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Assessment of indigenous knowledge on propagation of native trees in the agro-ecological zone of Ghana

Abdul-Aziz Adam · Dzigbodi Adzo Doke · Rikke Reisner Hansen · Anne Mette Lykke · Felix Kofi Abagale · Albert Kojo Quainoo

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Abstract Despite the ecological and socio-economic importance of native trees to rural livelihoods in West Africa, indigenous knowledge and scientific validation of their propagation remains poorly documented, especially in northern Ghana. In this study, we assessed local knowledge on the propagation of four key multipurpose native tree species, *Adansonia digitata, Parkia biglobosa, Lannea microcarpa,* and *Bombax costatum,* in the Guinean savanna agro-ecological zone of Ghana to inform domestication strategies. From September to October 2022, we conducted fieldwork across 13 communities in the Kassena Nankana municipality, Kumbungu district, and Nandom municipality. We used semi-structured questionnaires to interview 260 respondents (138 males and 122 females) selected through purposive sampling with local leaders. Our results revealed significant variations in propagation knowledge, fruiting perceptions, and perceived tree population trends across locations and age groups. Most respondents relied on seed-based propagation, while few had knowledge of vegetative techniques. Older participants, especially those aged 50–69, demonstrated greater propagation knowledge, particularly for *P. biglobosa*. Communities reported that fruit maturation varied seasonally and by location. Livestock herbivory emerged as the main constraint to seedling survival, alongside cultural taboos and ecological barriers such as seed dormancy. These findings highlight the importance of integrating indigenous knowledge into tree domestication and conservation strategies. By embedding this knowledge into policy and reforestation initiatives, we can promote more culturally relevant, ecologically sound, and socially inclusive approaches to landscape restoration and rural development.

Keywords Indigenous knowledge · Trees · Ethnobotanical · Propagation · Domestication

A.-A. Adam (✉) · D. A. Doke · F. K. Abagale
West African Center for Water Irrigation and Sustainable Agriculture (WACWISA), University for Development Studies, P.O. Box TL 1882, Tamale, Ghana
e-mail: azizadam14@gmail.com

A.-A. Adam · D. A. Doke
Department of Environment and Sustainability Sciences, University for Development Studies, Tamale, Ghana

A.-A. Adam
Department of Natural Resource Management, Tamale Technical University, Tamale, Ghana

R. R. Hansen · A. M. Lykke
Department of Ecoscience, Aarhus University, Aarhus, Denmark

A. K. Quainoo
Department of Biotechnology, University for Development Studies, Tamale, Ghana

Introduction

Trees play a critical ecological role and are fundamental components of terrestrial ecosystems. They

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contribute significantly to biogeochemical processes such as nutrient cycling and carbon sequestration, while also influencing soil formation, hydrology, and climate regulation (Sjöman et al. 2024). Indigenous tree species, sometimes referred to as native species, which have evolved in specific regions over ages, are well adapted to local environmental conditions and are closely associated with native fauna, including birds and pollinating insects (Wilkinson et al. 2014). These trees provide numerous benefits to rural communities, including food, nutrition, medicine, income, and raw materials for housing, fuel, fibre, and resin (Awodoyin et al. 2015; Leakey 2012).

In agricultural landscapes, indigenous trees perform multiple functions by promoting environmental sustainability and supporting livelihoods, particularly through agroforestry systems (Gouwakinnou et al. 2011). In northern Ghana, key native species include *Parkia biglobosa*, *Vitellaria paradoxa*, *Adansonia digitata*, *Bombax costatum*, and *Lannea macrocarpa*. These species are valued for both their socio-economic and ecological contributions.

Despite their ecological and socio-economic importance, native tree species across West Africa are increasingly threatened by habitat degradation, overexploitation, and lack of active conservation measures, leading to reported population declines in multiple regions (Ræbild et al. 2012; Belem et al. 2008; Lykke et al. 2025). Recent afforestation programs in Ghana, such as the Green Ghana Project and the Youth in Afforestation Programme, focus mostly on exotic fast-growing species (Forestry Commission 2022). Unfortunately, these programs often exclude native trees, which are more ecologically suitable and culturally significant. As a result, they contribute to the erosion of indigenous genetic resources and threaten long-term ecosystem resilience (Okunlola et al. 2011).

Moreover, many tree planting interventions are primarily guided by technical considerations and external knowledge systems, often overlooking the practical insights and needs of local communities (Brancalion and Holl 2020), an exclusion that has frequently contributed to project failures (Ayantunde et al. 2008). In contrast, rural farmers possess rich experiential knowledge rooted in generations of environmental interaction and traditional resource management practices (Brook and McLachlan 2008). Such indigenous knowledge systems are increasingly recognized as essential tools for biodiversity conservation, sustainable resource management, and the successful domestication of native tree species (Berkes et al. 2000; Uprety et al. 2011).

Unlike previous studies that primarily emphasized the economic value, cultural significance, or ecological functions of specific native tree species (Gouwakinnou et al. 2011; Houehanou et al. 2011), this study focuses specifically on indigenous propagation knowledge. While some ethnobotanical research in Ghana has emphasized the ecological or economic value of native species like *V. paradoxa* and *P. biglobosa* (Lovett and Haq 2000; Elias and Carney 2007), very few have explored how propagation knowledge of native trees varies across demographic groups or ecological settings. Even fewer have investigated this knowledge across multiple species and culturally diverse regions. This lack of targeted research into local propagation practices, especially in relation to age, location, and phenological insights, constitutes a critical knowledge gap that this study aims to address.

This study investigates indigenous propagation knowledge across three ecologically and culturally distinct districts: Kassena Nankana, Kumbungu, and Nandom, located in the Guinean savanna agro-ecological zone of northern Ghana. These districts were purposively selected based on their strong reliance on native tree species for livelihoods, differences in traditional land management systems, and varying degrees of exposure to conservation and afforestation programs. They also differ in their ecological conditions, farming systems, and cultural beliefs surrounding tree use and planting (Ghana Statistical Service (GSS) 2021; Backes 2001; Amoako 2012; Asare et al. 2013). This diversity offers a valuable socio-ecological gradient for assessing how context influences indigenous knowledge systems and propagation practices.

