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Farmers' use and preferences of agroforestry trees in Bauchi State, Nigeria

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Abstract Most of the Bauchi State's inhabitants face environmental and socio-economic challenges. Agroforestry trees can help these people by providing valuable environmental benefits such as windbreaks, soil improvement, shade, or additional income through fruits and medicine (services and products). The study aimed to identify the most important use of tree species by the farmers and their tree preferences, examine agroforestry practices on their farms, and spot the most preferred locations of trees on their farms. The fieldwork was conducted in both lowlands and highlands of Bauchi state. In total, 83 farmers were interviewed using semi-structured questionnaires. The results showed that farmers mostly use and prefer fruit trees (74 and 87%), followed by medicinal trees (66 and 18%) in lowlands and highlands, respectively. They also use trees for fencing and shading. *Adansonia digitata* was the most preferred species in the lowlands, while *Parkia biglobosa* was in the highlands. Scattered trees were the most used agroforestry practice (79 and 84%) in both the lowlands and the highlands. The bush field and the village field (47 and 37%) were the most preferred locations of trees on farms. In the future, we suggest that policymakers and extensionists should support research and improvement of varieties of the most preferred fruit/food tree species and develop and introduce improved disease-resistant and pest-tolerant native varieties.

Keywords *Adansonia digitata* · Highlands · Lowlands · *Parkia biglobosa* · Socio-economic challenges · Multipurpose tree species

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Introduction

Trees are crucial components of commonly occupied human agricultural fields, especially in rural areas in the tropics. Incorporating trees into agricultural fields through agroforestry systems can increase water-gaining access to the soil, soil nutrition, and mineral nutrients availability (Borris et al. 2018). Trees and woody shrubs can produce timber, fibre, fodder, fuel wood, and fruits that can enhance the livelihood of the rural community via revenue generation in one way or another (Nyaga et al. 2015). Tree integration in land use management can also increase carbon sequestration in above and below-ground biomass. This is linked to one of the most effective ways of mitigating climate change (Sinchair et al. 2019; Zomer et al.2016). Therefore, incorporating multipurpose trees and woody shrubs in arable lands can enhance poor rural inhabitants' nutritional and food security, contributing to ecosystem services and a resilient climate in arable lands worldwide (Kuyah et al. 2016). Consequently, rural populations worldwide play an important role in sustainable land use management and biodiversity conservation. They practice land use systems that can impact the protection of forests and ecosystems for economic, social, and environmental benefits (Garnett et al. 2018). For example, unlike in the old shifting cultivation, the rural population does not need to fell trees in the agroforestry management (land use); they instead allow trees to regrow naturally and replenish by planting tree seedlings together with their herbaceous crops (Reang et al. 2024).

Furthermore, among many rural farmers in the West African Sudan-Sahel regions, naturally, regenerated trees are the major means of domestic wood, medicinal products, food supplements, off-season feed, and soil improvement (Mulugeta 2014). However, these trees have low productivity due to inappropriate management, which cannot sufficiently meet the current demand for their products or services. They are over-used, resulting in ecosystem degradation and desertification (Mustapha and Jimoh 2012). On the other hand, agroforestry systems, one of the long-time-tested and widely accepted land use management in the tropical and subtropical regions (including West Africa), is widely considered for its support of food production, conservation of biodiversity and environmental protection through atmospheric carbon sequestration (Nath et al. 2022). Nevertheless, deforestation, soil fertility loss, growing scarcity of tree products, and environmental degradation have created serious land use problems in many developing countries. Estimation shows that over 50% of the forests and natural vegetation have been cleared for road construction, agriculture, and urban development, which converts most of these forests to savannas (Sharma et al. 2017). The savannas cover 75–80% of the land area in West Africa. In Nigeria, they cover 75.4% of the agricultural land area, while in the past, 23.6% of Nigerian land was covered by forest (World Bank 2020). The current forest cover of Nigeria is 12.2%, of which primary forest is only 2.9%; most losses of natural vegetation such as tree cover, grassland, and wetland to cropland happened between 2000–2013 (22%) when many irrigation programs in Nigeria were developed (Akinyemi and Ifejika Speranza 2024). In Bauchi State, most of the native tree species trace their origin to these forests as they were spared in the crop fields during shifting cultivations for their numerous products (Wunder 2001). Despite facing severe socio-economic challenges, most Indigenous inhabitants of Bauchi State are smallholder farmers who can still grow trees and crops of long and medium life spans on their farms (Musa et al. 2023). This makes indigenous knowledge of trees a vital resource for livelihood.

Although Indigenous knowledge is recognized to help inform (sustainable) management options, as was nicely done recently for instance (Steger et al. 2023), recognition is even reinforced by its relevance in the context of climate emergency and by the rise of decolonial approaches, as demonstrated recently (Moyo et al. 2022). In Bauchi State, farmers' indigenous knowledge is helpful in all the management practices associated with trees, especially those of native species found in crop fields (Nodza et al. 2013). Many beneficial indigenous woody species (trees and shrubs) are preserved in land use management that make up agricultural fields. Mustapha and Jimoh (2012) surveyed farmers' preferences for tree species in Ijebu North Local Government Area of Ogun State (which is one region out of 17 regions that make up Southern Nigeria) in Southwestern Nigeria (The tropical rainforest). They identified 72 tree species, but their research covered only one region. Their survey did not touch Northern Nigeria, which was covered mainly by Savannah. Similar surveys were carried out in Bauchi State (a region out of 19 regions that make up Northern Nigeria). Oyewole and Carsky (2001) identified 33 tree species and their uses, and Bauchi state was among the two study regions. Another research was conducted in Bauchi state (the study area) by Nodza et al. (2013), of which 47 tree species and their ethnobotanical uses were identified, and Akpan et al. (2010) identified 9 priority tree species for fuel wood, among others in the study area. However, none of the three mentioned research above covered all three administrative agricultural zones (The Western, Central, and Northern zones), as well as none of them covered the two different agroecological zones (the lowlands and the highlands) as these vary in elevation, rainfall, temperature, and vegetation cover which could be indicators for various tree species occurrence, preferences and uses among farmers (Ensslin et al. 2015; Halilu et al. 2024). Furthermore, none of the previous studies reported how the farmers incorporate the trees into their farming systems (agroforestry practice) or silvicultural management.

Our research aimed to assess the farmers' use, preferences, and abundance of tree species in Bauchi State, Nigeria's two agroecological zones (lowlands vs. highlands). We aimed to find the priority tree species and examine their incorporation into the local farming systems (agroforestry practice) and management. Based on our previous knowledge (literature), we expected that the use and preference of the tree species would be substantially different between lowlands and highlands farmers. The study provided information that can help farmers, policymakers, and future researchers in priority tree selection and intervention in decision-making.

Materials and methods

Study site

This study was conducted in the two different agroecological zones (the lowlands and the highlands) of Bauchi State. Bauchi State is one of the 36 states (regions) that make up Nigeria; the Capital is Abuja. Bauchi state is found in the Northeastern part of the country, 465 kms east of Abuja. Bauchi state as a region has 20 Local Government Areas (LGA). There are three agricultural zones (The western, central, and northern zones), which are public administrative settings used to distribute inputs and extension services to farmers in all the LGAs of Bauchi state. The agricultural zones are enveloped in two different agroecological zones (the lowlands and the highlands). For this study, six LGA were selected randomly to give an equal chance of participation from the two agroecological zones. The selected LGA from the lowlands were Darazo (10° 59′ 57.12" N 10° 24′ 38.23" E), Katagum (12°17′N 10°21′E), and Gamawa (12°08′N 10°32′E and from the highlands were Dass (10.0185´´N, 9.4780 " E), Toro (10°3´34.51´´N 9°4´5.36´´E), and Ningi (11°03´60.00´´N 9°33´59.99´´E). Three villages were further randomly selected from each LGA. That is nine villages from the low and highlands, respectively (Fig. 1). Five farms were further surveyed from each village based on the willingness of the farmers to participate in the study (giving a total of 90 respondents (45 in the lowlands and 45 in the highlands) (Table 1).

