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ASSESSMENT OF DIVERSITY AND COMPOSITION OF TREE SPECIES IN RESIDENTIAL AREAS OF CHOBE DISTRICT, NORTHERN BOTSWANA

SUMMARY

A vegetation survey was conducted in Chobe district to document tree species in residential areas. The survey resulted in 44 tree species, representing 44 genera and 22 families across the nine study villages. The diversity and evenness ranged from 2.47–3.15 and 0.77–0.90, respectively. An average of 19, 7 and 5 native, exotic and alien tree species respectively, were recorded. The most frequent native tree species, e.g. *Baikiaea plurijuga*, in the residential areas was also the dominant species in the neighbouring woodlands, suggesting that the species was retained when the woodlands were converted to residential use. The indigenous fruit bearing tree species, namely *Berchemia discolor* and *Sclerocarya birrea*, and the exotic fruit-bearing tree species, namely *Carica papaya* and *Mangifera indica*, were dominant in most residential areas, signifying their contribution to household food security. Invasive alien tree species, *Jatropha curcas* and *Leucaena leucocephala* were most frequent and, therefore, need continuous monitoring to prevent their spread into natural ecosystems. The study recommends raising of public awareness about invasiveness of alien invasive tree species.

Keywords: Native species; exotic species; alien species; invasive species; ecosystem services

INTRODUCTION

Tree species provide ecosystem services such as provisioning services (e.g. fuel-wood), cultural servies (e.g. spiritual service) and regulating services (e.g. climate regulation). In rural areas, they are essential in provision of firewood

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and building materials for the majority of the poor and vulnerable communities (de Neergaard et al., 2005).

In addition, trees provide food, shelter and ecological benefits to humans (Dickie et al., 2014). For instance, native species Sclerocarya birrea (A.Rich.) Hochst. and Berchemia discolor (Klotzsch) Hemsl. provide food for humans and exotic nitrogen fixing trees Prosopis species and Leucaena leucocephala provide fodder for livestock. In urban areas, trees provide a suite of benefits that enhance environmental quality and residential quality of life (Gerstenberg & Hofmann, 2016). They provide shade and reduce air temperature, sequester carbon to mitigate greenhouse gas emissions and purify atmospheric air (Nowak et al., 2013). The role of trees become even more important in the face of the negative impact of climate change.

Alien trees are a double-edged sword. They provide ecosystem services and, at the same time, harm biodiversity and ecosystem functioning (van Wilgen & Richardson, 2014), leading to a reduction in ecosystem services. The multiple benefits of trees also present a challenge for their control, as eradication programmes sometimes elicit emotional responses (Dickie et al., 2014).

A number of tree species were intentionally introduced to Botswana to stabilize sand dunes and restore vegetation in the arid southwest part of the country. These include species, such as Prosopis spp. (Fabaceae), Eucalyptus camaldulensis Dehnh (Myrtaceae), E. sideroxylon, Leucaena leucocephala (Lam) de Wit (Fabaceae), Acacia saligna (Labill.) H.L. Wendl. (Fabaceae) and Casuarina cunninghamiana Miq. (Casuarinaceae) (Lepetu, 1998). Other species such as Schinus molle L., Melia azedarach L., Ailanthus altissima (Mill.) Swingle, Spathodea campanulata P. Beauv, Tecoma stans (L.) Juss. ex Humb., Bonpl. & Kunth and Senna spectabilis (DC.) H. S. Irwin & Barneby, are present as garden or street trees.

Alien invasive plant species have been extensively studied in neighbouring South Africa (Keet et al., 2022; Potgieter et al., 2019; Shackleton et al., 2019). Despite evidence of exotic tree species in Botswana, an inventory documenting tree species in residential areas of various districts is surprisingly scarce. The only study to date was by Mafokate et al. (2013) who surveyed exotic woody plant species in the city of Gaborone in southern Botswana. Thus, similar studies are needed in other parts of the country to develop a national inventory documenting tree species in residential areas. Such inventory would be useful for effective conservation and management of tree species in residential areas.