By documenting how local communities propagate native trees, this study provides practical insights for policy and reforestation planning. It supports more culturally grounded and ecologically sound restoration efforts. These insights can guide reforms to better integrate native species into afforestation programs, improve seedling survival using locally adapted practices, and strengthen community engagement in conservation. This study therefore, assessed the indigenous knowledge related to the propagation of four multipurpose native trees, *A. digitata*, *P. biglobosa*, *L. macrocarpa*, and *B costatum,* across three locations in the Guinean savanna agro-ecological zone of northern Ghana. Specifically, the study investigated: (i) the local experiences in propagating these species, (ii) the variations in fruiting seasons across locations, (iii) the changes in tree population status over the past two decades, and (iv) the key constraints to tree seedling survival, among age groups across the three locations.

Hypothesis

The study tested the hypothesis that indigenous knowledge on propagation, fruiting periods, and perceived population trends of *A. digitata*, *P. biglobosa*, *L. microcarpa*, and *B. costatum* significantly differs across age groups and study locations.

Null Hypothesis (H_0): There are no significant differences in indigenous knowledge on the propagation, fruiting periods, and perceived population trends of native trees across age groups and study locations.

Alternative Hypothesis (H_1): Indigenous knowledge on the propagation, fruiting periods, and perceived population trends of native trees significantly varies across age groups and study locations.

Materials and methods

Study area

The study was conducted from September to October 2022 in 13 communities within the Guinean savanna agro-ecological zone of Ghana, specifically in the Kassena Nankana Municipality (Upper East Region), Kumbungu District (Northern Region), and Nandom Municipality (Upper West Region). These sites were purposively selected based on the presence of the four focal native species (*A. digitata, P. biglobosa, Lannea microcarpa,* and *B. costatum*), cultural relevance, accessibility for fieldwork, and differences in exposure to afforestation and conservation programs.

Kassena Nankana Municipality lies between latitudes 10°40′N–11°10′N and longitudes 1°10′W–1°00′W. It receives an average annual rainfall of approximately 950 mm, with temperatures ranging between 18 °C and 42 °C. Common trees include *P. biglobosa, A. digitata, V. paradoxa,* and *Mangifera indica.*

Kumbungu District spans latitudes 9°35′N–9°45′N and longitudes 0°57′W–1°07′W, with an average annual rainfall of about 1000 mm and temperatures fluctuating between 15 °C and 42 °C. The vegetation consists of grassland interspersed with drought-resistant trees such as *P. biglobosa, V. paradoxa,* and *M. indica*.

Nandom Municipality lies between latitudes 10°20′N–11°00′N and longitudes 2°25′W–2°45′W. It experiences daily temperatures from 23 to 42 °C and about 950 mm of annual rainfall. Its vegetation comprises short grasses and scattered fire-resistant species like *V. paradoxa, A. digitata,* and *Acacia Senegal* (Ghana Statistical Service 2014).

The study communities included Chiana, Kologo, Naaga, and Pindaa (Kassena Nankana); Gbullung, Gizaa, Gundaa, Jakpahi, and Kpalga (Kumbungu); and Kussele, Lisa, Munyapelli, and Tuoperi (Nandom). Figure 1 shows the geographic locations of these communities, based on GPS coordinates collected during field reconnaissance, to illustrate the spatial distribution of the study sites within the Guinean savanna agro-ecological zone.

Characteristics of selected native trees

Adansonia digitata (baobab) is one of Africa's most important indigenous fruit trees targeted for domestication (Gebauer et al. 2016). However, natural populations are under increasing pressure due to agricultural expansion, infrastructure development, and land use change (Duvall 2007). Propagation methods include sexual reproduction via seeds and asexual methods such as grafting, cuttings, and in vitro techniques (Agbohessou et al. 2020; N'doye et al. 2012; Anjarwalla et al. 2016; Egbadzor and Akuaku 2022).

Parkia biglobosa thrives under diverse environmental conditions, with annual rainfall ranging from 600 to 1500 mm and a dry season lasting 5–7 months (Abbas et al. 2018). While seed propagation is the most widely used method, vegetative approaches such as root cuttings, air layering, and tissue culture are also reported (Lamien et al. 2011).

Lannea microcarpa is a dioecious species confined to the Sudanian zone and is commonly integrated into agroforestry systems. It prefers areas with annual rainfall between 500 and 1100 mm and is primarily propagated by seed (Sinsin and Kampmann 2010; Haarmeyer et al. 2013; Neya 2006).