Lowlands vs. highlands environmental and socio-economic Features

The lowlands study sites (All Darazo, Katagum, and Gamawa; 333–499 m.a.s.l) are found in the Northern part of Bauchi state. They receive rainfall during the summers of every year mostly from June to early September, while the winters have no rainfall. The rainfall ranges from 616 to 850 mm, with the highest amount in August. In addition to the rainfall, several dams provide water for irrigation such as the Maladumba Lake and River Jama'are. The average temperature is around 26.5 °C (Climate data 2019). The vegetation of this area is the Sahel savannah, which is also known as semi-arid, the vegetation comprises isolated stands of thorny shrubs and sparse grasses, and the soil type of these areas is generally sandy (Akinyemi and Ifejika Speranza, 2024). About 80% of the lowlands' inhabitants are subsistence farmers who stay in a large family settlement, especially in the villages (compound) that accommodate an average of 43–50 individuals, Hausa and Fulfulde are the commonly spoken local languages (Madaki et al. 2023; Haruna et al. 2012; Roger 2021). They supplemented subsistence farming with small-scale livestock management (guineafowl, cattle, fowl, sheep, and goat), the commonly grown crops are peanut (*Arachis hypogea*) cowpea (*Vigna unguiculata*), millet (*Panicum* miliaceum), sorghum (*Sorghum* bicolor L.) and some trees such as mango (*Mangifera indica*), neem

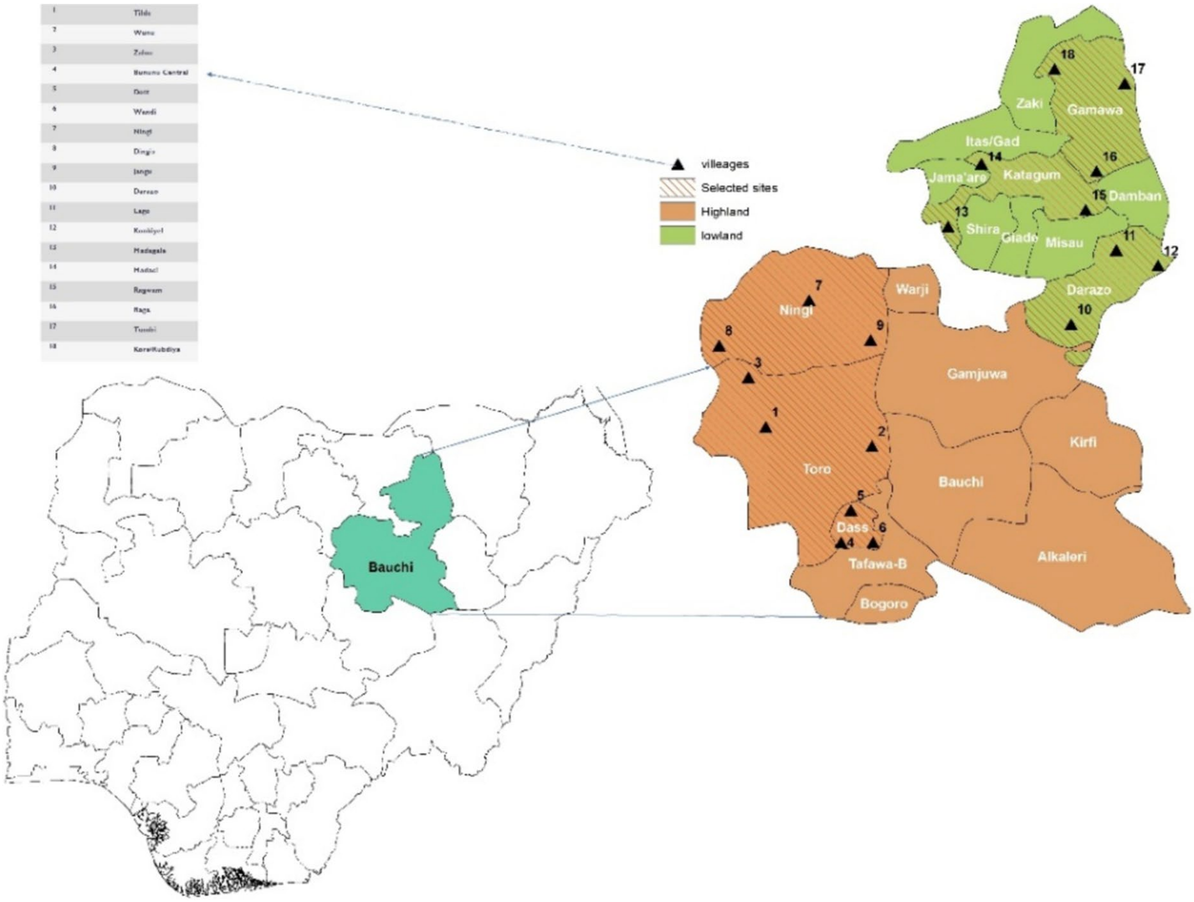

Fig. 1 The map of the study sites

(*Azadirachta indica*), moringa (*Moringa oleifera*), and baobab (*Adansonia digitata*) (Sakariyau et al. 2023).

The highlands study sites (All Toro, Dass, and Ningi; 600–900 m a.s.l.) are in the Southern part of Bauchi state. They experience rainfall in the summer months mostly from May to the end of September annually, while there is no precipitation in the winter from October to April. The rainfall ranges between 954 and 1,232 mm, with the highest amount in August. In addition to the precipitation, some dams in Gumau, Pingel, and other villages support dry-season farming. The average temperature is around 24.8 °C, (Climate data 2019). The vegetation of this area is the Sudan savannah. The vegetation is richer toward the south, especially around water bodies or rivers. Still, generally, the vegetation is less uniform, and grasses are shorter than what grows further south, that is, in the forest zone of the so-called middle belt of Nigeria (Akinyemi and Ifejika Speranza, 2024). The highlands especially, the southwestern part of the region (Bauchi state) is mountainous because of the continuation of the Jos Plateau and the soil here is mostly clay loams, sandy loam, and loamy sand in texture and slightly acidic (Musa et al. 2023). Like their lowlands counterparts, most of the inhabitants of the highlands are small farmers about 76%, some are civil servants but still depend on farming and trading (Sakariyau et al. 2023). In addition, the Fadama/River flood plain allows year-round gardens which are managed by individuals who own plots along seasonally flooded riverbanks at one boundary of villages. During the dry season, villagers exploit the residual soil moisture of the *Fadama* and supplement it with shadoof/bucket irrigation and,

Table 1 Characterization of the selected study sites

Agro-ecological zones	Location (LGA)	Altitudes ma.s.l	Villages	Number of farms	Climate class	Average temperature°C	Average rainfall mm per year
Lowlands	Darazo	499	Konkiyel	5	BSh	26.6	851
			Lago	5	BSh		
			Darazo	5	BSh		
	Gamawa	397	Kore	5	BSh	26.3	642
			Raga	5	BSh		
			Tumbi	5	BSh		
	Katagum	333	Madaci	5	BSh	26.7	616
			Madangala	5	BSh		
			Ragwam	5	BSh		
Total			9	**45**			
Highlands	Toro	900	Tilde	5	Aw	23.7	1232
			Wonu	5	Aw		
			Zalau	5	Aw		
	Dass	700	Wandi	5	Aw	25.5	1096
			Bununu central	5	Aw		
			Dott	5	Aw		
	Ningi	600	Dingis	5	Aw	25.4	954
			Ningi	5	Aw		
			Jangu	5	Aw		
Total			**9**	**45**			

