INDIGENOUS FODDER TREE SPECIES COMPOSITION, BIOMASS YIELD AND SOCIOECONOMIC CONTRIBUTION IN SIDAMA RIGIONAL STATE, ETHIOPIA †

[COMPOSICIÓN DE ESPECIES INDÏGENAS DE ÁRBOLES FORRAJEROS, RENDIMIENTO DE BIOMASA Y CONTRIBUCIÓN SOCIOECONÓMICA EN EL ESTADO RIGIONAL DE SIDAMA, ETIOPÍA]

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SUMMARY

Background. 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. **Objective**. To assess species composition, biomass yield and socioeconomic contribution of IFT. **Methodology**. Three districts and 9 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. Semi-structured questionnaires and 36 key informants were used to collect primary data. **Results**. Twenty-eight IFT species belonging to 26 genera and 24 families were identified in three agroecologies. Species richness in lowland (11.08) was higher than in highland (9.6) and midland (7.7) ($p < 0.001$). Similarly, lowland (1.5) was 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, *Cordia africana*, *Ficus sur, Dracaena steudneri* and *Melleitia ferruginea* were dominant species, and *Acacia albida, A. tortolis, Balanites aegyptiaca* and *C. africana* were dominant in lowland, altogether accounting for 56.1 and 76.72% of the total basal area, respectively. *E. brucei*, *Dracaena steudneri* and *C. africana* had the highest biomass yield in highland, midland and lowland, respectively ($p < 0.05$). Farmers with large land sizes, small family sizes, practicing agroforestry, and having awareness and interest in fodder trees had significantly affected the decision to have IFT. In addition to fodder supply, IFT contributes to soil fertility improvement, income sources, and timber production. **Implication**. The current findings indicated that the dominant fodder tree species with the highest biomass yield can be an alternative source of fodder and used for enhancing the livelihood of farmers in the study area. **Conclusion**. The most abundant and highly dominant species in the three agroecologies contributed to higher biomass yield and can be a potential feed source.
Key words*:* Species Availability; Diversity; Indigenous Fodder Trees; Ethiopia.

RESUMEN

Antecedentes. Los árboles forrajeros son componentes integrales del sistema agroforestal en los trópicos. En Sidama, Etiopía, se cultivan árboles forrajeros autóctonos (IFT) para diferentes fines. Sin embargo, su composición, rendimiento de biomasa e importancia socioeconómica no se han estudiado adecuadamente. **Objetivo.** Evaluar la composición de especies, el rendimiento de biomasa y la contribución socioeconómica de los IFT. **Metodología.** Se seleccionaron intencionalmente tres distritos y 12 kebeles, de los cuales se seleccionaron aleatoriamente 273 hogares para la encuesta de hogares. Se seleccionaron al azar sesenta hogares para realizar un inventario dentro de cuadrados

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anidados de 20 x 20 m. Se utilizaron cuestionarios semiestructurados y 36 informantes clave para recopilar datos primarios. Resultados. Se identificaron veintiocho especies de IFT pertenecientes a 26 géneros y 24 familias en tres agroecologías. La riqueza de especies en las tierras bajas (11.08) fue mayor que en las tierras altas (9.6) y las tierras medias (7.7) ($p <0.001$). De manera similar, las tierras bajas (1.5) fueron más diversas que las tierras medias (1.2) y las tierras altas (0.8) ($p <0.001$). *Arundinaria alpine*, *Hygenia abyssinica* y *Erythrina brucei* fueron dominantes en el IFT y en conjunto representaron el 72.35% del área basal total. En las tierras medias, *Cordia africana*, *Ficus sur*, *Dracaena steudneri* y *Melleitia ferruginea* fueron las especies dominantes, y *Acacia albida*, *A. tortolis*, *Balanites aegyptiaca* y *C. africana* fueron las especies dominantes en las tierras bajas, representando en conjunto el 56.1 y el 76.72% del área basal total, respectivamente. *E. brucei*, *Dracaena steudneri* y *C. africana* tuvieron el mayor rendimiento de biomasa en las tierras altas, medias y bajas, respectivamente ($p < 0.05$). Los agricultores con grandes extensiones de tierra, familias pequeñas, que practican la agrosilvicultura y tienen conciencia e interés en los árboles forrajeros habían influido significativamente en la decisión de contar con el IFT. Además del suministro de forraje, el IFT contribuye a mejorar la fertilidad del suelo, la fuente de ingresos y la producción de madera. **Implicaciones**. Los hallazgos actuales indicaron que las especies de árboles forrajeros dominantes con mayor rendimiento de biomasa pueden ser una fuente alternativa de forraje y usarse para mejorar los medios de vida de los agricultores en el área de estudio. **Conclusión**. Las especies más abundantes y altamente dominantes en las tres agroecologías contribuyeron a un mayor rendimiento de biomasa y pueden ser una fuente potencial de alimento.
Palabra clave: Disponibilidad de especies; Diversidad; Árboles forrajeros autóctonos; Etiopía.

