution of individual fodder species was analyzed (Kent and Coker, 1992; Mata et al, 2011).

2.8. Leaf biomass yield analysis

The leaf biomass yield of IFT was estimated by measuring stem diameter using a measuring tape. The biomass yield of each IFT was calculated using the equation developed by Petmark (1983).

LogW = 2.24 logDT-1.5; Where W was leaf DM yield in kg, DT was the diameter of the trunk (cm) at 130 cm height.

3. Results

3.1. Availability of indigenous fodder tree species

The result of household survey revealed that 70.3%, 70.1% and 60% of the respondents were integrating IFT in the highland, midland, and lowland, respectively (Table 2). They indicated that smaller landholding, absence of livestock, lack of awareness and access to seed, and limited seedlings supply were the main factors affecting integration of IMPFT into their farm.

Table 2
Proportion of responses of sample households on integration of indigenous fodder trees in studied sites

Parameter (%)	Agro ecology			
	Highland (n = 91)	Midland (n = 107)	Lowland (n = 75)	Overall (n = 273)
Do you have IFT in your farm				
Yes	70.3	70.1	60	67.4
No	29.7	29.9	40	32.6
Do you have an interest to plant IFT in your farm				
Yes	70.3	62.6	68	66.7
No	29.7	37.4	32	33.3
Do you have access to seed and seedling of IFT				
Yes	60.4	70.1	60	64.1
No	39.6	29.9	40	35.9
Do you have awareness about IFT				
Yes	69.2	75.7	80	74.7
No	30.8	24.3	20	25.3

The overall binary logistic regression model was statistically significant when compared to the null model (X^2 = 110.49, $p < 0.001$) that explained 46.3% of the variation (Negelkerke R^2) and correctly predicted 80.3% of the cases. Family size, land size, land use type, awareness on IFT and interest to plant IFT significantly affected the integration of IFT ($p < 0.05$) (Table 3). Awareness for IFT increased the chance of integrating IFT by 11 times in the farms. Likewise, interest to plant IFT increased the chance of having IFT in the farm by 3.01 times. Additionally, farmers with large land size have 2.71 times more chance to have IFT in the farm. But, farmers with large family size had lower chance (41.9%) to have IFT. Similarly, farmers practicing agroforestry would have by 93% higher chance of integrating IFT than who did not practice in their farms.

Table 3
Effects of household characteristics, awareness and seed sources to indigenous fodder trees

Predictor	B	X^2	P value	Odds Ratio
Gender	0.78	3.48	0.62	2.19
Age	-0.01	0.25	0.62	0.99
Family size	-0.33	11.21	0.001	0.72
Land size	0.99	7.18	0.01	2.71
Land using practice	-2.53	26.56	0.00	0.08
Awareness about IFT	2.37	34.28	0.00	10.74
Access to seed and seedling	-0.31	0.71	0.40	0.73
Interest to plant IFT	1.10	9.83	0.002	3.00

3.2. Species composition

A total of 28 IFT species belonging to 26 genera and 24 families were identified in three AE (Appendix 1). There were 4 species of Fabaceae, followed by 2 species of Boraginaceae and the other families were represented by 1 species each. The most widely utilized IFT identified in the highland were *Arundinaria alpine, Hygenia abyssinica, Erythrina brucei*, and *Vernonia amygdalina*. Similarly, *Cordial africana, Mellettia ferruginea, Erythrina brucei* and *Dracaena steudneri* were the dominant one in the midland. In the lowland, *Balanites aegyptiaca, Acacia tortolis, Cordia africana* and *Euclea racemose* were predominate.

3.3. Species richness and diversity

The observed species richness and Shannon diversity indices (H') of IFT were significantly ($p < 0.0001$) different across the respective agro ecology (Table 4). Species richness in lowland (11.08) was significantly higher than highland (9.6) and then midland (7.7) ($p < 0.001$). Similarly, H' indicated that lowland (1.5) was significantly more diverse than midland (1.2) and then highland (0.8) ($p < 0.001$).