Location: *LGA* Local Government Area. Climate Class: Aw = Tropical wet and dry or savanna climate, BSh = Mid-latitude steppe and desert climate (The Köppen-Geiger climate classification). Source: (Climate data 2019)

most recently, small generator-driven pumps. Individual gardens are divided by earthen walls; trees and shrubs are permanent features of this landscape as well. Villagers cultivate a variety of staple food crops such as maize (*Zea mays*), rice (*Oryza sativa*), soya beans (*Glycine max*), sesame (*Sesamum indicum*), Irish potatoes (*Solanum tuberosum* L.) and sweet potatoes (*Ipomoea batatas*). They also cultivate leafy vegetables and other foods, including tomato (*Lycopersicon esculentum*), sesame (*Sesamum indicum*), sorrel (*Hibiscus sabdariffa*), okra (*Abelmoschus esculentus*), squash (Cucurbita *maxima*), pumpkin (*Cucurbita* spp.), onion (*Allium cepa*), garden egg (*Solanum melongena*). Fadama-grown plants include new or experimental foods that villagers may not eat themselves but produce for sale in regional and urban markets (Sadiq et al. 2014). Inhabitants in the study area especially in the rural areas, stay more in extended family settings known as the compound or basic domestic unit which accommodates between two and 40 individuals, sometimes even 100 and the native languages are Hausa and Fulfulde (Haruna et al. 2012).

Data collection

The adopted methodology was developed by ICRAF and ISNAR (Franzel et al. 1996) and inspired by similar studies by Mustapha and Jimoh (2012) who worked on farmers' preferences for tree Species in Nigeria, and Assogbadjo et al. (2012) who surveyed biodiversity and socioeconomic factors supporting farmers' choice of wild edible trees in the agroforestry systems of West Africa respectively. The data were collected from June to September 2018 using a semi-structured questionnaire. The questionnaire was divided into nine parts: socio-demographic data, tree species identification, field observation for species, an abundance of trees, utility description of the tree species, location of trees on farms, priority species of the farmer, agroforestry practice, and silvicultural management of the most preferred species. Finally, tree species were recorded, including scientific names, common names, and local names for each tree species. It recorded the life form, and use of the parts according to their utility function (as mentioned by the farmers).

The researcher met face-to-face with the farmers on their farms for the field observations. The interview was conducted by the researchers and with the help of two enumerators, the information was filled in their (farmers) farms. The language used in conducting the interview was Hausa which is native to both the farmers and the researcher/enumerators. This is because the farmers are more familiar with the tree names in the local language. No discrimination was done against any potential interviewee to get objective data for objective outcomes after data analysis. Ninety interviews were done (45 each for the lowlands and the highlands) but only 83 questionnaires were finally used in this study (92% response rate). The inability to retrieve some of the questionnaires only happened in some villages: Madaci, Madangala, and Ragwam 2, 3 and, 2 questionnaires respectively were retrieved instead of 5 each village in the lowlands (38 questionnaires retrieved) where one enumerator helped with the interview, but in the highlands (45 questionnaires were retrieved).

Data analysis

The data were analysed using descriptive statistics: citation frequency (percentage) and scoring. The species abundance on each farm was recorded, and we evaluated species occurrence and preference by following formulas (Suman et al. 2018):

(i) Citation Frequency (CF%) = n/N * 100 where;—n is = the number of people interviewed citing species and N is = total number of people interviewed.
(ii) For the evaluation of tree species abundance, all the tree species were summed up and evaluated individually and separately for each of the lowlands and the highlands
(iii) Scoring was used to achieve farmers' preference for each species.

$$= \sum_{i=1}^{n} (\mathrm{Pi} + \mathrm{Pip})$$

where p_i is the proportion of I species cited by farmers as priority species to the total number of priority species, p_{ip} is the proportion of mostly preferred species to the total number of priority species, and n is the number of respondents citing the i species as a priority.

For tree species identification, we used a textbook (Agishi and Shehu 2004) that translates local (Hausa) names into common and Latin names.

Results

Farmers' socio-economic description

The farmers owned different sizes of land in both lowlands and highlands. In the lowlands, the average size of farmer's land was larger than in the highlands: 19.7 ha and 3.7 ha, respectively (Table 2). In both agroecological zones, field crops were cultivated together with trees on farms. Millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata*), and groundnut (*Arachis hypogaea*) were inter-planted with trees in lowlands while maize (*Zea mays*), rice (*Oryza sativa*), bambaranut (*Vigna subterranea*) and soya bean (*Glycine max*) were inter-planted with trees in most of the compound in the highlands. The average farmer's annual income from farm sales was higher in the lowlands $3,285≈

Table 2 General socio-economic description of respondents

	Lowlands (N = 38)			Highlands (N = 45)		
Socio-economic data	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Age of farmer	20	80	**39.9**	19	75	**45.1**
Members of household	2	35	**11.7**	1	54	**13.4**
Farming experience (yrs)	2	50	**19.7**	3	65	**28.2**
Farm size (ha)	1	500	**19.7**	0.5	15	**3.77**
The average distance from the market (km)	1	47	**19.3**	0.5	15	**4.43**
Average farming income $/yr	$694.25	$3,332	**$3,285**	$61.0	$1,666	**$1,613**

N = number of respondents

(1,180,790 NGN) than in the highlands \$1,613 ≈ (579,800 NGN). Furthermore, the average farming experience of farmers in the lowlands was shorter than in the highlands (19 and 28 years respectively). The average distance for farmers to reach the local market in the lowlands was much longer (19.3 km) compared to the highlands (4.4 km).

Tree species used by farmers

Farmers mentioned 53 tree species that were of various utility functions to them, ranging from fencing, human food, animal feed, soil improvement, medicine, fuel wood, and windbreak to shading. However, eight of the tree species were unique only to the lowlands while 21 were unique to the highlands (Table 3). We found out that native species were more dominant than introduced species in both agroecological zones (37 vs. 16 respectively). Deciduous species were more common than evergreen species in both the lowlands and the highlands (46 vs. 7 respectively). The most mentioned species that had high multiple uses in the agroecological zones were Mango (*Mangifera indica*), locust bean (*Parkia biglobosa*), guava (*Psidium guajava*), baobab (*Adansonia digitata*), moringa (*Moringa oleifera*) and tamarind (*Tamarindus indica*).

For the species frequency in the lowland, the neem tree (*Azadirachta indica*) reached the highest frequency of citation (60%), followed by baobab (*Adansonia digitata*), mango (*Mangifera indica*), and tamarind (*Tamarindus indica*) (55%, 52%, and 50% respectively). In the highland, locust bean tree (*Parkia biglobosa*) (55%), followed by mango (*Mangifera indica*) (37%), and baobab (*Adansonia digitata*) (28%) were the most mentioned species (the grown and the most used).