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 the 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 (Tolera *et al.*, 2012).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 (Mekoya *et al*., 2008). Moreover, the domestication and integration of IFT into agroforestry system have several benefits (Ayenew *et al*., 2019). 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).

Currently, availability of IFT is declining due to agricultural expansion and livestock pressure, resulting 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 (Iiyama *et al*., 2017).

Sidama National Regional state of Ethiopia is known for practicing agroforestry systems where farmers integrate IFT with cash crop, enset, coffee and cereal crops (SNRSAB, 2022). 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 into 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 into the existing farming system are limited, which has hampered efficient utilization of the potential of agroforestry for fodder supply. Furthermore, IFTs have ecological and economic importance like improving soil fertility, serve as shed, and protect crops from wind damage, used for timber, firewood, bee forage and for other economic purposes. Hence, studying IFTs is important to identify the problem of farmers having IFTs in their farms and producing evidence-based findings for researchers and policy makers. Thus, the objective of this study was to assess species composition, diversity, biomass yield and socioeconomic factors determining the availability of IFT in Sidama National Regional State, Ethiopia.

MATERIALS AND METHODS

Description of study area

The study was conducted in three districts of Sidama National Regional state. It is located in southern Ethiopia, 275 km from Addis Abeba (Figure 1). The region has highland (2,500-3,700 m), midland (1500-2,300 m) and lowland (<1500 m) agroecologies. The total annual rainfall of highland, midland and lowland ranges 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 lowland are 12 to 14.5 °C, 15 to 19.9 °C and 20 to 24.9 °C, respectively (SNRSAB, 2022).

Sampling techniques

Multi-stage sampling technique was applied to select the study sites. First, 35 districts were grouped into three based on agroecology. Second, one district was purposively selected from each category based on the availability of IFT and road accessibility. Accordingly, Hulla, Aleta Chuko, 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 (Figure 1). Then, 273 sample households were randomly selected for interview using Yamane (1967) formula at 96 % confidence level. The size of sample households from each kebele was determined in proportion to the total household (Table 1).

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 offices about location, rainfall, temperature, types of crops, livestock size and total number of households.