The aim of the study was to assess the diversity and composition of tree species in residential areas of Chobe District, northern Botswana. The specific objectives were to (i) assess diversity and evenness and (ii) determine the composition of tree species in residential areas.

MATERIAL AND METHODS

Study area

The study was conducted in Chobe District (Figure 1), in the villages of Pandamatenga (pop. est. 1798), Lesoma (pop. est. 613), Kasane (pop. est 9008) and Kazungula (pop. est 4133), and the western villages namely Mabele (pop. est. 773), Kavimba (pop. est. 549), Kachikau (pop. est. 1356), Satau (pop. est. 605) and Parakarungu (pop. est. 845) (Statistics Botswana, 2011). The western villages are referred to as Chobe Enclave and covers 1690 km2 (Jones, 2002). Kasane township is the district's headquarter and a gateway to tourism in northern Botswana. It is the main government service center and houses accommodation facilities, such as hotels, lodges and guest houses. Communities in the villages of Kazungula, Kasane and western villages are settled in close proximity to Chobe River and depend on the river for resources, such as fish, farming and transportation. Pandamatenga is about 100 km south of Kasane and due to its fertile pellic vertisols (Pardo et al., 2003), it has been designated for commercial arable farming to promote government's policy of national food self-sufficiency. Chobe District receives an annual rainfall of about 640 mm occurring in the hot summer months from October to April (Botswana Meteorological Service Department unpublished data). October is usually the hottest month with a mean daily temperature of 35 oC and a mean daily minimum of 14 oC. The winter season is from the months of May to July and is dry with mean monthly temperature range of 8 - 28.5 oC. Deciduous trees start to drop their leaves in July.

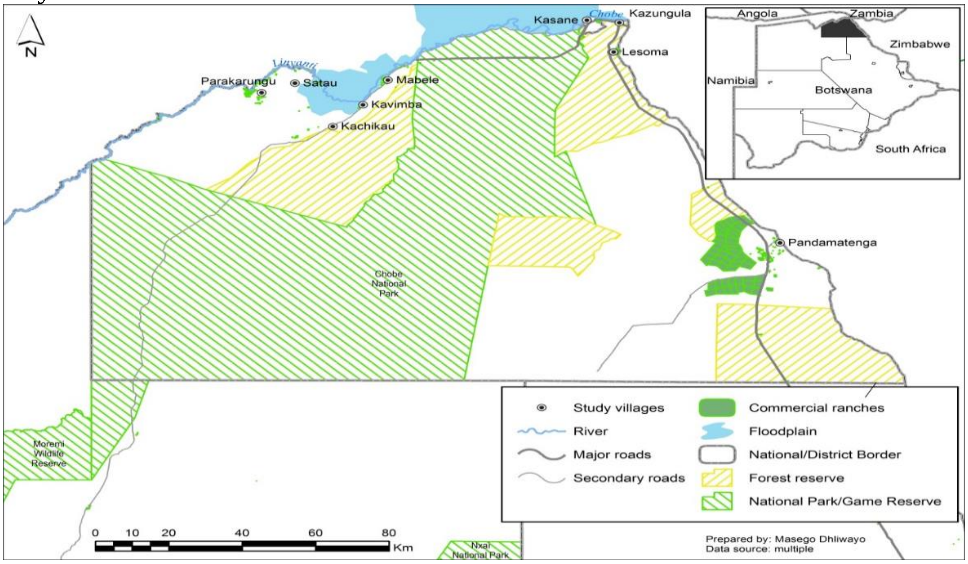

Figure 1. Map of the study area.

Data collection

The diversity of woody species was analysed using Shannon Diversity Index (H'). It is also referred to as the Shannon-Weiner or Weaver Diversity Index

(Magurran, 2004). The woody species diversity was determined by using the following formula:

$$H' = -\sum_{i=1}^{S} Pi \ln Pi$$

Where, H' = Shannon index, S = species richness, P_i = proportion of S made up of the i^{th} species (relative abundance).