Tree species abundance, agroforestry practices, and locations of farms

In general, tree abundance in the lowlands was much higher than in the highlands (9,782 individuals vs. 2,854 individuals) (Table 4). Moringa was the most abundant tree species in both agroecological zones, but much higher in the lowlands (3,730 individuals) than in the highlands (530 individuals). In the lowlands, mango was the second most planted woody species (1,413 individuals) while in the highlands, orange was the second most planted species (498 individuals). while, in the lowlands, orange was the third most planted tree (820 individuals). Mango in the highlands occupied the third place (388 individuals). Other tree species were not so commonly planted compared to the above-mentioned species.

The commonly found agroforestry system in both the lowlands and the highlands was silvoarable agroforestry. This is a system where trees and crops are grown on the same piece of agricultural land. In this system, trees were used in different agroforestry practices in the lowlands and the highlands (Fig. 2). The most mentioned agroforestry practice by the farmers in both the lowlands and the highlands was scattered trees on cropland (79%, and 84%, respectively). The second most mentioned agroforestry practice was fencing in the lowlands and highlands (16%, and 13%, respectively), whereas growing trees on slash-and-burn fields was the third most mentioned practice (5% in the lowlands) by the farmers. Some fruit trees, especially mango, guava, orange, cashew, and moringa trees, were introduced and planted. Most of the tree species that are native were spared during slash and burnt (retained on fields) such as locust beans, and baobab. Both native and introduced tree species undergo certain management such as irrigation (shallow roots like orange and guava), pruning (all species), and thinning (especially locust bean) in the Savannah zones of Nigeria (Chukwujekwu 2010).

However, regarding the locations of farmers' fields in the study area, bush fields and wastelands were the most mentioned farm locations in the lowlands (47 and 37%, respectively). In the highlands, on the contrary, village fields and bush fields (42 and 37%, respectively) were the most mentioned (Fig. 3). The compound field is nearest to the home. The village field is further away from the homes than the compound field. Bush field is a distant field well away from the homes. A wasteland field is a field that was left for fallowing but is used by farmers due to competition in the other locations.

Uses of tree species

The use of trees as human food stuff was mostly mentioned in both lowlands and highlands, 74 and 87% respectively (Fig. 4). The use of trees as a medicine was the second most mentioned utilisation in both lowlands and highlands (66 and 18% respectively).

Table 3 All tree species cited and used by farmers in the study area and their descriptions

Scientific name	English name	Local name	Origin	Life form	Use	Lowland or Highland	Frequency (%)		
							L (38)	H (45)	LH (83)
Acacia nilotica	Thorny acacia	Gabaruwa	N	D	HF, M	L, H	2.6	0	1.2
Adansonia digitata L	Baobab	Kuuka	N	D	HF, AF, SI, M, FW, WB, S	L, H	55	28	40
Albizia coriaria	Women tongue acacia	Doruwan bature	I	D	AF, WB	H	0	2.2	1.2
Anacardium occiden-tale	Cashew	Kashew	I	D	F, HF, M, FW, WB, S	L, H	31	20	25
Annona sen-egalensis	Wild custard	Gwandar daaji	N	D	HF, AF, M, WB	L	10	0	4.8
Annona squamosa	Sugar apples	Gwadar Masar	I	D	HF	L	2.6	0	1.2
Anogeissus leiocarpus	African birch	Marke	N	D	F, AF, M, FW, WB, S	L, H	28	26	27
Azadirachta indica	Neem	Dogon yaro	I	D	F, AF, SI, M, FW, WB, S	L, H	60	22	39
Balanites aegyptica	Soap berry tree	Aduwa	N	D	HF, FW	L	13	0	6
Bombax costatum	Kapok	Gujiya	N	D	HF, AF, SI, FW, WB, S	L	0	4.4	2.4
Scientific name	English name	Local name	Origin	Life form	Use	Lowland or Highland	Frequency (%)		
							L (38)	H (45)	LH (83)
Borassus aethiopum	palmyra	Giiginya	N	E	F, FW, WB	L, H	7.8	8.8	8.4
Boswelia dalzieli	Frankincense	Ararrabi	N	D	M	H	0	2.2	1.2
Citrus spp.	Orange	Lemo	I	D	HF, M, WB	L, H	10	22	16
Cocos nucifera	Coconut	Kwakwa	I	E	F, HF, FW	H	0	8.8	4.8
Combretum hypopilinum	Combretum	Tarauniya	N	D	AF	L	7.8	0	3.6
Commiphora dalzielli	African myrrh	Qaro	N	D	M	H	0	2.2	1.2

Table 3 (continued)

Scientific name	English name	Local name	Origin	Life form	Use	Lowland or Highland	Frequency (%)		
							L (38)	H (45)	LH (83)
Daniellia olieveri	West African Kopal	Maaje	N	D	AF, M, FW, WB, S	L	0	8.8	4.5
Detarium microcarpum	Sweet detar	Taura	N	D	HF	L	2.6	0	1.2
Dichrostachys cinerea	Sickle bush	Dundu	N	D	FW	H	0	2.2	1.2
Diospyros mespiliformis	West African Ebony	Kanya	N	D	HF, AF, M, FW, WB, S	L, H	23	13	18
Elais guineensis	Oil palm	Kwakwan manja	N	E	F, HF, FW	H	0	6.6	3.6
Eucalyptus spp.	Eucalypt	Zaiti	I	D	M, FW, WB	H	0	8.8	2.4
Faidherbia albida	White acacia	Gawo	N	D	AF, SI, FW, WB, S	L, H	21	13	16
Ficus sycomorus	Sycamore fig	Baure	N	D	HF, AF, FW, WB, S	L	0	6.6	3.6
Scientific name	English name	Local name	Origin	Life form	Use	Lowlands or Highlands	Frequency (%) L (38)	H (45)	LH (83)
Ficus thonningii	Blume	Dirmi	N	D	F, AF, FW, WB, S	H	0	4.4	2.4
Gmelina fasciculiflora	Gmelina	Malaina	I	D	SI	L	15	0	15
Hyphaene thebaica	Doum palm	Goruba	N	E	F, HF	L, H	18	2.2	9.6
Jatropha curcas	Physic nut	Bita da zuku	I	D	F, M, FW, WB	H	0	8.8	4.8
Khaya senegalensis	Mahogany	Madaci	I	D	M, FW	H	0	6.6	3.6
Mangifera indica	Mango	Mangoro	I	D	F, HF, AF, SI, M, FW, WB, S	L, H	52	37	44
Moringa oleifera	Drum stick tree	Zogale gandi	I	D	F, HF, AF, SI, M, WB	L, H	21	26	24
Nauclea latifolia	African peach	Tafashiya	N	D	HF, SI, FW, WB, S	H	0	2.2	1.2
Newbouldia laevis	Boundary tree	Aduruku	N	E	F, M, FW, WB, S	L, H	2.6	8.8	6
Parkia biglobosa	Locust bean	Doruwa	N	D	HF, AF, SI, M, FW, WB, S	L, H	28	55	43
Phoenix dactylifera	Date palm	Debino	I	E	F, HF, M, FW	L, H	18	17	18
Pilistigma reticulatum	Camel's foot	Kargo	N	D	AF, SI, M, WB, FW, S	L, H	7.8	6.6	7.2
Prosopis africana	Iron wood	Kirya	N	D	AF, FW	L	13	0	6
Psidium guajava	Guava	Gweba	I	D	F, HF, AF, SI, M, FW, WB, S	L, H	36	24	30
Scientific name	English name	Local name	Origin	Life form	Use	Low Land-sor High lands	Frequency (%) L (38)	H (45)	LH (83)
Pterocarpus erinaceus	Blood tree	Madobiya	N	D	AF, M, WB	H	0	2.2	1.2

Table 3 (continued)

