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Restoration of diversity and regeneration of woody species through area exclosure: the case of Maun International Airport in northern Botswana

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Abstract

Deforested and degraded areas can be cheaply and conveniently restored through establishment of exclosures. An area exclosure excludes animals and humans from accessing an area to promote natural regeneration of plants and rehabilitate ecological condition of the area. The study was aimed at: (i) determining the diversity (species richness, diversity and evenness); (ii) assessing the stand structure (densities); and (iii) assessing regeneration status of woody species inside and outside exclosed Maun International Airport, northern Botswana. Vegetation sampling was conducted from April to May 2018. A total of 48 and 37 quadrats of 20 x 20 m were laid down at 50 m intervals along transect lines inside and outside Maun International Airport, respectively. Identity, number of all live individuals and height of all woody species were recorded in all the quadrats. The diversity of all woody species was analysed by using Shannon Diversity Index (H') and regeneration status of each woody species was assessed using frequency distribution of height class. The diversity, evenness and species richness were significantly higher inside than outside Maun International Airport. *Colophospermum mopane* was the most abundant species both inside (75% of all woody species) and outside (96% of all woody species) Maun International Airport. More species showed healthy regeneration status inside than outside Maun International Airport. The inside of Maun International Airport recorded more alien invasive woody species compared with the outside, owing to its original use as a residential area. The local communities might have introduced these species as ornamental trees. This study has demonstrated the important role exclosures play in enhancing woody species richness, diversity and evenness as well as facilitating regeneration of woody species. This study has highlighted that degraded woodlands and other similar ecosystems can be cheaply and conveniently restored through establishment of exclosures.

Keywords: Density; evenness; population structure; regeneration

Introduction, scope and main objectives

[Tropical dry forests and woodlands, including those in Botswana, account for about 42% of all tropical and sub-tropical forest area (Hasnat andHossain 2020). Tropical dry forests have high species richness and are the most diversified terrestrial ecosystem (Pradhan et al. 2019), making them the richest biological communities on earth (Naidu and Kumar 2016). Owing to their wealth of biological communities, tropical dry forests are home to a large proportion of global biodiversity (Baraloto et al. 2013). Forests and woodlands provide a suite of valuable ecosystem services that are important livelihood activities for majority of the rural communities (Shackleton and Shackleton 2004), particularly the poor and vulnerable communities in Sub-Saharan Africa (SSA) who strongly depend on forest and non-timber forest products (NTFPs) for sustenance (Kabubo-Mariara 2013; Van Passel et al.2020). The ecosystem services provided include provisioning services (e.g. fuelwood, timber, food) (Boy and Witt 2013), regulating services (e.g. carbon sequestration, erosion control and reduction of air pollution) (Morgenroth et al. 2016) and cultural services (spiritual, religious, cognitive effects and tree monuments) (Dallimer et al. 2012).

Tree species diversity represents a substantial component of forest ecosystems (Tchouto et al. 2006) and has tremendous social, economic and ecological significance (Pickett et al. 2011; Dickie et al. 2014). Dieng et al. (2009) estimated that 65% of the people in SSA depend on forests and NTFPs for their livelihoods. The provision of ecosystem services by forests and the associated products depends on availability of forest resources (Pradhan et al. 2019).

However, forests are being destroyed at an alarming rate worldwide (Elliot et al., 2013), with an estimated loss of about 1–4% of their current area per annum (Naidu and Kumar 2016). The destruction is attributable to increasing anthropogenic activities, deforestation and natural factors (Chow et al. 2013; Siyum 2020). The destruction of forests is, largely, driven by human and livestock populations, which result in land use changes from forestry to agriculture and human settlement (Neelo et al. 2013), owing to their favourable climatic conditions (Ewel 1999). Moreover, climate change and its associated impacts on temperature and rainfall patterns are expected to affect dry woodlands and forests (IPCC 2014). Additionally, forests are overexploited for fuelwood, construction material and timber.