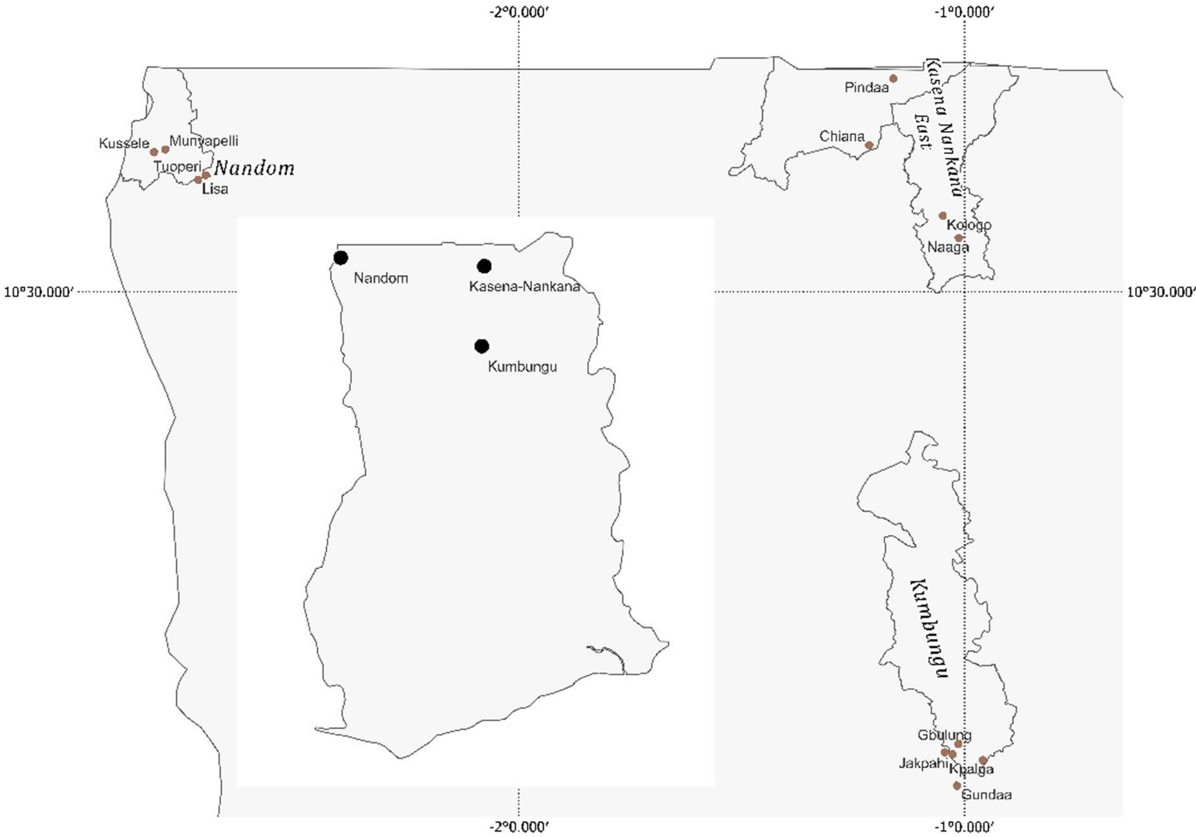

Fig. 1 Map of study communities in the Guinean savanna agroecological zone

Bombax costatum occurs in areas receiving 800–1500 mm of annual rainfall. It is typically propagated through seeds and vegetatively via root cuttings, air layering, grafting, and sucker stimulation (Belem 2009; Oyen 2011).

Data collection procedure

Sampling design and rationale

This study used a multistage purposive sampling approach. At the national level, the northern ecological belt was selected due to its rich biodiversity and high reliance on native trees. Within this belt, three administrative regions were considered for their variation in socio-cultural practices and land-use systems. At the district level, sites were selected to reflect ecological and cultural variation. Communities within each district were identified based on the presence of native tree populations and community willingness to participate.

Sample size determination

A total of 260 respondents were selected using Cochran's formula for categorical data (Cochran 1977). The formula is given as:

$$n_0 = \frac{.p.(1-p)}{e^2},\ n_0 = \frac{(1.96)^2.0.5.(1-0.5)}{(0.06)^2},\ \mathrm{n}_0 = 267$$

.

Where: n_0=sample size; Z = Z-value (1.96 for 95% confidence level), p = estimated proportion of an attribute (commonly 0.5 when unknown), e = desire level of precision or margin of error (eg 0.06 for ± 6%).

Although the calculated sample size was 267, we used a final sample of 260 respondents for practical implementation. This number was considered statistically robust, logistically feasible, and consistent with standard practices in ethnobotanical and indigenous knowledge research, where depth of information is prioritized over broad population generalizability (Tongco 2007). The sample allowed adequate representation across the 13 study communities and four generational age groups.

The combined population of the three study districts, Kassena Nankana Municipality**,** Kumbungu District, and Nandom Municipality, is approximately 261,809 (Ghana Statistical Service (GSS) 2021). The sample size of 260 therefore, represents about 0.10% of the total population. While this proportion may appear small, it is appropriate for qualitative research where the aim is to obtain rich, contextual insights from individuals with specific knowledge. Stratification by age and spatial distribution across all communities further strengthened the representativeness of the sample within the study's scope and objectives.

Participant selection and ethical considerations

Criterion-based purposive sampling was used to select informants. Individuals were identified with assistance from community leaders based on their observable engagement with native tree propagation. Participants included farmers, herbalists, traditional custodians, and traders. The classification of respondents into four age groups (15–29, 30–49, 50–69, 70 + years) was informed by generational cohorts often used in rural demographic studies. Age was prioritized because ecological knowledge is typically acquired over time, with older individuals more likely to retain long-term experiential knowledge of tree use, fruiting behavior, and regeneration patterns. Although gender and community role diversity were considered during participant selection to ensure inclusivity, the primary classification variable was age, based on its widely recognized association with knowledge accumulation and transmission in ecological studies (Ayantunde et al. 2008). Socioeconomic variables such as income and education were excluded to maintain focus on ecological knowledge transmission.

Before data collection, verbal informed consent was obtained after explaining the purpose of the study, confidentiality, and voluntary participation. The research protocol was reviewed and approved by the supervisory team. No personal identifiers were recorded. Community entry was facilitated through local leaders to ensure cultural appropriateness and consent.

Data collection procedure

Prior to fieldwork, three research assistants and six community-based facilitators were trained. The interview guide was pre-tested in August 2022 with 12 respondents from demographically similar but non-sampled communities. The pre-test helped refine question clarity, sequencing, and cultural sensitivity.

Data were collected simultaneously across all three districts within a one-month period (September–October 2022). This was made possible through advance planning, team deployment across sites, and coordination with local leaders. The use of semi-structured interviews allowed flexibility and depth during interactions, supporting high-quality data within a short timeframe.

Data analysis

Quantitative data were analyzed using SPSS Version 26.0. Chi-square (χ^2) tests were used to test associations between demographic variables (location and age) and indigenous knowledge variables (propagation methods, fruiting seasons, population trends, and survival constraints). Statistical significance was determined at $p < 0.05$.

Limitations

While this study provides valuable insights, it has limitations. Socioeconomic variables were not examined, limiting the analysis of broader social determinants. The purposive sampling technique, while effective for accessing knowledge-rich individuals, may limit generalizability. Additionally, recall bias may have affected responses regarding historical population trends and fruiting periods.

Results

Knowledge of the propagation of trees in the study locations

Indigenous knowledge on the propagation of native trees varied significantly among the three study locations for *A. digitata* ($\chi^2 = 21.9$, $p < 0.005$), *P. biglobosa* ($\chi^2 = 39.0$, $p < 0.000$), and *L. microcarpa* ($\chi^2 = 22.4$, $p < 0.001$). The highest levels of propagation experience for *A. digitata* (32.0%) and *P. biglobosa* (29.0%) were recorded in Kassena Nankana, in contrast to 8.0% and 12.0% respectively in Kumbungu. For *L. microcarpa*, the highest experience (17.6%) was observed in Nandom compared to 5.1% in Kumbungu.

The relatively low propagation experience in Kumbungu may reflect a combination of factors, including customary beliefs about tree planting, land tenure arrangements, limited incentives for active propagation, or a greater reliance on natural regeneration.

Seed propagation was the dominant method used across all species, practiced by an average of 29.4% of respondents. In contrast, budding was the least used method (0.3%). Specifically, for *A. digitata*, 51.0% of respondents used seeds, while only 1.0% used grafting or budding. For *P. biglobosa*, 49.0% relied on seeds, with only 1.0% using grafting and none using budding. *Lannea. microcarpa* was mostly propagated by seeds (13.8%), and rarely through grafting (1.3%). For *B. costatum*, 3.8% each used seeds and cuttings, with no reports of grafting or budding use (Fig. 2).