Scientific name	English name	Local name	Origin	Life form	Use	Low Landsor High lands	Frequency (%)		
							L (38)	H (45)	LH (83)
Sclerocarya birrea	Malura	Danya	N	D	HF, AF, M, FW, WB, S	L, H	5.2	2.2	3.6
Spondias mombin	Hog plum	Tsada	N	D	HF, AF, WB	H	0	2.2	1.2
Tamarindus indica	Tamarind	Tsamiya	N	D	HF, AF, SI, M, FW, WB	L, H	50	15	31
Tectona grandis	Teak	Tektoniya	I	D	FW, WB	L, H	2.6	4.4	3.6
Vernonia amygdalina	Bitter leaf	Shuwaka	N	D	HF, AF, FW, WB, S	H	0	2.2	1.2
Vitellaria paradoxa	Shea butter	Kadanya	N	D	HF, AF, SI, M, FW, WB, S	L, H	2.6	15	9.6
Vitex doniana	Black plump	Dinya	N	D	HF, AF, M, FW, WB, S	L, H	2.6	15	9.6
Vitis vinifera	Grapes	Inabi	I	D	HF	H	0	2.2	1.2
Ziziphus mauritiana	Chinese date	Magarya	N	D	HF, AF, M, FW, WB, S	L	13	0	6
Ziziphus spina-christi	Christ's thorn	Kurna	N	D	H, AF, M	L, H	5.2	2.2	3.6
Unidentified	Unidentified	Zuwo	N	D	AF, FW, WB, S	L, H	2.6	2.2	2.4
Dacryodes edulis	Monkey salt	Rukuki	N	D	HF	H	0	2.2	1.2
Commiphora kerstinghii	frankincense	Barmagada	N	E	F, FW	L, H	0	8.8	4.8
Unidentified	Fireproof calabash	Sharifin Kwarya	I	D	FW	H	0	2.2	1.2

Total Number of trees identified in the study area: 53, Origin: *N* Native, *I* Introduced, Life form: *D* Deciduous, *E* Ever green, Usage frequency: *F* Fencing, *HF* Human food, *AF* Animal feed, *SI* Soil improvement, *M* Medicine, *FW* Fuel wood, *WB* Wind break and *S* Shade.

Table 4 Tree species abundance on farms in lowlands and highlands

Lowlands						Highlands					
Latin name	English name	Darazo	Katagum	Gamawa	Total individuals	Latin name	English name	Toro	Dass	Ningi	Total individuals
Moringa oleifera	Moringa	0	3,730	0	3,730	*Moringa oleifera*	Moringa	489	34	7	530
Mangifera indica	Mango	383	1030	0	1,413	*Citrus* spp.	Orange	415	83	0	498
Citrus spp.	Orange	0	820	0	820	*Mangifera indica*	Mango	224	149	15	388
Psidium guajava	Guava	382	240	0	622	*Psidium guajava*	Guava	110	84	100	294
Azadirachta indica	Neem	251	195	96	542	*Jatropha curcas*	Physic nut	0	270	0	270
Phoenix dactylifera	Date palm	461	25	0	486	*Parkia biglobosa*	Locust bean	109	46	36	191
Tectona grandis	Teak	50	250	150	450	*Anacardium occidentale*	Cashew	45	23	30	98
Gmelina fasciculiflora	Gmelina	450	0	0	450	*Adansonia digitata*	Baobab	18	50	6	74
Anacardium occidentale	Cashew	100	170	0	270	*Azadirachta indica*	Neem	8	58	5	71
Adansonia digitata	Baobab	120	0	43	163	*Faidherbia albida*	White acacia	2	54	6	62
Annona squamosa	Sugar apples	0	160	0	160	*Phoenix dactylifera*	Date palm	9	26	0	35
Vitis vinifera	Grapes	0	160	0	160	*Newbouldia laevis*	Boundary tree	5	25	1	31
Tamarindus indica	Tamarind	119	0	22	141	*Anogeissus leiocarpus*	African birch	11	8	9	28
Anogeissus leiocarpus	African birch	73	0	46	119	*Borassus aethiopum*	Palmyra	0	28	0	28
Lowlands						Highlands					
Latin name	English name	Darazo	Katagum	Gamawa	Total individuals	Latin name	English name	Toro	Dass	Ningi	Total individuals
Ziziphus mauritiana	Chinese date	48	0	0	48	*Cocos nucifera*	Coconut	10	8	0	18
Borassus aethiopum	Palmyra	30	0	2	32	*Tamarindus indica*	Tamarind	3	0	14	17
Annona senegalensis	Wild custard	24	0	0	24	*Khaya senegalensis*	Mahogany	0	16	0	16
Balanite aegyptica	Soap berry tree	0	0	21	21	*Ficus sycomorus*	Sycamore fig	1	10	4	15
Piliostigma reticulatum	Camel's foot	0	20	0	20	*Eucalyptus* spp.	Eucalypt	0	13	0	13
Detarium microcarpum	Sweet detar	17	0	0	17	*Elais guineensis*	Oil palm	0	11	0	11
Faidherbia albida	White acacia	0	0	15	15	*Ficus thonningii*	Blume	5	3	2	10
Prosopis africana	Iron wood	0	0	14	14	*Ficus iteophylla*	Ficus	1	9	0	10
Vitex doniana	Black plum	10	0	0	10	*Gmelina fasciculiflora*	Gmelina	0	10	0	10
Ziziphus spina-christi	Christ's thorn	0	0	6	6	*Tectona grandis*	Teak	10	0	0	10
Sclerocarya birrea	Marula	0	0	3	3	*Hyphaene thebaica*	Doum palm	0	2	7	9
Vitellaria paradoxa	Shea butter	0	0	2	2	*Vernonia amygdalina*	Bitter leaf	0	2	4	6

Table 4 (continued)

Lowlands						Highlands					
Latin name	English name	Darazo	Katagum	Gamawa	Total individuals	Latin name	English name	Toro	Dass	Ningi	Total individuals
Acacia nilotica	Thorny acacia	0	0	1	1	*Nauclea latifolia*	African peach	0	0	5	5
Newbouldia laevis	Boundary tree	0	1	0	1	*Bombax costatum*	Kapok	0	5	0	5
Total					**9,782**					**2,854**	

Another important use was the production of animal feed (26 and 4% respectively). The use of trees for timber was not mentioned in either of the two agroecological zones (lowlands or highlands).

The ecosystem services provided by trees in the lowlands were mentioned much more often than in the highlands, especially fencing and shading (15 and 16%, respectively), while in the highlands, fencing and shading scored 9 and 2%, respectively. We found that windbreaks and soil improvement were the second most mentioned use, with scores of 8% each, respectively, in the lowlands (Fig. 5). Interestingly, there was no mention of soil improvement use of trees in the highlands.

Tree species preference

Different preferences for tree species were found in both agroecological zones (Table 5). In the lowlands, baobab was the most preferred species (scored 7.76 points) and the most used by farmers, followed by neem (scored 6.55 points) and moringa (5.51 points). In the highlands, we found that the most preferred species was the locust bean (scored 14.94 points), followed by mango (5.59 points) and moringa (4.64 points).