For instance, in Botswana, unsustainable use and the ineffective management of mopane woodlands as well as their conversion to other land use types are depriving the local communities of full benefits from the mopane woodlands (Makhado et al. 2012; Teketay et al. 2018).The reduction and degradation of forests calls for strategies to conserve and maintain the remaining forests and simultaneously restore deforested and degraded areas (Teketay et al. 2018). One such strategy that has been used recently to reverse deforestation and degradation is the establishment of area exclosures. Alternatively, this practice is also known as “enclosure” (Girmay et al. 2009; Verdoodt et al. 2010) and “area enclosure” (Abebe et al. 2006). Area exclosure is used as a fast, cheap and convenient approach of restoring degraded forest and woodland areas. An area exclosure is closed from animals and human access to promote natural regeneration of plants and rehabilitate the ecological condition of the area (Teketay et al. 2018; Atsbha et al. 2019). Exclosures have been used in many countries across the world: China (Park et al. 2013; Liu et al. 2019), central America (Griscom and Ashton 2011), Australia (Bastin et al., 2003; Silcock & Fensham, 2013), Scotland (Shaw, Iason, Pakeman, & Young, 2010), Iran (Ebrahimi et al. 2016), Ethiopia (Gebregerges et al. 2018; Ubuy et al. 2018; Atsbha et al. 2019; Asmare and Gure 2019), Kenya (Wairore et al. 2016) and South Africa (Mbatha and Ward 2013).

For Botswana, various studies on the area exclosure have been conducted in Mokolodi Nature Reserve (MNR) in southern (Flyman 1999; Käller 2003; Bengtsson-Sjörs 2006; Teketay et al. 2016) and northern (Neelo et al. 2015, 2015; Teketay et al. 2018) parts of the country. In case of studies in MNR, Flymann (1999) excluded herbivores to determine the fate of seedlings of woody species. Besides, Kaller (2003) investigated growth pattern and reproduction of woody vegetation. Also, Bengtsson-Sjörs (2006) studied establishment and survival of woody seedlings. Recently, Teketay et al. (2016) demonstrated that most woody species exhibited unstable population structure and hampered natural regeneration, indicating that MNR is in a recovery phase following its exposure to overgrazing and other heavy anthropogenic impacts. In northern Botswana, studies on exclosure were conducted in sites close to the current study area by Neelo et al. (2015) and Teketay et al. (2018). Neelo et al. (2015) discovered that exclosure had similar diversity and density values compared with open areas and attributed such observations to heavy over-grazing and cutting of trees before establishment of the exclosure as well as seasonal flooding of the large portion of the exclosed area owing to its close proximity to Thamalakane River. In the study reported by Teketay et al. (2018), mean density, population structure and regeneration status of woody species inside the exclosure was better than outside. All these studies on area exclosures in Botswana were conducted on formerly degraded grazing lands. Studies on the impact of exclosure on areas formerly used as residential areas or human settlement are limited in Botswana.

Therefore, this study aimed at conducting a comparative study on woody species diversity, stand structure of woodlands and regeneration status of the woody species in an area exclosure (10 years) and open area in close proximity to Maun International Airport, northern Botswana. The specific objectives of the study were to: (1) determine the diversity (species richness, diversity and evenness); (2) assess the stand structure (densities and frequencies); and (3) assess regeneration status of woody species inside and outside the area exclosure.

Materials and methods

1- Study area

[The study was conducted in Maun Village, Ngamiland District, northern Botswana (Figure 1). The village is located within the Okavango Delta, which is the distal part of the Okavango River Basin. It originates in the Angolan highlands where Cuito and Cubango Rivers receive 876 and 983 mm of rain per annum, respectively (Wolski and Murray-Hudson 2008). The Okavango River, then, discharges 10 km^3 into the alluvial fan of about 12, 000 km^2 (McCarthy 2006). The flood wave peak discharge at the Panhandle between April and May, and then meanders across 250 km of seasonal floodplains to arrive at Thamalakane River in Maun between July and August (McCarthy, 2000; Mazvimavi and Mmopelwa 2006).