Table 4
Mean (± SD) of indigenous fodder tree species richness and Shannon diversity in different agro ecology of Sidama, Ethiopia

Agro ecology	Plot number	Species richness	Shannon Diversity Indices
Highland	20	9.6 (2.1)^{b}	0.8 (0.3)^{c}
Midland	20	7.7 (1.1)^{c}	1.2 (0.2)^{b}
Lowland	20	11.8 (1.5)^{a}	1.5 (0.2)^{a}
F value		22.3	14.4
P value		< 0.0001	< 0.0001

Mean values in a column having different superscripts differ significantly each other; SD = Standard deviation

3.4. Structure of indigenous fodder tree

The vegetation structure of IFT species are summarized in Table 5. The highest density of IFT species was found in the highland and the least was in the lowland. The IFT species such as *A. alpine, E. brucei, H abicinica and V. amygdalina* were abundant species in the highland while *M. ferruginea, C. africana*, Ficus sur and V. amygdalina were abundant in midland. In the lowland *A. seyal, D. viscosa, M. arbutifolia and B. aegyptiaca* were the most abundant ones.

Table 5
the structure of indigenous fodder trees in three agro ecology in selected sites of Sidama, south Ethiopia

Scientific name	Density (stems/ha)	Dominance (m^2/ha)	IVI
Highland			
Commiphora campestris	5	0.8	3.14
Faurea rochetiana	5	0.5	2.86
Hygenia abyssinica	50	3.4	13.65
Vernonia amygdalina	10	0.7	3.36
Mellettia ferruginea	3.75	1.0	2.89
Erythrina brucei	76.25	3.6	15.28
Pittosporum abyssinica	7.5	1.3	5.12
Ilex mitis	5	0.8	3.45
Buddleja polystachya	1.25	0.3	0.95
Maesa lanceolata	1.25	0.8	1.70
Arundinaria alpine	1917.5	8.7	48.27
Commiphora campestris	5	0.8	3.14
Midland			
Ehretia cymosa	3.75	2.9	5.22
Schefflera abyssinica	2.5	3.6	6.15
Vernonia amygdalina	21.25	0.3	6.99
Mellettia ferruginea	100	1.7	21.64
Dracaena steudneri	16.25	3.1	11.04
Ficus sur	36.25	4.9	18.51
Celtis africana	7.5	1.4	3.40
Cordia africana	66.25	2.8	18.80
Erythrina brucei	20	1.6	8.25
Lowland			
Balanites aegyptiaca	60.29	1.30	33.53
Maytenus arbutifolia	52.78	0.94	18.72

Scientific name	Density (stems/ha)	Dominance (m^2/ha)	IVI
Acacia albida	62.50	3.79	26.17
Searsia natalensis	37.50	12.25	23.40
Olea europae	36.11	2.21	19.00
Carrisa spinarum	75.00	2.93	17.28
Dodanaea viscosa	150.00	2.68	14.15
Euclea racemose	43.75	32.10	56.51
Ficus sur	25.00	3.50	9.60
Boscia angustifolia	75.00	0.88	5.15
Acacia tortolis	98.33	2.02	42.11
Acacia seyal	83.33	1.30	30.56
Cordia africana	50.00	1.48	20.81

Similarly, *A. alpine*, *H. abyssinica* and *E. brucei* were the most dominant IFT, altogether accounting for 72.35% of the total basal area. In midland, *C. africana*, *F. sur, D. steudneri* and *M. ferruginea* were dominant IFT species, and *E. racemose, A. albida, A. tortolis* and *S. natalensis* were dominant in lowland, altogether accounting for 56.1 and 76.72% of the total basal area, respectively. In the highland, *H. abyssinica*, *E. brucei*, *V. amygdalina* and *A. alpine* were the most frequent species which were found in 75%, 85%, 20% and 35% of the total sample plots, respectively. Likewise, in the midland, *M. ferruginea* (80%), *C. africana* (75%) and *D. steudneri* (50%) were frequently observed species. In lowland, *B. aegyptiaca (85%), A. tortolis (85%)* and *A. seyal (70%)* were the most frequent IFT species. The highest important value indices recorded were 48.27, 21.64 and 56.51 in the highland, midland and lowland, respectively.