Evenness or equitability, measure similarity of the abundance of the different woody species in the different habitats and was analysed by using Shannon's Evenness. Its value ranges from 0 to 1 with 1 being complete evenness. It is calculated by the following formula:

$$J' = \frac{H'}{\ln(S)},$$

Where, J' = evenness and S = species richness.

The frequency was calculated as the proportion (%) of the number of household or residential plots in which each tree species was recorded from the total number of residential plots surveyed in each of the villages.

RESULTS

A total of 44 tree species, representing 44 genera and 22 families were recorded across the nine villages (Tables 1 and 2). Of these, 19, 7 and 5 were native, exotic and alien invasive tree species, respectively (Figure 2). Lesoma exhibited the highest richness in native tree species followed by Kasane township and Kazungula. The villages of Mabele and Satau had lowest native tree species richness. For exotic species, Kasane township was the richest with 12 species, followed by its "suburb" Kazungula with nine species, and Lesoma and Kachikau with eight each. The other villages recorded seven or less number of species with Mabele and Kavimba being the least with five species each. Similarly, Kasane township and Kazungula, recorded most alien invasive tree species together with Satau. The villages of Lesoma and Satau recorded the lowest with 3 species each.

Overall, Fabaceae was the richest family with seven species followed by Combretaceae with three, and Anacardiaceae and Arecaceae with two each. Fabaceae exhibited the highest richness in tree species in Lesoma, Kasane and Kachikau followed by Kazungula and Kavimba. Fabaceae was least diverse in Pandamatenga, Satau and Parakarungu. Combretaceae was the richest family in Lesoma followed by Pandamatenga and Kavimba. Combretaceae had lowest species richness in Mabele and Satau where it was represented by only one species. However, the proportion of Combretaceae family in Kasane township (5%) and Kazungula village (7.7%) was low compared with Pandamatenga (15.4%) and Lesoma (14.3%) (Table 3).

Table 1. List of tree species with their frequencies (%) recorded in residential areas of the study villages