The inflow into the Delta results in the inundated area to expand from a low of 4,000–6,000 km^2 in January or February to a high of 8,000–12,000 km^2 in August or September (Wolski and Murray-Hudson 2008). Local rainfall, although small (500 mm per annum), falls over a wide area of the Delta and make a significant contribution of 6 x 10^9 m^3 to the inflow (McCarthy and Ellery 1998). About two percent (2%) of the inflow leaves as outflow and the rest is lost through evapotranspiration within the Delta (Ramberg et al. 2005).

The Okavango Delta is globally renowned Wetland of International Importance and Ramsar site and was inscribed as UNESCO's 1000th World Heritage Site in 2014. The stunning scenery of the Delta characterized by an array of plant and animal life, swamps and islands attract thousands of tourists who visit every year (Mbaiwa 2018). The tourism sector is only surpassed by mining and contribute about 4.5% to the country's Gross Domestic Product (Mbaiwa and Hambira 2020). The riparian communities depend on the Delta's ecosystem resources for their livelihoods. Common livelihood activities include dry and flood recession farming, fishing, collection of veld products, harvesting of thatching grass and reeds, basket making and tourism (Blackie 2019).

2- Study site

The actual study site was Maun International Airport (MIA) (Figure 1). Maun is the fifth largest village in Botswana with a population of 60,263 (Statistics Botswana 2014). MIA is the second busiest airport to Sir Seretse Khama International Airport (SSKIA) in terms of the number of passengers (CAAB 2019). It caters for both domestic and international flights. Owing to its close proximity to the Okavango Delta, it mainly serves as the gateway for tourists visiting the Delta. MIA traffic is dominated by small single- and twin-engine aircrafts that fly daily to and from airfields in the Delta. In 2014, there were 24,864 landings, 24,870 departures and 234,896 passengers (Mmolai 2015). In response to an increase in air traffic within MIA, the Government of Botswana relocated 1,595 families within the vicinity of the airport to pave way for expansion and upgrading of the airport in 2006. An exclosure was, then, established in 2010 in the formerly residential areas or human settlement to be part of MIA.

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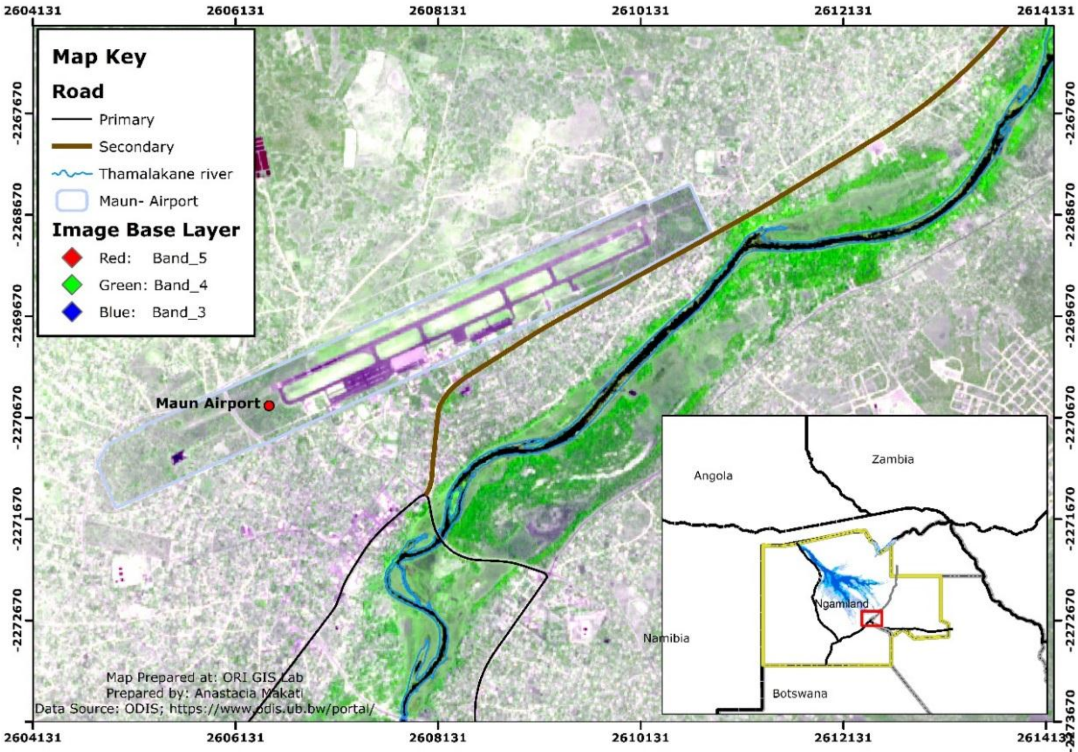