3.5. Leaf biomass yield of major indigenous fodder trees

The biomass DM yield of IFT is presented in Table 6. Biomass DM yields of IFT were significantly different ($p < 0.05$) across agro ecologies. In the high land, biomass yield/ha were greatest ($p < 0.05$) for *E. brucei* followed by *H. abyssinica* and *V. amygdalina* while the lowest was for A. *alpine.* In the midland, *D. steudneri* had the highest ($p = 0.001$) biomass yield/tree while the least was observed in *M. ferruginea* and *V. amygdalina*. The highest biomass yield in the low land was for *C. africana and E. racemose.* In general, the average DM biomass yields were 0.22–15.43, 0.28–23.154.1–10.81 kg DM/tree for highland, midland and lowland, respectively.

Table 6
the leaf biomass yields (kg) of major selected indigenous fodder trees of the three agro ecology

Plant species	**Density (plant/ha)**	**Biomass Yield (kg DM /plant)**	**Total biomass (kg DM/ha)**
Highland			
Arundinaria alpina	1523^{a}	0.22^{d}	335.06^{c}
Hygenia abyssinica	76.7^{b}	5.22^{b}	400.37^{b}
Erythrina brucei	43.3^{c}	15.43^{a}	668.12^{a}
Vernonia amygdalina	28.3^{d}	1.13^{c}	31.98^{d}
CV	24.5	44.12	24.8
p value	0.004	0.001	0.03
Midland			
Cordia Africana	86.7^{b}	7.1^{c}	615.57^{b}
Erythrina brucei	23.3^{d}	8.07^{b}	188.03^{d}
Mellettia ferruginea	220^{a}	2.97^{d}	653.4^{a}
Vernonia amygdalina	31.7^{c}	0.28^{e}	8.88^{e}
Dracaena steudneri	18.3^{e}	23.15^{a}	423.65^{c}
CV	18.2	16.27	22.3
p value	0.02	0.001	0.002
Lowland			
Balanites aegyptiaca	43.3^{b}	7.1^{b}	307.43^{a}
Cordia Africana	20^{c}	10.81^{a}	216.2^{c}
Acacia tortolis	66.7^{a}	4.1^{c}	273.47^{b}
Euclea racemose	8.3^{d}	9.67^{a}	80.26^{d}
CV	26.1	24.44	25.1
p value	0.005	0.001	0.006

Mean values in a column within AEZ having different superscripts differ significantly each other; kg = kilogram; DM = Dry mater; ha = hectare

3.6. Socioeconomic contribution of indigenous fodder trees

The IFT were used for various purposes in the study sites (Table 7). In the highland and midland, farmers used IFT mainly for soil fertility improvement and as income source. Income source, timber production and construction wood in descending order was the major use in the lowland. Besides, IFT were used to fumigate milk utensil to preserve and give good flavor to milk across the studied agro ecologies.

Table 7
socioeconomic contribution of indigenous fodder trees in different agro ecologies of Sidama, south central Ethiopia

Type of Benefits	Rank of Benefits of IFT in the study areas					
	Highland (n = 64)		Midland (n = 75)		Lowland (n = 45)	
	Index	Rank	Index	Rank	Index	Rank
Timber	0.167	3	0.148	4	0.180	2
Income	0.170	2	0.185	1	0.199	1
Soil fertility improvement	0.201	1	0.163	2	0.151	3
Fuel wood	0.147	4	0.157	3	0.146	4
Fodder	0.128	5	0.138	5	0.119	5
Cultural value	0.101	6	0.125	6	0.101	6
Shade	0.034	8	0.036	8	0.044	8
Household utensil	0.052	7	0.047	7	0.061	7