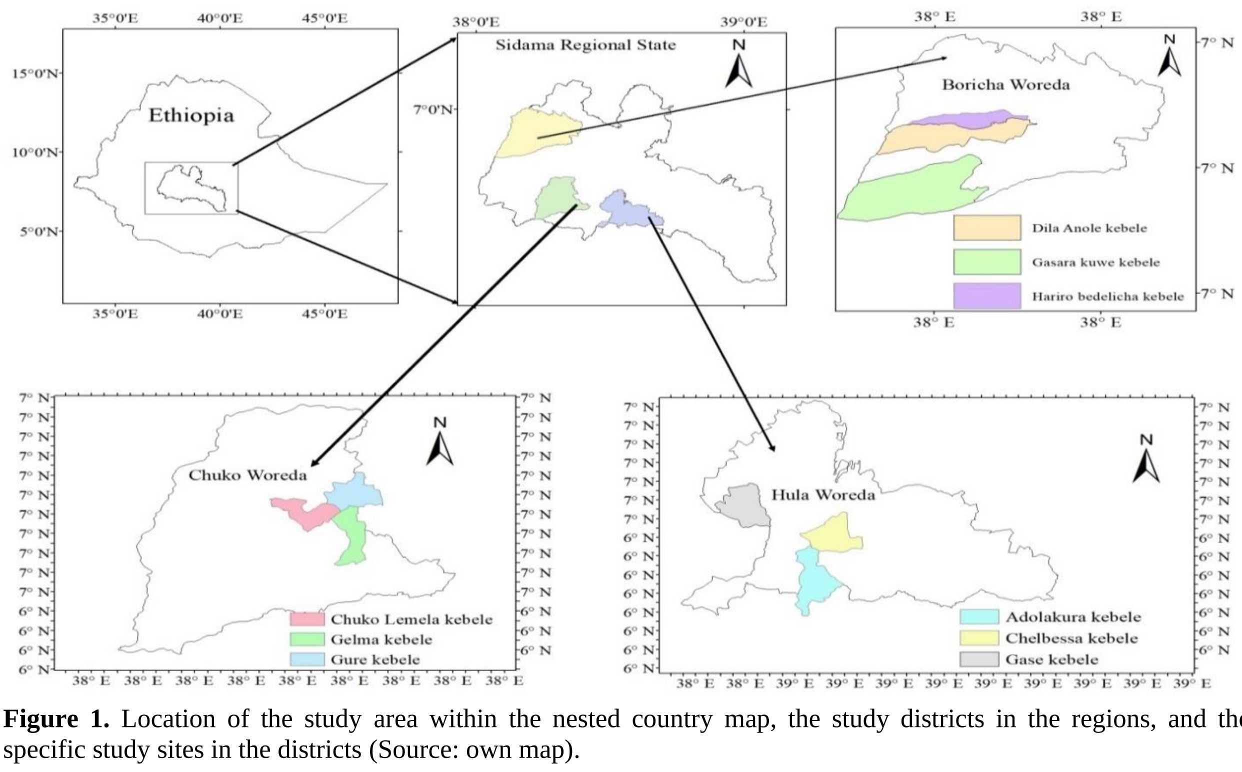

Figure 1. Location of the study area within the nested country map, the study districts in the regions, and the specific study sites in the districts (Source: own map).

Table 1. Sample households selected across agroecologies in Sidama, Ethiopia.

Agro ecology	District	Kebele	Total household	Sample household
Highland	Hulla	Adola kure	1519	29
		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

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 (Negash *et al*., 2012). 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 (Azene, 2007), and local informants.

Data analysis

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 ($\chi 2$) 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. To analyze the data, SPSS and SAS Version 19.0 (SAS, 2008) software were used. The statistical model used was:

$$Yi = \mu + Ai + ei.$$

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):

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

Where;

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

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

Species richness 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, 1993). 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:

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

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

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, 1993, Mata *et al.*, 2011).

Measure leaf biomass yield

In this study all identified plant species used by farmers for fodder purposes were only tree species. 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 Mark (1983) for all tropical tree species.

LogW = 2.24 logDT-1.5(for tree species);

Where W was leaf DM yield in kg, DT was the diameter of the trunk (cm) at 130 cm height.

RESULTS

Availability of indigenous fodder tree species

The result of the 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 the integration of IFT into their farm.

The overall binary logistic regression model was statistically significant when compared to the null model (X^2= 110.49, $p < 0.001$) which 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 in planting IFT increased the chance of having IFT in the farm by 3.01 times. Additionally, farmers with large land size had 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 had 93% higher chance of integrating IFT than who did not practice in their farms.

Species composition

A total of 28 IFT species belonging to 26 genera and 24 families were identified in three agroecologies (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 predominant.

Table 2. Proportion of responses of sample households on integration of indigenous fodder trees in studied sites of Sidama, Ethiopia.

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

Table 3. Effects of household characteristics, awareness and seed sources to indigenous fodder trees in Sidama, Ethiopia.

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

Species richness and diversity

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

Structure of indigenous fodder tree

The vegetation structure of IFT species is 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.

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 the 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.

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 agroecologies. In the high land, biomass yield/ha was 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 lowland was for *C. africana and E. racemose.* In general, the average DM biomass yields were 0.22- 15.43, 0.28–23.1 and 10.81 –54.1 kg DM/tree for highland, midland and lowland, respectively.

Table 4. Mean (± SD) of indigenous fodder tree species richness and Shannon diversity in different agroecology 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}
P value		<0.0001	<0.0001

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

Table 5. the structure of indigenous fodder trees in three agroecology in selected sites of Sidama, Ethiopia.

Scientific name	Density (stems/ha)	Dominance (m^2/ha)	Frequency (%)	IVI
Highland				
Commiphora campestris	5	0.8	20	3.14
Faurea rochetiana	5	0.5	20	2.86
Hygenia abyssinica	50	3.4	75	13.65
Vernonia amygdalina	10	0.7	20	3.36
Mellettia ferruginea	3.75	1.0	15	2.89
Erythrina brucei	76.25	3.6	85	15.28
Pittosporum abyssinica	7.5	1.3	30	5.12
Ilex mitis	5	0.8	20	3.45
Buddleja polystachya	1.25	0.3	5	0.95
Maesa lanceolata	1.25	0.8	5	1.70
Arundinaria alpine	1917.5	8.7	35	48.27
Commiphora campestris	5	0.8	20	3.14
Midland				
Ehretia cymosa	3.75	2.9	5	5.22
Schefflera abyssinica	2.5	3.6	5	6.15
Vernonia amygdalina	21.25	0.3	45	6.99
Mellettia ferruginea	100	1.7	80	21.64
Dracaena steudneri	16.25	3.1	50	11.04
Ficus sur	36.25	4.9	75	18.51
Celtis africana	7.5	1.4	5	3.40
Cordia africana	66.25	2.8	75	18.80
Erythrina brucei	20	1.6	40	8.25
Lowland				
Balanites aegyptiaca	60.29	1.30	85	33.53
Maytenus arbutifolia	52.78	0.94	55	18.72
Acacia albida	62.50	3.79	35	26.17
Searsia natalensis	37.50	12.25	20	23.40
Olea europae	36.11	2.21	55	19.00
Carrisa spinarum	75.00	2.93	20	17.28
Dodanaea viscosa	150.00	2.68	15	14.15
Euclea racemose	43.75	32.10	50	56.51
Ficus sur	25.00	3.50	20	9.60
Boscia angustifolia	75.00	0.88	15	5.15
Acacia tortolis	98.33	2.02	85	42.11
Acacia seyal	83.33	1.30	70	30.56
Cordia africana	50.00	1.48	60	20.81