Detailed of most preferred species

It was found that farmers had a reasonable focus on the tree species with clear economic product, mostly derived from the sales of their fruits such as mango (*Mangifera indica)*, orange (*Citrus* sp), guava (*Psidium guajava*), and baobab (*Adansonia digitata*). The other preferred species were mostly native, underutilized, and for commercial and self-subsistence purposes such as black plum (*Vitex doniana*), palmyra (*Borassus aethiopum*), and Shea butter (*Vitellaria paradoxa)*. The data (qualitative) indicated that farmers had many shortcomings that affected the trees on their farms. Insufficiency of water, pests, and diseases were the most common challenges (Table 6). For the above-mentioned, control of both pests and diseases is needed to achieve maximum production by reducing their impact by using both local and modern control methods. Mentioning the traits of the trees, farmers had a significant interest in the size of the fruit and its taste. Moringa was mostly used for leaves as both food and medicine. The seeds were also in

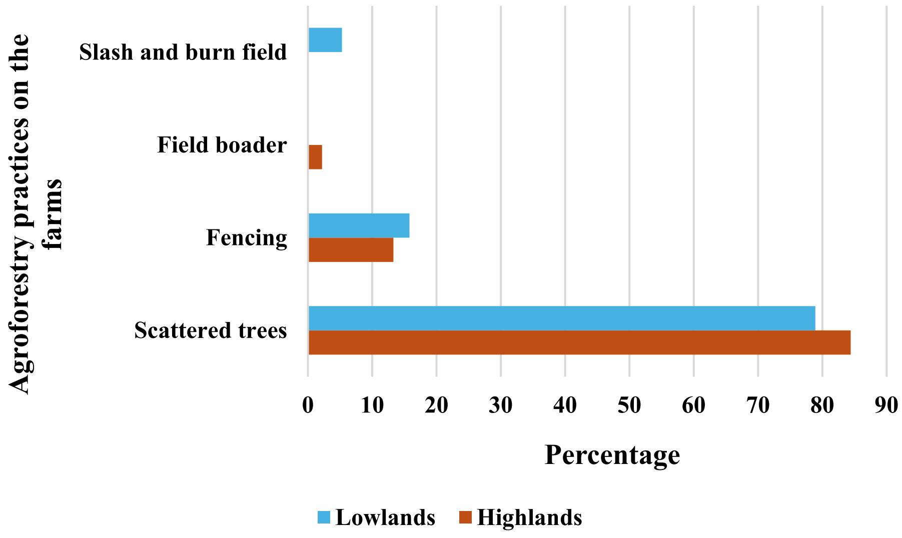

Fig. 2 Agroforestry practices on the farmers' plots

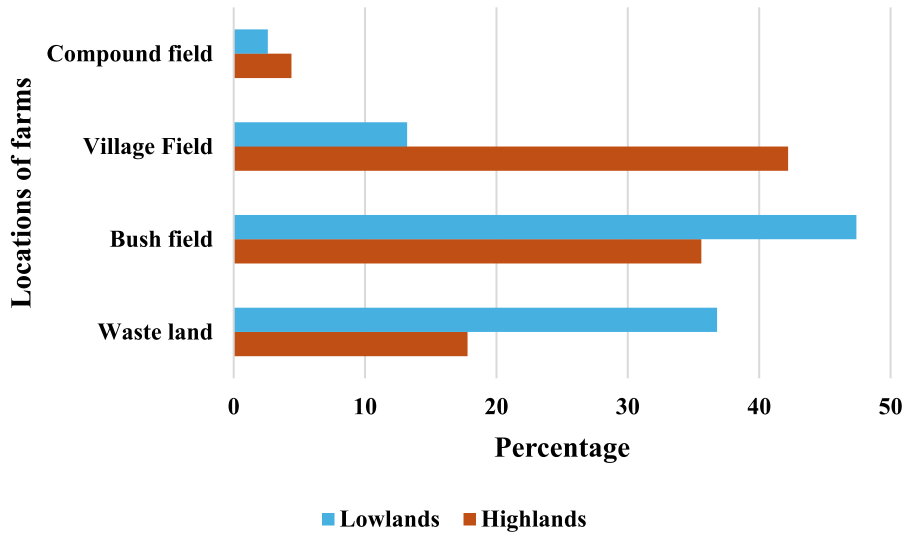

Fig. 3 Locations of farms' compounds

commercial demand, for propagation, medicine, oil extraction, and for medicinal purposes.

Discussion

Regarding the socio-economic description of respondents, the average farm size of a farmer in the lowlands was higher than in the highlands (Table 2). Furthermore, the farmer's annual income in the lowlands was higher than in the highlands. This is connected to the larger farm size and lower households of the average farmer in the lowlands compared to the highlands, which is consistent with (Sunday and Adam 2022; Maigari et al. 2023), who reported that smaller farm sizes and a higher number of households members were among the major constraints to saving among highland farmers.

Concerning the tree species in the study area, this study identified 53 species in both agroecological zones. It was the highest-ever recorded number of agroforestry tree species in the study area (Bauchi State). This was in contrast with Oyewole and Carsky (2001), Nodza et al. (2013), and Akpan et al. (2010), who reported 33, 47, and 9 species in their surveys, respectively, in the same study area.