Species	**Village***								
	PND	**LSM**	**KZN**	**KSN**	**MBL**	**KVB**	**KCH**	**STU**	**PRK**
Vachellia erioloba E.Mey.	-	1	1	0.3	-	4.3	-	-	19
Vachellia kirkii Oliv.	-	3.1	-	-	2	4.3	1.4	2.8	-
Senegalia nigrescens Oliv.	6.6	3.1	2.9	1.3	8	4.3	2.8	-	-
Vachellia tortilis (Forssk.)	1.5	37.5	17.3	1.9	8	8.7	8.5	-	1.7
Adansonia digitata L.	2.9	3.1	8.7	2.2	-	4.3	4.2	5.6	
Ailanthus altissima (Mill.)	-	-	3.8	1	8	2.2	7	36.1	1.7
Albizia versicolor Welw. Ex Oliv.	-	-	-	-	-	-	-	11.1	3.4
Azanza garckeana (F.Hoffm.) Exell & Hillc.	6.6	15.6	6.7	3.5	4	-	-	-	1.7
Baikiaea plurijuga Harms	-	2.1	52.9	31.4	-	45.7	31	-	-
Baphia massaiensis Taub.	-	-	1.9	11.4	-	-	1.4	-	1.7
Berchemia discolor (Klotzsch) Hemsl.	16.2	19.8	28.8	35.2	26	37	49.3	30.6	29.3
Boscia albitrunca (Burch.) Gilg & Benedict	0.7	3.1	-	-	-	4.3	1.4		17.2
Burkea africana Hook.	-	3.1	2.9	1.6	-	-	-	-	-
Carica papaya L.	2.9	7.3	14.4	13.3	14	26.1	12.7	19.4	20.7
Citrus limon (L.) Burm.	-	-	-	0.3	-	-	-	-	-
Citrus sinensis (L.) Osbeck	-	-	-	0.3	-	-	-	-	1.7
Colophospermum mopane (Benth.) J.Léonard	61	14.6	-	11.4	46	4.3	2.8	-	-
Combretum apiculatum Sond.	8.1	16.7	-	-	-	8.7	7	-	-
Combretum hereroense Schinz	8.8	10.4	1	-	-	-	-	-	10.3
Combretum imberbe Wawra	1.5	12.5	1.9	0.6	4	2.2	-	-	
Croton megalobotrys Müll.Arg.	-	-	-		-	4.3	1.4		5.2
Cupressus macrocarpa Hartw.	-	-	-	0.6	-	-	1.4	2.8	3.4
Dichrostachys cinerea (L.) Wight & Arn.	1.5	25	4.8	2.2	-	-	-	-	-
Eucalyptus spp.	-	-	3.8	4.8	-	2.2	-	11.1	1.7
Ficus benjamina L.	-	2.1	3.8	2.2	-	-	1.4	2.8	-
Ficus sp.	-	-	-	0.3	-	-	-	-	-
Ficus sycomorus L.	-	-	1.9	1	-	-	-	2.8	-
Hyphaene petersiana Klotzsch ex Mart	2.2	12.5	17.3	7	20	15.2	15.5	41.7	37.9
Jacaranda spp.	2.9	4.2	7.7	10.5		6.5	5.6	8.3	8.6
Jatropha curcas L.	8.8	4.2	16.3	6	10	6.5	4.2	2.8	12.1
Kigelia africana (Lam.) Benth.	-	2.1	1	0.3	-	-	-	11.1	5.2
Kirkia acuminate Oliv.	33.8	7.3	1.9	2.5	30	6.5	1.4	-	-
Leucaena leucocephala (Lam.) de Wit	-	1	16.3	23.2	12	6.5	9.9	2.8	-
Mangifera indica L.	2.2	8.3	29.8	22.9	10	8.7	12.7	11.1	5.2
Melia azedarach L.	0.7	4.2	1	-	-	-	-	2.8	5.2
Moringa oleifera Lam.	2.2	4.2	9.6	4.1	4	8.7	9.9	11.1	3.4
Morus spp.	5.9	5.2	13.5	10.2	2	2.2	11.3	5.6	1.7
Musa spp.	1.5	6.3	1	0.6	8	6.5	2.8	2.8	-
Philenoptera violacea (Klotzsch) Schrire	-	3.1	3.8	-	6	4.3	5.6	5.6	8.6
Phoenix reclinata Jacq.	0.7	3.1	9.6	4.4	-	4.3	5.6	2.8	-
Psidium guajava L.	-	1	3.8	1.6	-	-	7	13.9	10.3
Sclerocarya birrea (A.Rich.) Hochst.	25	9.4	10.6	7.6	24	13	9.9	11.1	1.7
Terminalia sericea Burch. Ex DC.	2.2	14.6	2.9	5.4	-	2.2	2.8	33.3	56.9
Trichilia emetica Vahl	7.4	14.6	21.2	19.4	26	30.4	25.4	25	17.2

Myrtaceae had highest proportion in Kasane township (10%) than in any other study villages. This family was dominated by exotic fruit tree (*Psidium guajava*) and *alien invasive tree species* (*Eucalyptus* spp.) in Kasane.The diversity of tree species ranged from 2.47 in Pandamatenga to the highest of 3.15 in Lesoma (Table 3). Similarly evenness ranged from 0.77 in Pandamatenga to 0.90 in Lesoma and Mabele (Table 3).

Table 2. Proportion of tree families (%) in residential areas of the study villages.