4. Discussion

4.1. Availability of indigenous fodder trees

According to respondent's access to seed, and limited seedlings supply were the main factors affecting integration of IFT into their farm. This is maybe due to less attention given by the government and farmers to prepare seed multiplication center. This finding is comparable with the study reported (67.2%) by Dargo (2019) for agroforestry system in Eastern Hararghe, Ethiopia. Farmers with large landholding, small family size, and possession of various agroforestry practices, adequate awareness and interest to plant trees better integrate IFT to their farms. Roothaert (2000) also asserts that farmers' decision to allow the availability of different types of trees species that grow on their farm is influenced by farmers' preferences on the importance of the species. On the other hand, Lameso (2021) reported shortage of knowledge, the expansion of cash crops and the small size of land holdings among others were constraints for maintaining tree species on farms despite their considerable uses and services.

4.2. Species composition and diversity

Most of the species identified in our study were also among the common fodder tree species reported in different parts of Ethiopia (Takele et al. 2014; Gochore et al., 2020). The high species richness in the current study indicates an important area for maintaining high flora diversity and availability of different types of fodder tree species as livestock feed (Tadesse et al. 2021). Species richness in the current study was lower than different parts across the country (Getahun et al. 2017). Low species richness in our study may be due to our focus only on IFT species. High diversity was found in the lowland, while the least values of diversity was observed in the highland and midland. This may be attributed to the type of management intensities of farmers and interest of farmers to hold IFT in the farm. In agreement with this finding, farmers who practiced agroforestry system in midland usually not only managed very few species per unit area but also accompanied with intensive management with lower tolerance to natural regeneration of other species, hence very few species richness (Molla 2016; Takele et al., 2014). Similarly, Tadesse et al. (2021) reported, species richness and diversity were influenced by intensive farmland management and farmers interest. Moreover, Molla (2016) also indicated significantly higher species richness and diversity in the lowland than midland. However, in contrast to current study, higher species richness and diversity was observed in midland followed by highland and lowland in Arba Minch, south Ethiopia (Gochore et al., 2020). This difference could be due the focus given to IFT in the current study.

4.3. Structure of indigenous fodder tree

The current study shows the highest density of IFT in the highland agroforestry because farmers want to have IFT that is fast growing, which needs less management and has high value in the market and which could be used as feed source such as *A. apine*. Similarly, Tadesse et al. (2021) reported that, farmers need to manage fast growing trees which are highly valuable in the market like *Eucalyptus spp*. Likewise, types and age of agroforestry practices, farm management strategies, among other local factors determine agroforestry stand structures (Lo´pez-Go´mez et al. 2008; Duguma and Hager 2010). However, to the contrary, Yifri *et al*. (2016) reported that tree density decrease with increasing altitude. This is may be due to the fact that other studies considered all types of trees but this study focused only on IFT.

4.4. Leaf biomass yield of major indigenous fodder tree species

The most widely utilized fodder trees identified in the current study were *A. alpine, H. byssinica, E. brucei, V. amygdalina, C. Africana, M. ferruginea, D. steudneri, B. aegyptiaca, A. tortolis* and *E. racemose* during dry season. The leaf biomass yield per hectare observed in the current study revealed that the fodder species had high leaf DM yield to supplement the poor quality feed during the dry season (Bayssa et al., 2016). This result was supported by previous studies with regard to the available shrubs and fodder trees in different AE of Ethiopia (Takele et al. 2014; Ayele et al, 2022). The variation in biomass DM yield of IFT in the current study could be due to tree management and differences in growth and dominance of the species as suggested by Ayele et al. (2022). Moreover, the biomass yield in each species was affected by variation in agro ecology, which is potentially attributed to altitudinal differences, climatic factors, soil fertility and land use system (Takele et al., 2014).