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 (using smoke of *Olea africana* tree) milk utensil to preserve and give good flavor to milk across the studied agroecologies.

DISCUSSION

Availability of indigenous fodder trees

According to respondent's access to seed, and limited seedlings supply were the main factors affecting the integration of IFT into their farm. This may be 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 and Haftay (2019) for agroforestry system in Eastern Hararghe, Ethiopia. Farmers with large landholding, small family size, and

Table 6. Leaf biomass yields (kg) of major selected indigenous fodder trees of the three agroecology sites of Sidama, Ethiopia.

Plant species	Density (plant/ha)	Biomass Yield (kg DM /plant)	Total biomass (kg DM/ha)
Highland			
Arundinaria alpina	1523[a]	0.22[d]	335.1[c]
Hygenia abyssinica	76.7[b]	5.22[b]	400.4[b]
Erythrina brucei	43.3[c]	15.43[a]	668.1[a]
Vernonia amygdalina	28.3[d]	1.13[c]	31.9[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]	615.6[b]
Erythrina brucei	23.3[d]	8.07[b]	188.0[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]	4237[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]	307.4[a]
Cordia Africana	20[c]	10.81[a]	216.2[c]
Acacia tortolis	66.7[a]	4.1[c]	273.5[b]
Euclea racemose	8.3[d]	9.67[a]	80.3[d]
CV	26.1	24.44	25.1
p value	0.005	0.001	0.006

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

Table 7. Socioeconomic contribution of indigenous fodder trees (IFT) in different agro-ecologies of Sidama, 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

possession of various agroforestry practices, adequate awareness and interest to plant trees better integrate IFT to their farms. Roothaert (1997) 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.

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 (Geta *et al*., 2014, Gochera *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 the findings reported for different parts of the country (Getahun *et al*., 2014). 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 were observed in the highland and midland. This may be attributed to the type of management intensities of farmers and interest of farmer's 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 (Geta *et al.*, 2014, Molla, 2016). Similarly, Tadesse *et al*. (2021) reported that species richness and diversity were influenced by intensive farmland management and farmers interests. Moreover, Molla (2016) also indicated significantly higher species richness and diversity in the lowland than midland. However, in contrast to the current study, higher species richness and diversity were observed in midland followed by highland and lowland in Arba Minch, south Ethiopia (Gochera *et al*., 2020). This difference could be due to the focus given to IFT in the current study.

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 (López-Gómez *et al*., 2008, Alemayehu and Hager, 2010). However, to the contrary, Yirefu *et al*. (2016) reported that tree density decreases with increasing altitude. This is may be because other studies considered all types of trees but this study focused only on IFT.

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 (Shimelse *et al.,* 2010). This result was supported by previous studies concerning the available shrubs and fodder trees in different agroecologies of Ethiopia (Ayele *et al.,* 2022, Geta *et al*., 2014). 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 agroecology, which is potentially attributed to altitudinal differences, climatic factors, soil fertility and land use system (Geta *et al*., 2014).

In agreement with the current finding, Ayele *et al*. (2022) reported that on average mid land agroecology 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, Shimelse *et al.* (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, Geta *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 the 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 (Geta *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 the three districts and lowest in *V. amygdalina*. In agreement with the current study Geta *et al.* (2014) reported that *E. brucei* and *C. africana* have high crude protein content and can be sources of protein supplements for ruminant animals. Some possible inconsistencies in biomass yield and values of chemical composition reported by Mekoya *et al*. (2008) could be due to variations in season of samples collection, soil fertility and altitudinal differences of the sampling site.