Species	**Village***								
	PND	**LSM**	**KZN**	**KSN**	**MBL**	**KVB**	**KCH**	**STU**	**PRK**
Anacardiaceae	7.7	5.7	5.1	5.0	13.6	9.4	9.1	7.4	7.1
Arecaceae	7.7	5.7	5.1	5.0	4.5	6.3	6.1	7.4	3.6
Bignoniaceae	3.8	5.7	7.7	7.5	0	3.1	3.0	7.4	7.1
Bombacaceae	0	0	2.6	2.5	0	3.1	3.0	3.7	0
Capparaceae	3.8	2.9	0	0	0	3.1	0	0	3.6
Caricaceae	3.8	2.9	2.6	2.5	4.5	3.1	3.0	3.7	3.6
Combretaceae	15.4	14.3	7.7	5.0	4.5	12.5	6.1	3.7	10.7
Cupressaceae	0	0	0	2.5	0	0	3.0	3.7	3.6
Euphorbiaceae	3.8	2.9	2.6	2.5	4.5	6.3	6.1	3.7	7.1
Fabaceae	15.4	28.5	23.1	25.0	27.3	25.0	30.3	18.5	17.9
Kirkiaceae	3.8	2.9	2.6	2.5	4.5	3.1	3.0	0	0
Malvaceae	3.8	2.9	2.6	2.5	4.5	3.1	0	0	3.6
Meliaceae	7.7	5.8	5.1	2.5	4.5	3.1	3.0	7.4	7.1
Moraceae	3.8	5.8	10.3	5.0	4.5	3.1	6	11.1	3.6
Moringaceae	3.8	2.9	2.6	2.5	4.5	3.1	3.0	3.7	3.6
Musaceae	3.8	2.9	2.6	2.5	4.5	3.1	3	3.7	0
Myrtaceae	3.8	2.9	5.1	10.0	0	3.1	3.0	7.4	7.1
Rhamnaceae	3.8	2.9	5.1	2.5	4.5	3.1	3.0	3.7	3.6
Rutaceae	0	0	0	5.0	0	0	0	0	3.6
Sapindaceae	0	0	2.6	2.5	4.5	0	3.0	0	0
Simaroubaceae	0	0	2.6	2.5	4.5	3.1	3.0	3.7	0
Tiliaceae	3.8	2.9	2.6	2.5	0	0	0	0	0

The frequencies of tree species ranged between 0.3 and 61% across the study villages. The five most frequent tree species were native species, namely *Colophospermum mopane* (61%) in Pandamatenga, *Terminalia sericea* (56.9%) in Parakarungu, *Baikiaea plurijuga* (52.9%) in Kazungula, *Berchemia discolor* (49.3%) in Kachikau and *Hyphaene petersiana* in Satau. Fruit trees, both native and exotic species were observed in the study villages.

The exotic fruit tree species recorded in all the study villages were *Carica papaya*, *Mangifera indica*, *Morus* and *Musa* species. The two most frequent species were *M. indica* in Kazungula and *C. papaya* in Kavimba. *Berchemia discolor* and *Sclerocarya birrea*, indigenous fruit tree species, were observed in all the study villages and were the most frequent with 49.3% in Kachikau and 25% in Pandamatenga, respectively.

Table 3. Diversity and evenness of trees species in residential areas of the study villages

Village	**Diversity (*H'*)**	**Evenness (*J'*)**
Pandamatenga	2.47	0.77
Lesoma	3.15	0.90
Kazungula	3.03	0.86
Kasane	2.94	0.82
Mabele	2.69	0.90
Kavimba	2.93	0.87
Kachikau	2.92	0.86
Satau	2.88	0.88
Parakarungu	2.77	0.84