In agreement with the current finding, Ayele et al. (2022) reported that on average mid land agro ecology had less biomass yield of fodder trees (7.98–19.78 kg/tree) than lowland (9.87–178.06 kg/tree) in Kellem wolega, Ethiopia. Additionally, Bekele (2010) reported similar results for leaf biomass DM yield of browse species which ranged from 77.6 to 871 kg/plant in Nechisar national park, Ethiopia. In contrast to the current findings, Takele et al. (2014) reported higher biomass yields of 24.55 kg/tree to 958.76 kg/tree of IFT in Wolayta zone, southern Ethiopia. The total biomass yield per hectare reported in current study was less than the value (500–800 kg/ha) reported by Ayele et al. (2022) in Kellem Wollega and 29 kg/ha – 959 kg/ha in Wolayta, south Ethiopia (Takele et al., 2014). This variation may be due to difference in land use, soil fertility and amount of rain fall. Generally, the result revealed that the highest biomass yield was recorded in *E. brucei* followed by *M. ferruginea*, then C. africana in three districts and lowest in *V. amygdalina*. In agreement with the current Geta et al. (2014) reported that *E. brucei* and *C. africana* have high CP content and can be source of protein supplements for ruminant animals. Some possible inconsistencies in biomass yield and values of chemical composition reported by Mekoya et al. (2008) and Bekele et al. (2010) could be due to variations in season of samples collection, soil fertility and altitudinal differences of the sampling site.

4.5. Socioeconomic importance of indigenous fodder tree

Farmers keep trees depending on the tangible uses that they render to the household such as food, fodder, firewood, soil fertility, windbreak, bee keeping and other forms of income generation (Negese and Motuma, 2021), and provision of poles, construction materials and fodder (Habte et al., 2021). Additionally, trees planting create employment opportunities (Lemeso L., 2021). Moreover, leaves, twigs and fruit pods of IFT are rich in crude protein, minerals and energy hence can be source of feed during dry season (Takele et al., 2014). For instance, in the mid rift valley of Ethiopia, IMPFT are most favored by goats and also utilized by cattle and sheep (Shenkute et al., 2012). Additionally, IFT trees are also used as honey bee forage and for traditional medicine (Latamo and Wondmagegn, 2020).

Likewise, farmers need IFT when conducting ceremonies, social gatherings and celebrating religious holidays (Seta et al., 2013). Habte et al. (2021) also reported that *Acacia abyssinica, Albizia gummifera, M. ferruginia, C. africana* and *F. sur* are found growing in home gardens for providing shade for underneath crops.

5. Conclusion

Farmers, who practiced traditional agroforestry, have awareness and interest, have a large land size and small family member have higher chance to have IFT in their farm. The highest IFT species richness was identified in lowland, followed by highland and midland. Species diversity of lowland was higher, followed by midland and highland. Widely utilized IFT in the highland were *Arundinaria alpine, Hygenia abyssinica, Erythrina brucei*, and *Vernonia amygdalina*. Similarly, *Cordial africana, Mellettia ferruginea, Erythrina brucei* and *Dracaena steudneri* were the dominant one in the midland. In the lowland, *Balanites aegyptiaca, Acacia tortolis, Cordia africana* and *Euclea racemose* were dominant species. The total biomass yield of IFT was higher in highland followed by midland and then lowland. Besides fodder values, IFT serve for income generation, shade, fuel wood and fence, fodder value and construction materials and soil fertility improvement in different AE. Hence, the most abundant and highly dominant species in the three agro ecologies contributed to higher biomass yield and can be a potential source of feed. Additionally, IFT play great role to enhance livelihood of farmers by maintaining biodiversity, creating alternative income opportunities for household. Therefore, farmers should select these abundant and dominant IFT to consider and utilize as a source of feed during the dry season. Further research is needed on evaluation of the nutritive value of IFT.

Declarations

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Declaration of interest statement

The authors declare no conflict of interest.