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, provision of poles, construction materials and fodder (Habte *et al*., 2021). Additionally, trees planting create employment opportunities (Lameso, 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 (Geta *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 (Mekoya *et al*., 2008). 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.

CONCLUSION

Farmers who practice traditional agroforestry, and who have awareness, interest, large land size, and small families have a higher chance of integrating IFT in to 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, have fodder value and construction materials and soil fertility improvement in different agroecologies. Hence, the most abundant and highly dominant species in the three agroecologies 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.

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Author contribution statement (CRediT)
A. Gebregiorgis - Conceptualization, Data curation, Formal analysis, Investigation, Methodology, and Writing-original draft., **A. Nurfeta** – Conceptualization, Investigation, Methodology, supervision, Validation, Writing-review and editing., **M. Negash** - Conceptualization, Methodology, Supervision, Validation, Writing-review and editing., **M. Bayssa-** Methodology, Supervision, Validation, Writing-review and editing.

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Appendix

Appendix 1 scientific name, vernacular name, edible parts and livestock preferred of major indigenous fodder trees in different agro ecologies

Scientific name	Family Name	Vernacular Name	Edible parts	Livestock preferred
Highland				
Pittosporum abyssinica	Pittosporacea	Boncho	Leaf	Cattle and Sheep
Buddleja polystachya	Loganiaceae	Bulancho	Leaf	Cattle and Sheep
Hygenia abyssinica	Rosaceae	Dadako	Leaf	Cattle and Sheep
Faurea rochetiana	Proteaceae	Daanshicho	Leaf	Cattle and Sheep
Maesa lanceolata	Myrsinaceae	Gowacho	Leaf	Cattle and Sheep
Vernonia amygdalina	Asteraceae	Hechcho	Leaf	Cattle, Sheep, goat
Mellettia ferruginea	Fabaceae	Hengedicho	Leaf/fruits	Cattle, Sheep, goat
Commiphora campestris	Burseracea	Kincho	Leaf	Cattle and Sheep
Arundinaria alpine	Poaceae	Leemicho	Leaf	Cattle and Sheep
Ilex mitis	Aquifoliaceae	Miiqicho	Leaf	Cattle and Sheep
Erythrina brucei	Fabaceae	Welako	Leaf	Cattle, Sheep, goat
Midland				
Ehretia cymosa	Boraginaceae	Gidincho	Leaf	Cattle, Sheep, goat
Schefflera abyssinica	Araliaceae	Gataamme	Leaf/fruits	Cattle, Sheep, goat
Vernonia amygdalina	Asteraceae	Hechcho	Leaf	Cattle, Sheep, goat
Mellettia ferruginea	Fabaceae	Hengedicho	Leaf/fruits	Cattle, Sheep, goat
Dracaena steudneri	Dracaenaceae	Lanticho	Leaf/stem	Cattle, Sheep, goat
Ficus sur	Moraceae	Odako	Leaf/fruits	Cattle, Sheep, goat
Celtis Africana	Ulmaceae	Shisho	Leaf	Cattle, Sheep, goat
Cordia Africana	Boraginaceae	Wadicho	Leaf/fruits	Cattle, Sheep, goat
Erythrina brucei	Fabaceae	Welako	Leaf	Cattle, Sheep, goat
Lowland				
Balanites aegyptiaca	Balanitaceae	Baddana	Leaf/fruits	Cattle and goat
Maytenus arbutifolia	Celastraceae	Chucho	Leaf	Cattle, Sheep, goat
Acacia albida	Fabaceae	Burra	Leaf/fruits	Cattle, Sheep, goat
Searsia natalensis	Anacardiaceae	Dawowessa	Leaf	Cattle, Sheep, goat
Olea africana	Oleaceae	Ejerssa	Leaf	Cattle, Sheep, goat
Carrisa spinarum	Apocynaceae	Hagalla	Leaf	Cattle, Sheep, goat
Dodanaea viscosa	Sapindaceae	Itancha	Leaf	Cattle, Sheep, goat
Euclea racemose	Ebenaceae	Me’essa	Leaf	Cattle, Sheep, goat
Ficus sur	Moraceae	Odako	Leaf/fruits	Cattle, Sheep, goat
Boscia angustifolia	Capparidaceae	Shiishsha	Leaf/fruits	Cattle, Sheep, goat
Acacia tortolis	Fabaceae	Tadacha	Leaf/fruits	Cattle, Sheep, goat
Acacia seyal	Fabaceae	Wacho	Leaf/fruits	Cattle and Sheep
Cordia Africana	Boraginaceae	Wadicho	Leaf/fruits	Cattle, Sheep, goat