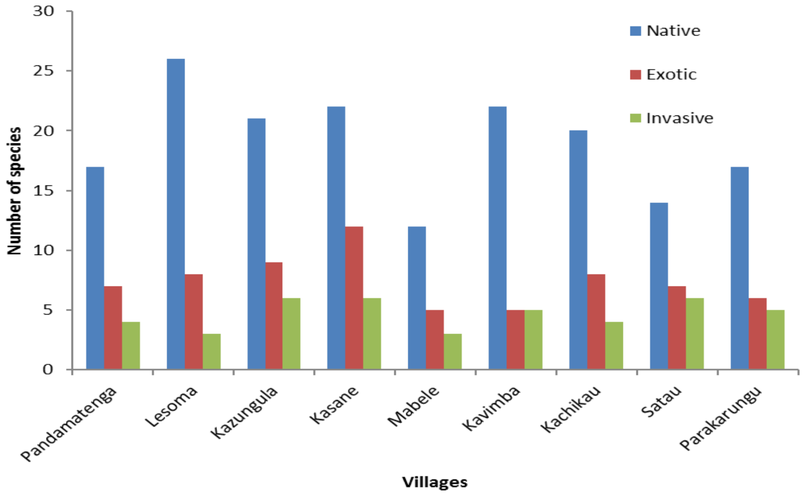

Figure 2. Number of tree species by types in the study villages in Chobe District.

Invasive alien tree species at different stages of infestation were recorded in different areas. *Ailanthus altissima*, *Jatropha curcas* and *Leucaena leucocephala* were at advanced stage of infestation and were recorded in almost all the study villages. These invasive species were most frequent in Satau, Kazungula and Kasane, with frequencies of 36.1, 16.3 and 23.2%, respectively. *Eucalyptus* spp. and *Melia azedarach* were at low stages of infestation and were only observed in half of the study villages at low frequencies.

DISCUSSION

The results demonstrated that the residential areas of the villages in Chobe District exhibited diversity of tree species. The overall diversity of tree species is much higher in all the study villages with a range of 2.47 to 3.15, indicating high species richness. The value of H' usually falls between 1.5 and 3.5 (Magurran, 2004). This implies that the diversity of tree species in the study villages falls on the higher value of the diversity range.

The residential areas in the different study villages were dominated by species that were also the dominant species in surrounding woodlands, suggesting that they were the main species before the woodlands were converted to residential use and were retained in homestead to provide ecosystem services. It is safe to suggest that some residents retained these species for their ecosystem services, e.g. shade and food provision. *Colophospermum mopane* exhibited high frequency in Pandamatenga and Mabele. It grows in a variety of soils from heavy clay soils to sandy soils (Mapaure, 1994), and some areas on "black cotton soils" (Barbosa, 1970). It was, therefore, not surprising to observe that it was dominant in Pandamatenga, an area that has been designated for commercial arable farming owing to its fertile "black cotton soils" (Pardo et al., 2003; Abdullahi, 2004). *Baikiaea plurijuga* was the most frequent species in residential areas of Kazungula, Kasane and Kavimba. This observation is consistent with vegetation studies in the same area, which also found *B. plurijuga* to be one of the dominant species in the mixed woodlands (Ben-Shahar, 1998; Rutina et al., 2005).

The residential areas in the villages of Satau and Parakarungu were dominated by *Hyphaene petersiana*, a species usually common on islands in the floodplains (Heath & Heath, 2009). The two villages partly lie in the floodplain of Chobe River and thus explain why this species was recorded in most residential areas of these villages. The abundance of *H. petersiana* can also be attributed to its multiple uses. Its sap is a source of palm wine and young unopened leaves are used to weave baskets (Mollet et al., 2000; Babitseng & Teketay, 2013). Basketry production is an important income generating activity, particularly for women in Botswana. In addition to *H. petersiana*, *Terminalia sericea* was also dominant in Satau and Parakarungu than in any other villages. Its abundance could be partly explained by its preference to transition zone between sandy and clay soils (Tinly, 1992). Additional, *T. sericea* is common and widely distributed in southern Africa (McGaw et al., 2001; Shackleton, 2001) where it provides a suite of ecosystem services, such as fuel, timber and medicine (Van Wyk & van Wyk, 2013). It is used to treat both ethnoveterinary infections and a variety of human infections (Mongalo et al., 2016