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Figures

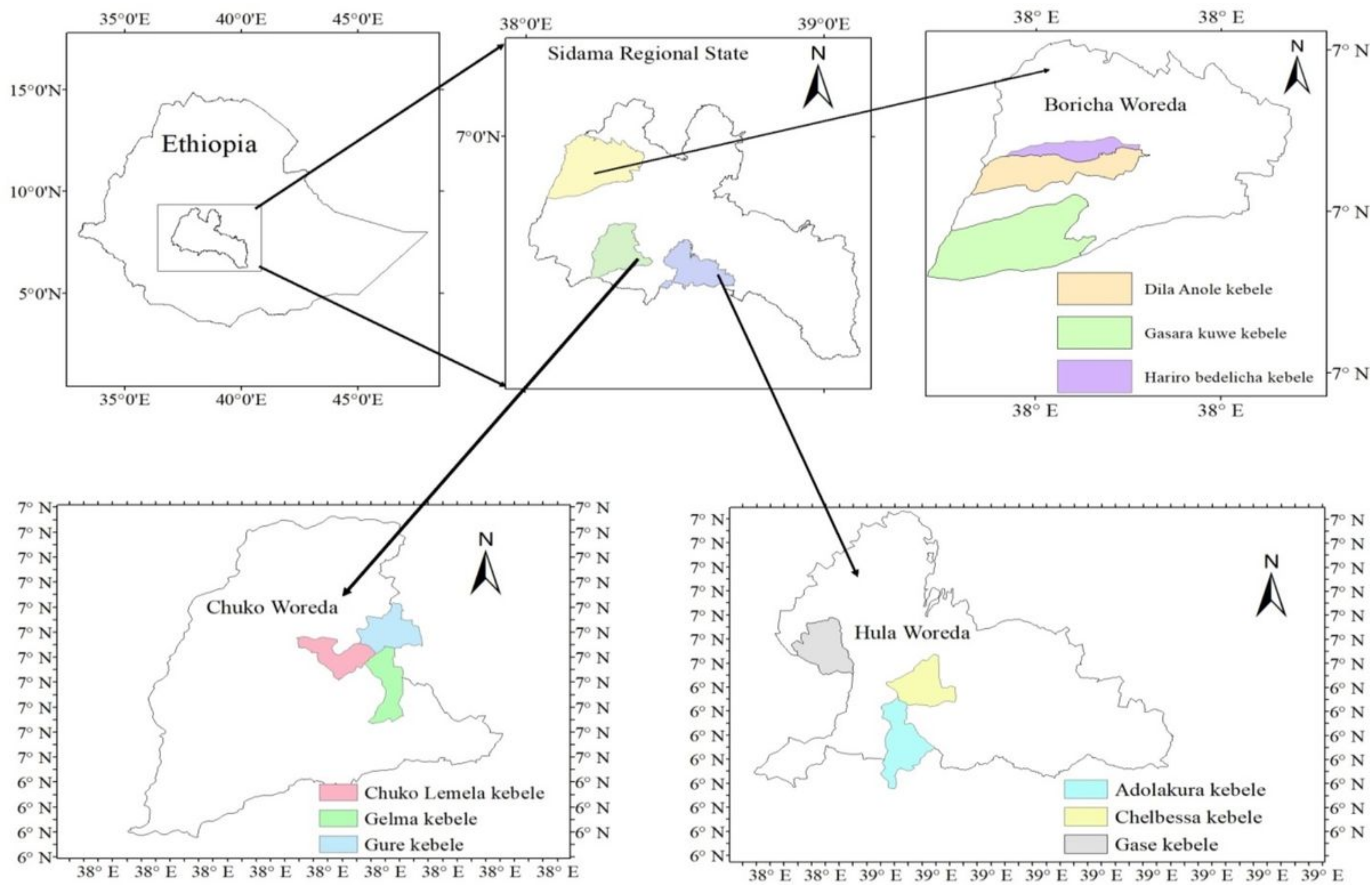

Figure 1

Location of the study region within the nested country map, the study districts in the regions, and the specific study sites in the districts

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