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Fig. 1: Map of the study area

3- Data collection

The species, genera, family, diversity (richness and evenness) and regeneration status of the woody species was determined by laying six and five parallel line transect, 50 m apart inside and outside MIA, respectively. The number of transect lines was informed by the size of the area and spatial heterogeneity of the vegetation. On the transect lines, quadrats measuring 20 x 20 m (400 m^2) were laid down at 50 m intervals, leading to a total of 48 quadrats inside and 37 quadrats outside MIA. The first quadrat was placed 20 m away from the first transect line to minimize the border effect. Following the procedure adopted by Neelo et al (2013; 2015) and Teketay et al. (2016; 2018), the following parameters were recorded in each of the quadrats: identity of all woody species, number of all live individuals of each woody species and height of all woody species. A graduated 20 mm polyvinyl chloride (PVC) conduit was used to measure plant height.

The woody species were identified directly at the sites using books published on the flora of Botswana (Heath and Heath 2010; Setshogo 2002, 2005; Setshogo and Venter 2003) and with assistance from the forest officers and local communities familiar with the flora. Where species could not be identified, herbarium specimens were collected and photographs were taken for later identification at the Peter Smith University of Botswana Herbarium (PSUB). In this article, woody species nomenclature follows that of Setshogo and Venter (2003) and Setshogo (2005).

4- Data analysis

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, measures 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.

Regeneration status of each woody species in the two sites was assessed using frequency distribution of diameter classes. Histograms were constructed by using the density of individuals of each species categorised into 5 height classes i.e. 0–0.5 m; 0.5–1 m; 1–2 m; 2–4 m and > 4 m. The woody species were, then, grouped into different groups based on the pattern of the histograms. The number of groups was determined by the number of pattern of histograms.

Results

1. Species diversity and density

The diversity (H') and eveness (E) of woody species were 1.06 and 0.43 inside, and 0.21 and 0.07 outside MIA, respectively. There were more (26) species inside than outside (11) MIA (Table 1).

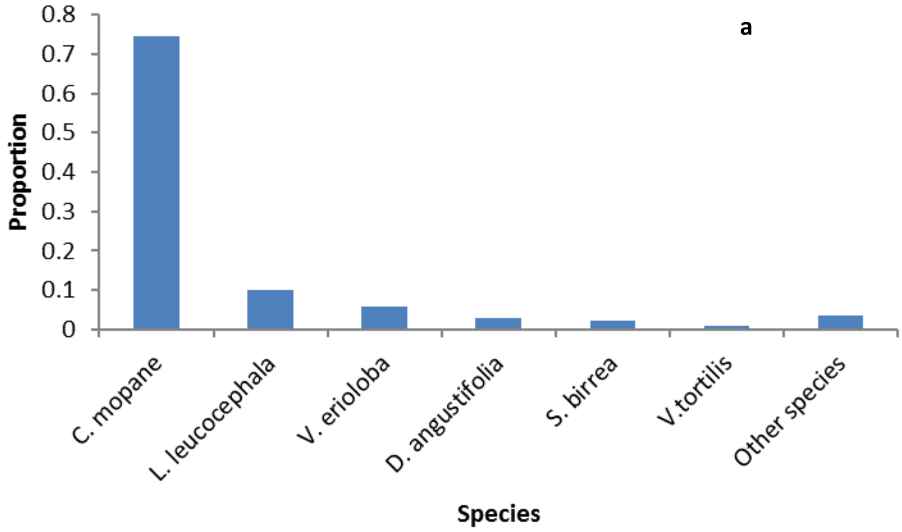
Table 1: Diversity indices of woody species