This pattern suggests a general familiarity with seed-based techniques among respondents, possibly due to their simplicity, accessibility, or traditional use.

Knowledge of fruit maturity times in study locations

Perceptions of fruit maturity periods differed significantly across study locations for *A. digitata* ($\chi^2 = 55.2$, $p < 0.000$), *P. biglobosa* ($\chi^2 = 30.1$, $p < 0.000$), *L. microcarpa* ($\chi^2 = 12.7$, $p < 0.048$), and *B. costatum* ($\chi^2 = 35.1$, $p < 0.000$). In Kumbungu, 68.0% of respondents observed that *A. digitata* fruits mature between October and December, compared to 30.0% in Kassena Nankana. For *P. biglobosa*, 81.0% of respondents in Kumbungu reported fruiting between April and June (onset of rains), against 47.0% in Kassena Nankana. For *L. microcarpa*, 90.0% of Kassena Nankana informants reported fruit maturity in April to June, compared to 75.0% in Kumbungu. *B. costatum* maturity was most commonly

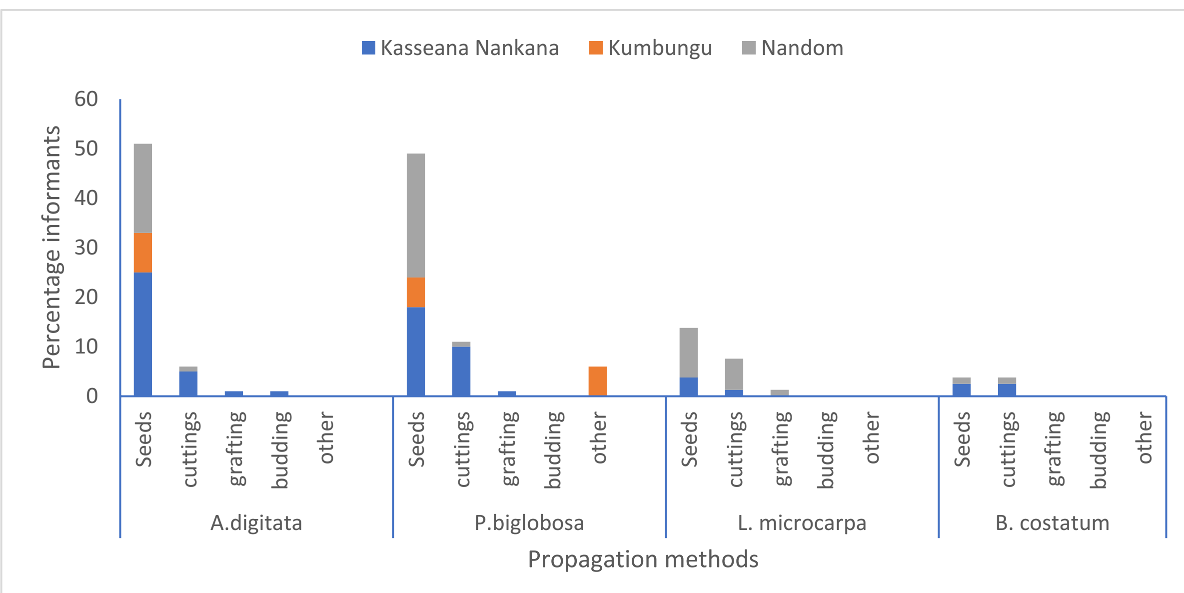

Fig. 2 Propagation knowledge and experience of indigenous trees

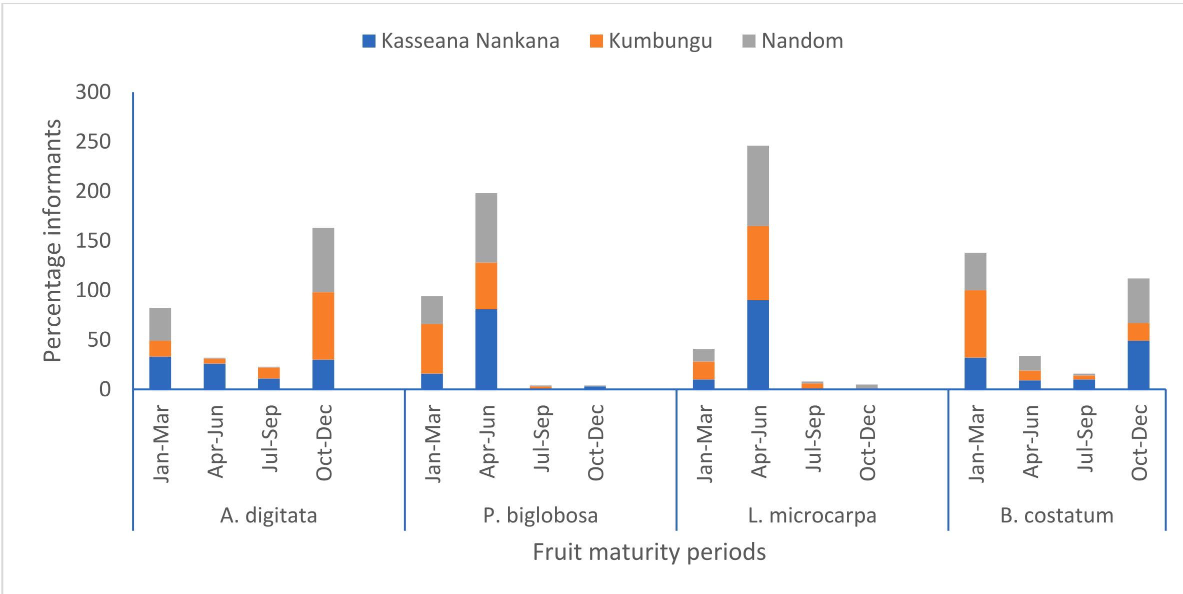

Fig. 3 Fruit maturity periods in the study location

observed between January and March in Kumbungu (68.0%) versus 32.0% in Kassena Nankana (Fig. 3).

Perceptions of fruit maturity periods across locations, indicate localized ecological observations or differences in seasonal awareness. Respondents from Kumbungu more frequently associated fruiting with the dry or transition seasons, while those in Kassena Nankana reported earlier maturity for some species.