The diversity of exotic and indigenous fruit-bearing trees in the residential areas highlights their contribution to household food security. The indigenous fruit-bearing tree species, namely *Berchemia discolor* and *Sclerocarya birrea*, were recorded in residential areas of all the study villages at higher frequencies, signifying their importance as a source of food and shade. The fruits of these two tree species are rich in vitamins C which are higher than that of the exotic species

(Chivandi et al., 2012). Exotic fruit-bearing trees were dominated by *Carica papaya* and *Mangifera indica* which were observed in residential areas of all the study villages at high frequencies. *Mangifera indica* was preferred probably for its drought tolerance (Greisbach, 2003) and ability to produce many fruits (200 - 500) per year (Jama et al., 2008). Furthermore, *M. indica* can be easily propagated vegetatively or by seed (Greisbach, 2003). Similarly, *Carica papaya* was probably favoured for its fast-growth, with the fruits produced within 10 - 14 months from germination (Silva et al., 2007). The fruit is eaten as fresh fruit and as a vegetable. It is easily propagated by seeds (Chaves-Bedoya & Nuñez, 2007). The two species are widely distributed and adapted to climatic and environmental conditions in Sub-Saharan Africa (Chivandi et al., 2012).

Invasive alien tree species *Jatropha curcas* (Negussie et al., 2013) and *Leucaena leucocephala* (Lyons & Miller, 1999) were the most frequent in residential areas of the study villages. These fast-growing trees were intentionally introduced to Botswana as candidate for biodiesel and fodder production respectively. They have since escaped their intended use and communities are now planting them for landscaping, shade and building material. If not properly managed, the two species can become invasive and invade neighbouring ecosystems. Such invasion will negatively impact ecosystem functioning and consequently, ecosystem services (Dickie et al., 2014). Invasive alien tree species were more prevalent in Kasane township and its “suburb” Kazungula. In a similar study in the Eastern Cape, South Africa, Mabusela et al. (2021) recorded more woody invasive alien species in townships than in other neighbourhoods. In Western Cape, South Africa, McLean et al. (2018) also found 50% alien invasive plant species recorded to be naturalized within town. Mafokate et al. (2013) recorded 26 alien invasive woody species in Gaborone, capital city of Botswana. This was not surprising because majority of invasive species are usually more prolific in cities because of high disturbance and habitat fragmentation that facilitate invasion process (Gaertner et al., 2016). On the contrary, the invasive and poisonous *Ailanthus altissima* (Rebbeck & Jolliff, 2018; Petruzzellis et al., 2018) was almost absent in Kasane but was the second dominant species in the rural village of Satau, where it is grown as an ornamental and shade tree. The impact of alien invasive tree species can be profoundly massive (Hejda et al., 2017), and often occupy a wide modified area (Pyšek et al., 2012), creating conditions unfavourable for some indigenous species (Richardson & Rejmánek, 2011).

CONCLUSIONS

Woody species diversity is an essential component of forest or woodland diversity and thus central to their biodiversity. The information on plant diversity is useful for planning effective conservation and management strategies. The study revealed a relatively high species and family richness of tree species in the study area. The diversity and evenness values of the villages were relatively high suggesting that most tree species were uniformly distributed across the study villages. The study also revealed that most residential areas in Choke District were dominated by native tree species, which indicates their importance in provision of ecosystem services. Such important species were probably retained when the woodlands were converted to residential use implying the importance of conserving indigenous tree species. The study also showed prevalence of alien trees species particularly in residential areas of ‘town’ and surrounding villages, indicating the need for continuous monitoring to prevent their spread into other ecosystems. The study recommends consultation with the local community to remove invasive tree species from their homesteads and replace them with indigenous tree species that will provide the same ecosystem services. The study further recommends ethnobotanical survey of woody species in the study area to generate information on how communities are using the different species.

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