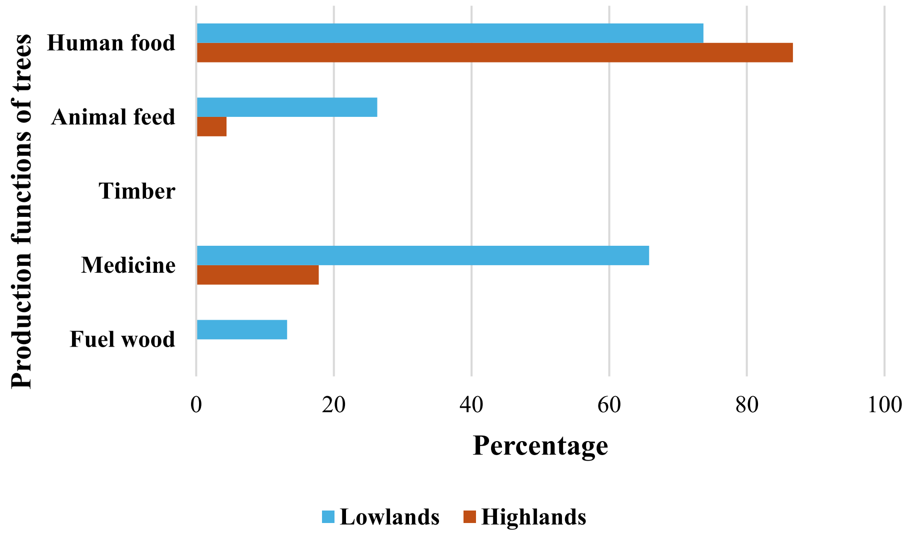

Fig. 4 The Production functions of trees

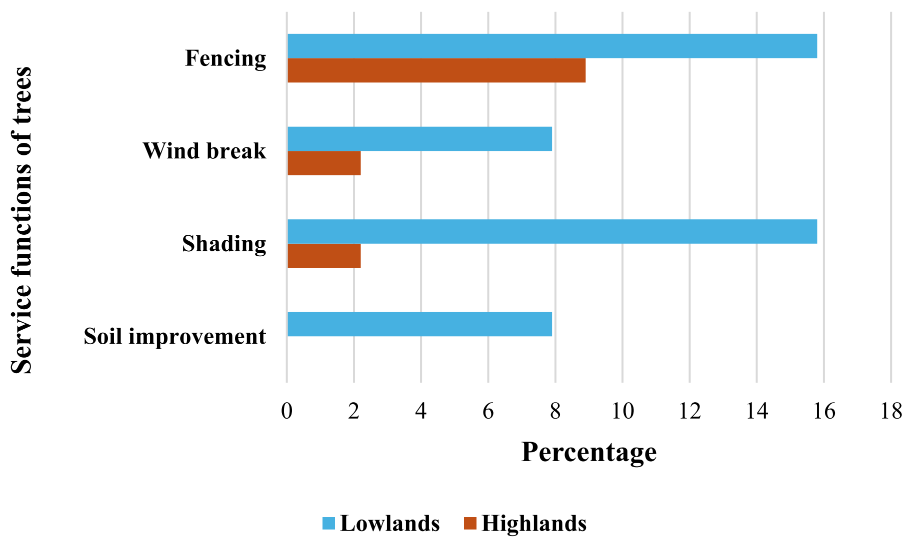

Fig. 5 The service function of trees

The highest number of species recorded by this study is probably due to the wider scope covered during the data collection compared to the previous studies. However, we found out that native species were more dominant than introduced species in both agroecological zones (37 vs. 16 respectively); this may be attributed to the fact that native species are more adaptive to the environment than the introduced ones. Eight of the tree species were unique only to the lowlands while 21 were unique to the highlands (Table 4). This shows species composition differences between the two agroecological zones due to variations in temperature, rainfall, altitude, humidity, soil (ecological condition), and human factors (introduction of some new species e.g., in the highlands' 21 unique species, *Cocos nucifera* and *Elais guineensis* were brought far from Southwestern Nigeria) between the two different agroecological zones. The two zones fall under different Climatic Classes: BSh (Mid-latitude steppe and desert climate) in the lowlands and Aw (tropical wet and dry or savanna climate) in the highlands, otherwise known as Sahel Savannah for the former and Sudan Savannah for the latter. These different climatic classes of the lowlands and the highlands could strongly affect plant species distribution, land

Table 5 Farmers 'preferences of tree species in Lowland and Highland

Lowlands								Highlands							
Latin name	English name	Origin	Darazo	Katagum	Gamawa	Total score	Ranking	Latin name	English name	Origin	Toro	Dass	Ningi	Total score	Ranking
Adansonia digitata	Baobab	N	0.72	0	7.04	7.76	**1**	*Parkia biglobosa*	Locust bean	N	3.82	4.82	6.3	14.94	**1**
Azadichrata indica	Neem	I	0.36	0.14	6.05	6.55	**2**	*Mangifera indica*	Mango	I	3.15	2.11	0.33	5.59	**2**
Mangifera indica	Mango	I	3.43	2.08	0	5.51	**3**	*Moringa oleifera*	Drumstick tree	I	1.83	0.65	2.16	4.64	**3**
Moringa oleifera	Drumstick tree	I	0	3.6	0	3.6	**4**	*Citrus* spp.	Orange	I	2.08	0.95	0	3.03	**4**
Tamarindus indica	Tamarind	N	1.85	0	0.83	2.68	**5**	*Psidium guajava*	Guava	I	1.25	0.5	0.66	2.41	**5**
Parkia biglobosa	Locust bean	N	2.52	0	0	2.52	**6**	*Adansonia digitata*	Baobab	N	0.66	0.83	0.58	2.07	**6**
Psidium guajava	Guava	I	1.22	0.5	0	1.72	**7**	*Faidherbia albida*	White acacia	N	0.25	1	0	1.25	**7**
Anacardium occidentale	Cashew	I	1.16	0.5	0	1.66	**8**	*Tamarindus indica*	Tamarind	N	0	0	1.24	1.24	**8**
Phoenix dactylifera	Date palm	I	0.99	0	0	0.99	**9**	*Jatropha curcas*	Physic nut	I	0	1	0	1	**9**
Diospyros mespiliformis	W/Africa ebony	N	0.7	0	0	0.7	**10–11**	*Cocos nucifera*	Coconut	I	0	0.91	0	0.91	**10–11**

Origin: N = Native, I = Introduced

Table 6 Specific description of the most preferred tree species in Bauchi State, Nigeria

Latin name	English name	Commercial or subsistence	Constraints	The use	Where/how is species	Pests and diseases	Harvest time	Source of planting material
Parkia biglobosa	Locust bean	Commercial	Shortage of water at the tender age	Seeds for seasoning	Wild grown on cropland	Termites at seedling	May–June	Seeds and seedlings
Mangifera indica	Mango	Both	Nurturing seedlings	Fruits for food	Orchard as scattered trees 5 m spacing	Bats/Stem end rot/ Aspegillus rot	April–May	Seedlings
Adansonia digitata	Baobab	Both	Animal destruction at early stage	Leaves for soup	Mostly near homes without proper management	No specified pest or disease	October–November	Seeds and cuttings
Moringa oleifera	Drum stick tree	Both	Irrigation and labour cost	Leaves for food and vegetable	Orchard and home as fencing 3 m between trees	Pod fly, budworm, red mites/fruit rot, stem rots	May–July	Seeds and Seedlings
Azadirachta indica	Neem	Subsistence	Nurturing seedlings	Leaves and bark for medicine	Both home and farm as boundary and scattered 5 m spacing -between stands	Ash weevil, myllocerus species /Fusarium oxysporum affects seedlings	March-November	Seeds and seedlings
Psidium guajava	Guava	Both	Animal destruction at early stage	Fruit size and taste for food	Orchard as scattered at 5 m between	Bats, birds/Physalopara psidii	August–September	Seeds and seedlings
Latin name	English name	Commercial or subsistence	Constraints	The use	Where/how is grow	Pests and diseases	Harvest time	Source of planting material
Citrus spp.	Orange	Both	Irrigation and cost of maintenance	Fruits and taste for food	Orchards and scattered at 4-5 m spacing between trees	Birds, bats, aphids, citrus white fly/greasy spot, sooty mold, root rot	August-January	Seeds and seedlings
Phoenix dactylifera	Date palm	Both	Irrigation at start	Fruit size and taste for food	At home as fence or scattered 3-5 m between stands	Insects and mites/ bayoud disease, black scorch, rotting of aerial offshoots	March–April	Seeds and seedlings
Anogeissus leiocarpus	African birch	Subsistence	Non	Whole tree for fuel	Wild grown without management	Red termites/fungal disease	All year round	Seeds by natural regeneration

Table 6 (continued)

Latin name	English name	Commercial or subsistence	Constraints	The use	Where/how is grow	Pests and diseases	Harvest time	Source of planting material
Vitellaria paradoxa	Shea butter	Subsistence	Non	Fruits taste for food	Wild grown without management	Birds, insects, worms/ fungal diseases	June-November	Seeds by natural regeneration
Diospyros mespiliformis	West African ebony	Subsistence	Non	Fruits taste for food	Wild grown without management	Birds, insects/fungus blight	May–June	Seeds by natural regeneration
Jatropha curcas	Physic nut	Subsistence	Irrigation	Leaves and exudates for medicine	Homegrown and on crop fields mostly as fencing at closed range 1-2 m between stand	Red termites/ Anthracnose	November-January	Seeds and cuttings
Cocos nucifera	Coconut	Commercial	Sourcing seedlings	The seed taste and size for food	Homegrown home gardens	Stem borers, red ants, hover fly/ root wilt	All year round	Seeds and seedlings
Annona squamosa	Sugar apple	Commercial	Kick-off cost	Fruit taste and size	Orchard -trees at 4-5 m	Mealy bug, yellow peach moth/soil fungi	February-November	Seedlings

use, tree biomass, shrubs and herbs, species differences, and farmers' preferences for woody species as reported in Tanzania, Nigeria, and Ethiopia (Ensslin et al. 2015; Halilu et al. 2024; Akinyemi and Ifejjika 2024).