Knowledge on changes in tree population status in the study locations

Observations of changes in tree population status over the past two decades varied significantly across the study sites. Significant differences were observed for *A. digitata* ($\chi^2=61.7$, $p<0.000$), *P. biglobosa* ($\chi^2=44.5$, $p<0.000$), *L. microcarpa* ($\chi^2=75.9$, $p<0.000$), and *B. costatum* ($\chi^2=59.6$, $p<0.000$). Kumbungu recorded the highest average decline (93.0%) across all four species. Specifically, 96.0% of respondents in Kumbungu reported declines in both *A. digitata* and *P. biglobosa*, 91.0% in *L. microcarpa*, and 88.0% in *B. costatum*. This contrasts with Kassena Nankana, where respective decline rates were lower: 65.0%, 72.0%, 56.0%, and 58.8% (Fig. 4).

Perceived highest declines in tree population in Kumbungu across all species, may be partly explained by limited propagation practices in the area, possibly influenced by traditional customs, land tenure systems, or a reliance on natural regeneration over active planting.

Influence of informant's age on population, propagation and fruit seasons on native trees

Age significantly influenced propagation knowledge for *P. biglobosa* ($\chi^2=25.65$, $p<0.012$), with the 50–69 age group reporting the highest experience (35.3%), compared to only 3.6% in the 15–29 age group. Age also significantly influenced perceptions of population decline in *A. digitata* ($\chi^2=26.85$, $p<0.008$), with respondents aged over 70 reporting the highest perceived decline (93.4%), compared to 63.6% in the youngest group.

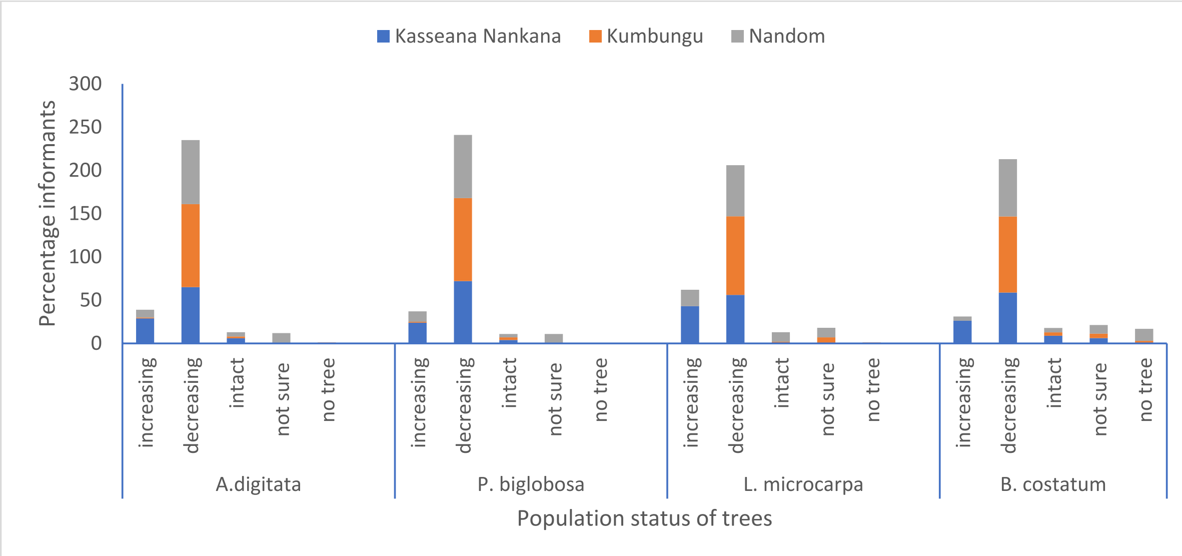

Fig. 4 Population status of native trees in the study location

However, age did not significantly influence knowledge of fruiting periods for any of the species, nor did it significantly affect propagation knowledge for *A. digitata*, *L. microcarpa*, and *B. costatum* or perceived populations of *P. biglobosa, L. microcarpa* and *B. costatum* (Table 1).

Older respondents reporting more propagation experience for *P. biglobosa* and perceive population declines in *A. digitata,* may reflect their longer-term engagement with the landscape and cumulative knowledge. These highlight a clear intergenerational knowledge gap, with younger respondents possessing limited propagation knowledge and less awareness of tree population changes. This gap poses a potential risk for the continuity of indigenous ecological knowledge, particularly as older knowledge holders age.

Constraints to seedling survival in study locations

Livestock herbivory was the major constraint to seedling survival across all locations, with an average of 42.0% of informants attributing seedling destruction by herbivory, followed by drought (18.0%) and bushfires (16.0%), and the least was mechanization (3.0%) (agricultural land preparation) (Fig. 5).

Livestock herbivory as the main constraint indicates a widespread challenge in protecting young trees in open landscapes. Drought and bushfires were also notable concerns, while mechanized land preparation was mentioned less frequently. These findings suggest that natural and human-induced pressures continue to affect early-stage regeneration.

Discussion

Knowledge of the propagation of trees in the study locations

This study found significant geographic variation in indigenous knowledge of tree propagation, statistically supported by Chi-square results for *A. digitata* ($\chi^2 = 21.9$, $p < 0.005$), *P. biglobosa* ($\chi^2 = 39.0$, $p < 0.000$), and *L. microcarpa* ($\chi^2 = 22.4$, $p < 0.001$).

Table 1 Relations between the age group and tree knowledge

Tree	Age group (years)	Percentage informants													
		Seeds	Cuttings	Grafting	Budding	other	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Increasing	Declining	intact	not sure	no tree
Adansonia digitata	15–29	5.5	0	0	0	0	33	18	5	44	23.6	63.6	5.5	7.3	0
	30–49	17.8	1.9	0	0	0	25	6	11	58	10.3	79.4	5.6	4.7	0
	50–69	25	4.4	1.5	1.5	0	25	13	6	56	10.3	86.7	1.5	1.5	0
	> 70	10	0	0	0	0	20	7	7	66	0	93.4	3.3	0	3.3
Parkia biglobosa	15–29	1.8	0	0	0	1.8	27	71	0	2	16.3	69.1	7.3	7.3	0
	30–49	19.6	2.8	0	0	2.8	36	59	3	2	10.3	81.3	4.7	3.7	0
	50–69	23.5	7.4	1.5	0	2.9	31	68	1	0	13.2	85.3	0	1.5	0
	> 70	6.7	3.3	0	0	0	33	67	0	0	3.3	96.7	0	0	0
Lannea microcarpa	15–29	0	0	0	0	0	7	89	2	2	34	58	4	4	0
	30–49	6.5	2.8	0	0	0	18	76	4	2	13	73	6	8	0
	50–69	5.9	1.5	1.5	0	0	15	79	4	2	19.1	69.1	4.4	5.9	1.5
	> 70	0	6.7	0	0	0	7	93	0	0	10	86.7	0	3.3	0
Bombax costatum	15–29	0	0	0	0	0	38.2	18.2	3.6	40	12.7	61.8	9.1	9.1	7.3
	30–49	2.8	0.9	0	0	0	51.4	11.2	5.6	31.8	10.4	68.2	8.4	6.5	6.5
	50–69	0	1.5	0	0	0	48.5	8.8	5.9	36.8	8.8	80.9	0	8.9	1.4
	> 70	0	3.3	0	0	0	50	3.3	6.7	40	3.3	86.7	3.3	0	6.7

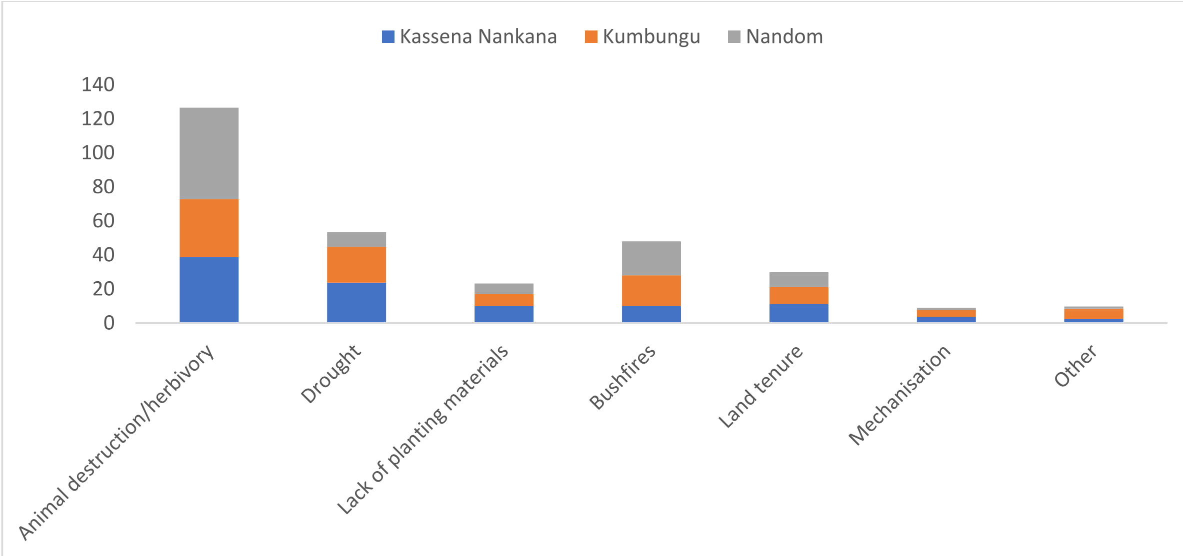

Fig. 5 Constraints to survival of tree seedlings in study locations

These findings indicate that differences in propagation experience across districts are not due to random variation but reflect real structural and cultural disparities in knowledge systems and practices.

Specifically, the higher propagation experience recorded in Nandom and Kassena Nankana for all three species likely stems from stronger community dependence on the ecosystem services these trees provide, as well as more frequent exposure to tree domestication initiatives. These statistically significant trends align with existing literature emphasizing the role of livelihood integration and cultural familiarity in shaping propagation behavior (Assogbadjo et al. 2012, Gouwakinnou et al. 2011, Schreckenberg et al. 2006).

Conversely, the Chi-square analysis revealed consistently lower propagation knowledge in Kumbungu across all species. This pattern suggests structural limitations beyond just ecological conditions. It may reflect local socio-cultural constraints, such as spiritual taboos associated with planting *A. digitata*, and limited extension exposure, both of which restrict the diffusion of propagation knowledge. Previous studies by Tomomatsu (2014) and Wickens and Lowe (2008) confirm that in some African communities, *A. digitata* planting is discouraged by beliefs in spiritual ownership or ancestral custodianship. Such taboos can discourage proactive cultivation even where ecological conditions are suitable.

Additionally, land tenure insecurity and fragmented local governance systems, as discussed by Smith et al. (1996), may inhibit collective planting efforts, particularly for *P. biglobosa*. These socio-institutional barriers correspond with the statistically lower engagement in propagation reported in Kumbungu, highlighting the critical need to address not only technical knowledge gaps but also the cultural and institutional contexts that shape planting decisions.

Customizing agroforestry interventions to reflect these localized cultural beliefs and governance dynamics is essential for improving adoption rates. In areas like Kumbungu, where statistical results point to minimal propagation knowledge, participatory dialogue and culturally sensitive educational outreach can help demystify traditional taboos and encourage tree planting.

Interestingly, the widespread reliance on seed propagation across all districts, despite its known limitations, may be attributed to its simplicity and local familiarity (Franzel et al. 2008). However, seed-based methods pose challenges such as dormancy and long juvenile phases, which likely contribute to the overall low propagation engagement observed. For instance, *A. digitata* and *P. biglobosa* are known to flower only after 23 and 15 years, respectively (Diop et al. 2005; Sambe et al. 2010), which diminishes their attractiveness to farmers. Low germination rates caused by seed coat dormancy (e.g., less than 20% for untreated *A. digitata* seeds (Danthu et al. 1995)) and oil-rich seed physiology in *L. microcarpa* further reduce success rates (Hall et al. 1997; Neya et al. 2008).

The extremely low uptake of vegetative propagation techniques, with only 1.0% and 0.3% reportedly using grafting and budding, reveals a critical technical gap, reinforcing the need for targeted capacity building. This deficiency is consistent with patterns observed in the quantitative data and indicates that most farmers rely on traditional methods due to lack of training, access, or confidence in improved techniques. Studies by Tchoundjeu et al. (2006) and Leakey et al. (2005) support this, showing that participatory extension programs can significantly boost farmer adoption of improved propagation techniques, reduce time to fruiting, and improve genetic uniformity in cultivated trees.

The geographic disparities in propagation knowledge underscore the need for culturally responsive policies, participatory extension models, and conservation strategies that integrate local beliefs, land tenure realities, and practical training to enhance adoption of native tree propagation across Ghana's savanna zones.

Knowledge of fruit maturity periods in the study location.