Comparing the tree abundance, more trees were grown in the lowlands than in the highlands (Table 5). Firstly, farmers in the lowlands had larger farm sizes than their highlands counterparts and thus could plant more trees. Farmers in the lowlands were probably more interested in planting trees on their farms to control desertification. Neem tree is commonly planted as windbreaks in the lowlands, which is a challenging reality in their environment, and trees were found to control desertification and improve soil conditions (Borris et al. 2018; Reang et al. 2024; Nath et al. 2022). Another plausible reason for the increase in tree abundance in the lowlands was the preferred location of trees on farms. The bush field was the most preferred, and farms in that location were larger than those farms in the village field, which were commonly found in the highlands. Regarding tree species richness, *Moringa oleifera* was the most cultivated tree species in both zones. Although it was not the most preferred and not the most utilised in the lowlands and the highlands, it has great potential to improve local food security and income generation. Moringa is now very popular among farmers in both agroecological zones for its commercial value as a multipurpose tree used for many utility functions, including—medicine and consumption, among others, as in other African countries Ugwuoke and Ochiaka (2013).

Pertaining to the incorporation of trees into farmers' fields (agroforestry practice) (Fig. 2), contrary to the findings of (Idu et al. 2007; Oriola 2009; Oyewole & Carsky 2001), we found most mentioned agroforestry practice in both the lowlands and the highlands to be scattered trees on cropland. Some of the tree species were retained in the fields while clearing farms for cultivation (mostly native species), especially locust beans and baobab; the farmers also preferred scattered trees on their fields for relatively low competition for light, water, and nutrients with their herbaceous crops. This agroforestry practice mimics the natural savannah landscape. The second most mentioned agroforestry practice in both zones was tree fencing, which is mostly used as the boundary between farms of neighbouring farmers or shield against herders trespassing and wind break to protect the farms against windstorms.

With respect to the preference for the place of incorporating trees on different crop fields (locations of farms) (Fig. 3), bush fields and village fields were the most mentioned by the farmers in the lowlands and the highlands. The bush fields associated with the lowlands farmers are the most distant away (fields) from homes; they are larger than the village fields next to the compounds (farmers' settlements) associated with the highland's farmers. The variations in farm sizes affected their incomes as lowlands farmers earned more than highlands farmers. This corresponds with Zira et al. (2016), who reported that age, farm size, and farming experience could improve farmers' income. This preference in the locations of farms among farmers based on the two agroecological zones is first reported by this study in the Savannahs of Bauchi state.

In relation to the uses of trees, human food, medicine, and animal feed were dominant in both agroecological zones (Fig. 4). This shows the centeredness of the locals on trees for livelihood, both for subsistence and economy. This was in correspondence with the finding of (Oyewole and Carsky 2001; Idu et al. 2007) who reported trees in the area for the aforementioned uses. Other studies mentioned such production functions of trees in the Savannah zones of Nigeria and the global south (Salami and Lawal 2018; Nyaga et al. 2015). Further research in the study area on medicinal trees would be of great benefit, especially to know the specific parts of the trees used in that aspect, and laboratory analysis of the tree biomass would be crucial.

Interestingly, tree use as timber was not mentioned among farmers either in the lowlands or in the highlands (Fig. 4). This is probably due to the dependence of the farmers and the locals on wild species found outside farmers' fields, importation of timber products from neighbouring regions, and the longer time, financial burden, and silvicultural management needed by timber species to grow (Mazadu et al. 2014; Mohammed 2014). However, the study identified a blood tree (*Pterocarpus erinaceus)* which is normally spared in the fields of the study area mostly for medicine, and it is a good timber species, fast-growing and indigenous, which could be a good timber species in the agroforestry farms of the Savannah zones. We also found fencing and shading to be the key ecosystem services farmers mentioned in the lowlands and the highlands (Fig. 5). Trees are used here as the boundary between the farms, watershed, or surrounding farms as protection against wind and trespassing of extensive animal herders in the area. Borris et al. (2018), Nodza et al. (2013), and Oriola (2009) also reported such services rendered by trees in their studies.

With reference to tree species preference, baobab was the most preferred species in the lowlands, while in the highlands, the most preferred species was the locust bean (Table 5). Both species are typical multipurpose trees; baobab is used as vegetables, either raw or dried (the leaves), the mesocarp (in powdered form) is used as beverages, and the bark (raw or dried) is used as medicine, especially blood enhancement in pregnant women and people with anaemia. The locust bean is used for seasoning (the seeds), the leaves are used as fodder in the off-season, and the mesocarp is used as a meal in pap, served mostly as breakfast or mixed with staple foods as lunch and dinner. Besides the production function of those tree species, they also serve in services like soil improvement (through litter fall), water infiltration and aeration (through root systems), windbreaks, shade, and landmarks within or between farms. These differences in species preferences among the farmers according to the lowlands and the highlands were first reported by this study. However, some studies (Oyewole and Carky, 2001; Idu et al. 2007) mentioned some of the species as a priority in the area. This implies that if policymakers would develop and introduce the improved variety of baobab (*Adansonia digitata)* and locust bean (*Parkia biglobosa),* which were the most preferred species in the study area, and encourage the farmers to promote them, they may accept them without hesitation for their uses is clear to the farmers.

It was, however, observed that farmers had many challenges in cultivating the priority species (as shown in Table 6), especially by the infestation of pests and diseases: flower abortion (in mango), stem end rot/Aspergillus *rot*, fruit rot, *Fusarium oxysporum* that affects seedlings, *Physalopara psidii,* and *Anthracnose*. Some pests such as soil fungi, termites, worms, red ants, stem borer beetles, and bats, among others, affect trees both at seedlings, developmental, and in the fruiting stages, which leads to many complications for the farmers, such as poor tree product, quality, and quantity. These (pests and diseases) were also reported by (Onyeani et al. 2012; Ojiako et al. 2011) as the major challenges that reduce tree production, quality, and vigor in the Savannah zones of Nigeria.

Conclusion

This research focused on identifying farmers' tree species, species abundance, agroforestry practices, the location of farms, use of agroforestry trees, and their tree species priorities in the lowlands and highlands of Bauchi State, Nigeria. In total, 53 tree species were identified by local farmers in both the lowlands and the highlands of the study area, where more trees were found in the lowlands. The most abundant tree species was found to be moringa (*Moringa oleifera),* both in the lowlands and the highlands. The most preferred integration of trees into local farming systems (agroforestry practice) in both agroecological zones was scattered trees on cropland. The most mentioned places for incorporating trees on crop fields (locations of farms) were bush fields and village fields in the lowlands and the highlands. The tree products (fruits, leaves, pods, barks, and roots) were intended mainly for human consumption and medicinal uses. Also, various service functions were among the reasons why the farmers grew trees in the study region (Bauchi state); fencing, shading, and windbreaks were mentioned as the most important. The preferred tree species differed between lowlands and highlands. The most preferred tree species for the lowlands was baobab (*Adansonia digitata)*, while for the highlands was locust bean (*Parkia biglobosa)*. These species are typical multipurpose trees, used as food and medicine, and almost all their parts are utilised.

Farmers prefer fruit species so that we would recommend some improvement on varieties of those fruit/food trees and more research on them; policymakers should develop and introduce improved native species that could be highly disease-resistant and pest-tolerant. The improved varieties should also be highly productive in yield quality and quantity, especially of the most preferred species.

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Author's contribution AYT: Research design, literature review, data collection, and first draft. MYM: Questionnaire design, data analysis, and point-to-point response letter. AM: Supervision, manuscript review, and validation. RKM: Questionnaire designing, data curing, and formatting. BL: Supervision, sourced funding, administration, and review.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors have no financial or non-financial interests that may influence the results of this study. The authors declare no competing interests.

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