The results revealed a significant variation in the perceived fruit maturity periods for *A. digitata*, *P. biglobosa*, *Lannea microcarpa*, and *B. costatum* across the study locations, as confirmed by Chi-square tests: *A. digitata* ($\chi^2 = 25.2$, $p < 0.001$), *P. biglobosa* ($\chi^2 = 32.6$, $p < 0.001$), *L. microcarpa* ($\chi^2 = 28.7$, $p < 0.001$), and *B. costatum* ($\chi^2 = 30.5$, $p < 0.001$). These statistically significant differences suggest that community perceptions of fruit maturity are not uniform and likely reflect localized environmental, cultural, and observational factors. These discrepancies may also be attributed to differences in soil types and microclimatic conditions that influence the flowering and fruiting cycles of native trees. Such localized knowledge is critical for guiding effective seed collection, conservation planning, and domestication strategies. Aligning propagation calendars with community observations of fruit ripeness can enhance both the accuracy of seed harvesting and local participation in conservation efforts. This observed knowledge aligns with published phenological patterns for some species. For instance, the observed peak in *A. digitata* fruit maturity during the early dry season corresponds with earlier reports that baobab fruiting typically occurs during dry periods (Assogbadjo et al. 2005). Similarly, the reported maturity of *P. biglobosa* and *L. microcarpa* between April and June is consistent with the findings of Sina and Traoré (2002), who noted that these species generally fruit during the transition from the dry season into the rainy season. Sacandé (2007) also documented that *L. microcarpa* fruits tend to mature at the onset of the rainy season, reinforcing the validity of local knowledge as an essential complement to scientific understanding in propagation planning.

Unlike the other tree species assessed, the fruiting period of *B. costatum* reported by respondents in this study differed from established literature. A substantial majority of informants observed fruit maturity between January and March, which contrasts with reports from previous studies that identify August to October as the typical fruiting window for this species in West Africa (Oyen 2011; Orwa et al. 2009). This divergence could point to differences in land use or disturbance regimes, environmental adaptations or genetic variation within local *B. costatum* populations. Several studies have shown that fire frequency, grazing pressure, and drought stress can influence the reproductive phenology of native trees, including *B. costatum*. In particular, Belem et al. (2008) demonstrated that *B. costatum* responds to root disturbance and fire damage by reallocating resources toward vegetative regrowth rather than reproduction. *B. costatum* exhibits phenological plasticity, and local ecotypes may have adapted to differing climatic triggers for flowering and fruiting. Similar observations were made by Ouédraogo et al. (2006), who found that flowering and fruiting phenology in native tree populations varied substantially across ecological gradients due to long-term environmental pressures.

While phenological plasticity is documented in savanna trees, these findings underscore the need for further ecophysiological and phenological studies to confirm whether distinct local ecotypes exist.

Such studies would provide crucial insights into intraspecific variation and inform the development of site-specific propagation and conservation strategies.

The observed variation in fruit maturity knowledge highlights the need for policies and extension programs to integrate community-based phenological insights into site-specific propagation calendars, seed collection strategies, and conservation planning to enhance the effectiveness and local relevance of native tree domestication efforts.

Influence of informant's age on knowledge of trees

The findings from this study revealed that age had a statistically significant influence on propagation knowledge of *P. biglobosa* ($\chi^2 = 25.6$, $p < 0.01$) and perceptions of population decline in *A. digitata* ($\chi^2 = 26.9$, $p < 0.01$). Notably, 35.3% of respondents aged 50–69 years reported experience in propagating *P. biglobosa*, while 93.4% of those aged over 70 identified *A. digitata* as declining in population. These quantitative patterns suggest that older individuals possess deeper and more nuanced knowledge related to native tree use and ecological change. These results are consistent with earlier studies indicating that traditional ecological knowledge accumulates with age, especially in contexts involving sustained land-use and environmental observation. Ayantunde et al. (2008) found that understanding of species diversity and ecological dynamics increases with experience, while Brook and McLachlan (2008) highlighted the role of elders in preserving biodiversity knowledge through long-term landscape interaction. The current findings confirm these patterns statistically and reinforce the importance of older generations in indigenous tree conservation and propagation practices.

Conversely, no significant age-related differences were observed for fruiting knowledge across all species assessed, as confirmed by Chi-square results: *A. digitata* ($\chi^2 = 12.4$, $p > 0.05$), *P. biglobosa* ($\chi^2 = 6.3$, $p > 0.05$), *L. microcarpa* ($\chi^2 = 8.4$, $p > 0.05$), and *B. costatum* ($\chi^2 = 7.2$, $p > 0.05$). This suggests that phenological knowledge, such as fruiting periods, is communal and broadly shared across age groups. Unlike propagation knowledge, fruiting is a highly visible and recurrent event, observed by community members of all ages during harvesting, food preparation, or market participation. This supports the findings of Lunelli et al. (2016), who reported that phenological knowledge is widely distributed across age and gender, driven by shared agroforestry practices.

The absence of age-based differences in propagation knowledge for *A. digitata*, *L. microcarpa*, and *B. costatum* may reflect technical constraints that limit active engagement with propagation tasks across all demographic groups. Seed dormancy, prolonged juvenile phases, and minimal adoption of vegetative techniques like grafting restrict practical exposure and may prevent knowledge accumulation, even among older individuals. This is especially evident in grafting and budding, which were reported by only 1.0% and 0.3% of respondents, respectively.

These patterns confirm that indigenous knowledge is domain-specific. While communal knowledge systems support widespread understanding of fruiting phenology, specialized knowledge such as tree propagation and long-term ecological trends tends to be concentrated among older adults with more prolonged engagement in farming and natural resource management. Recognizing and mobilizing this differentiation is essential for designing age-sensitive education and extension strategies. Programs that actively engage older knowledge holders while encouraging intergenerational transmission can help strengthen conservation efforts and sustain local knowledge systems for native tree propagation.

While this study focused on age as a key determinant of ecological knowledge, we acknowledge that other demographic variables, such as gender, education level, and income, may also influence the acquisition and transmission of propagation knowledge. For instance, gendered division of labor in agroforestry and land management could lead to differentiated knowledge domains, while education may affect exposure to external conservation messages (Howard 2003; Lozada et al. 2006). These factors were not quantitatively examined in this study to maintain analytic focus, but their potential influence should be explored in future research to provide a more intersectional understanding of indigenous ecological knowledge systems.

The concentration of propagation knowledge among older individuals highlights the need for age-responsive extension, policy, and conservation strategies that engage elders as knowledge custodians while promoting intergenerational transfer to sustain native tree propagation practices.

Knowledge on changes in tree population status

The study found widespread community perception of declining populations of native tree species, notably *A. digitata*, *P. biglobosa*, *L. microcarpa*, and *B. costatum*. These perceptions were statistically confirmed by significant Chi-square results indicating non-random variation in responses across locations: *A. digitata* ($\chi^2 = 61.7$, $p < 0.000$), *P. biglobosa* ($\chi^2 = 44.5$, $p < 0.000$), *L. microcarpa* ($\chi^2 = 75.9$, $p < 0.000$), and *B. costatum* ($\chi^2 = 59.6$, $p < 0.000$). These results reflect a consistent awareness of population decline, but also reveal site-specific differences in how communities perceive and experience these changes.

The widespread perception of declining populations of native tree species is consistent with ecological studies that document reduced natural regeneration across various landscapes. Informants' observations likely mirror actual ecological trends, particularly the limited recruitment of young individuals into mature populations, a key indicator of demographic decline. This is well illustrated by size-class distribution analyses of *A. digitata*, which reveal significant reductions in sapling and juvenile abundance, suggesting disrupted regeneration dynamics (Lykke et al. 2025; Wickens and Lowe 2008). Similarly, reported population declines of *P. biglobosa*, *L. microcarpa*, and *B. costatum* align with findings by Sina (2006), Bélem et al. (2008), and Ouédraogo et al. (2006), who documented comparable patterns across multiple sites in West Africa. These convergences between local knowledge and ecological data underscore the value of community-based observations in assessing long-term environmental change.

The confirmed local perceptions of native tree decline highlight the need for policies, conservation actions, and extension services to integrate community ecological knowledge into forest monitoring, restoration planning, and sustainable regeneration strategies.

Constraints to seedling survival in study locations

The results reveal that livestock herbivory is the most significant constraint to seedling survival across all study locations, with an average of 42.0% of informants citing it as the primary cause of seedling mortality. This finding strongly reflects the dominance of free-range livestock management systems within the Guinean savanna agro-ecological zone. In such systems, animals often roam freely, increasing the likelihood of browsing and trampling of young seedlings. These uncontrolled interactions between livestock and young trees severely compromise early establishment, especially in communal or unprotected landscapes.

This result is consistent with previous studies, such as Nyamukuru (2015), who reported that livestock interference was a major barrier to successful tree planting efforts. In response to this challenge, farmers often opt to plant trees within homestead boundaries where protection can be assured, thereby limiting the spatial expansion of reforestation or agroforestry initiatives. The need for physical protection, such as fencing, is frequently cited as a prerequisite for successful seedling establishment, but is often constrained by cost and labor availability in rural communities.

Drought and bushfires emerged as the second and third most frequently cited constraints to seedling survival, reflecting the characteristic environmental stressors of the Guinean savanna zone. These constraints are particularly acute where irrigation infrastructure, fire control measures, and land management practices are limited or absent. Comparable findings by Engelbrecht et al. (2005) and Odhiambo (2015) support this study's observation that limited water availability and inadequate fire management compromise seedling survival and establishment by intensifying drought-induced stress and exposing juvenile, fire-sensitive trees to recurrent, high-intensity fires that disrupt natural regeneration and hinder progression to maturity.

Mechanized land preparation, though mentioned by only 3.0% of respondents, is an emerging constraint in areas where agricultural intensification is taking place. The expansion of mechanized farming, often without integrated land-use planning, can lead to the destruction of seedlings during ploughing and harrowing activities. While this constraint is currently minimal compared to others, its importance may grow with increasing adoption of tractors and other machinery in smallholder systems.

Overall, these findings highlight the complex interplay of natural and anthropogenic pressures affecting tree seedling survival in the study areas. Addressing these challenges requires integrated strategies that combine physical protection measures (e.g., fencing, live hedges), improved fire management practices, community-based grazing regulation, and context-specific water conservation techniques. Moreover, targeted extension services that emphasize early-stage seedling care and community awareness on the importance of tree protection will be crucial for enhancing the success of domestication and reforestation efforts.

The identification of key seedling survival constraints highlights the need for policies that support protective infrastructure, extension services that build local capacity for tree care, and conservation programs that address livestock pressure, fire risk, and climate stress in savanna landscapes.

Based on the findings, the following actionable strategies can be followed to strengthen native tree conservation and propagation in northern Ghana. First, training programs on vegetative propagation techniques (e.g., grafting, budding, cuttings) should be introduced at the community level, particularly in areas like Kumbungu where propagation knowledge is limited. These programs should use participatory methods and local language to enhance adoption. Second, youth engagement initiatives, such as school agroforestry clubs, community demonstration plots, and mentorship programs led by older knowledge holders, could help address the intergenerational knowledge gap and build local capacity. To further stimulate youth interest, locally accessible digital platforms, such as WhatsApp groups and radio broadcasts, can be leveraged to share knowledge, success stories, and practical tips on tree propagation and conservation. Third, efforts to integrate indigenous knowledge systems into formal reforestation and agroforestry policies can improve the cultural relevance and success rates of afforestation programs. By documenting and applying traditional insights on fruiting periods, seed handling, and land tenure dynamics, such policies can ensure better alignment with local realities and community needs. Lastly, all interventions should adopt a gender-sensitive approach, recognizing the distinct roles men and women play in tree management to ensure inclusive participation and benefit-sharing.

Conclusion

This study highlights the complex interplay between ecological, cultural, and demographic factors shaping indigenous knowledge of native tree propagation in northern Ghana. While seed propagation remains dominant, its limitations, such as dormancy and long juvenile phases, underscore the need to enhance technical capacities through training in vegetative propagation. The findings also reveal that propagation knowledge is unevenly distributed, influenced by both geographic location and age, reflecting localized exposure to conservation efforts and generational knowledge transmission patterns.

More broadly, the study affirms the critical role of indigenous ecological knowledge in biodiversity conservation and agroforestry development. However, the erosion of this knowledge, particularly among younger generations, calls for urgent strategies to foster intergenerational learning and integrate traditional practices into formal extension systems. Equally, addressing socio-cultural constraints, such as spiritual taboos and land-use practices, is essential for the successful domestication of native species.

These findings emphasize the need to integrate indigenous knowledge into restoration programs, particularly community-based insights on optimal fruiting periods for seed collection and seed sowing based on rainfall onset, promote technical training in vegetative propagation in local communities, and strengthen seedling protection strategies. Doing so can enhance the sustainability of native tree domestication and improve the cultural relevance and ecological success of afforestation efforts in the Guinean savanna zone.

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Declarations

Conflict of interest The authors declare no competing interests.

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