Site	*H'*	Evenness	Species richness
Inside	1.06	0.43	26
Outside	0.21	0.07	12

There were several differences between the two study sites. The four most common woody species inside MIA were *Colopospermum mopane, Leucaena leucocephala, Vachellia erioloba* and *Dichrostacys angustifolia. Colophospermum mopane, V. erioloba, Vachellia tortilis* and *Boscia albitrunca* dominated outside MIA (Table 2). However, *C. mopane* was found to be the most abundant species both inside (75% of all woody species) and outside (96% of all woody species) (Figure 2). Interestingly, invasive woody species, *L. leucocephala* was the second most abundant species inside and was absent outside MIA. Similarly, other invasive woody species (*Ricinus communis, Jatropha curcas Ailanthus altissima and Jacaranda mimosifolia*) were encountered inside, but not found outside MIA. Some fruit-bearing woody species, such as *B. discolor, B. albitrunca* and *Z. mucronata* were found both inside and outside MIA. Other fruit-bearing species (*S. birrea, G. bicolor and H. petersiana*) were only present inside MIA.

Table 2 Mean density, life form and family names of woody species recorded inside and outside MIA

Species	Life form	Family	Density (individuals ha^{-1}) ± SEM	
			Inside	**Outside**
Colophospermum mopane	Tree	Fabaceae	1971 ± 398	6201 ± 872
Leucaena leucocephala	Shrub/small tree	Fabaceae	266 ± 64	0
Vachellia erioloba	Tree	Fabaceae	150 ± 73	130 ± 41
Dodonaea angustifolia	Shrub	Sapindaceae	77 ± 20	5 ± 4
Sclerocarya birrea	Tree	Anacardiaceae	56 ± 31	0
Vachellia tortilis	Tree	Fabaceae	25 ± 18	44 ± 32
Berchemia discolor	Tree	Rhamnaceae	15 ± 9	2 ± 2
Philenoptera nelsii	Tree	Fabaceae	14 ± 11	1 ± 1
Grewia bicolor	Shrub	Malvaceae	8 ± 6	0
Phyllanthus reticulatus	Shrub	Phyllanthaceae	7 ± 4	0
Ailanthus altissima	Tree	Simaroubaceae	7 ± 7	0
Combretum mossambicense	Tree	Combretaceae	6 ± 3	0
Combretum imberbe	Tree	Combretaceae	5 ± 4	0
Ricinus communis	Shrub/small tree	Euphorbiaceae	5 ± 5	0
Senegalia mellifera	Tree	Fabaceae	5 ± 5	2 ± 2
Boscia albitrunca	Tree	Capparaceae	5 ± 4	19 ± 13
Jatropha curcas	Shrub/small tree	Euphorbiaceae	4 ± 3	0
Ziziphus mucronata	Shrub/small tree	Rhamnaceae	4 ± 3	18 ± 12
Dichrostachys cinerea	Tree	Fabaceae	3 ± 3	6 ± 6
Philenoptera violacea	Tree	Fabaceae	2 ± 2	1 ± 1
Hyphaene petersiana	Tree	Arecaceae	2 ± 2	0
Combretum collinum	Tree	Combretaceae	1 ± 1	0
Croton megalobotrys	Tree	Euphorbiaceae	1 ± 1	0
Terminalia prunioides	Small tree/shrub	Combretaceae	1 ± 1	6 ± 5
Terminalia sericea	Tree	Combretaceae	1 ± 1	0
Jacaranda mimosifolia	Tree	Bignoniaceae	1 ± 1	0
Total			2,642 ± 281	6,435 ± 688



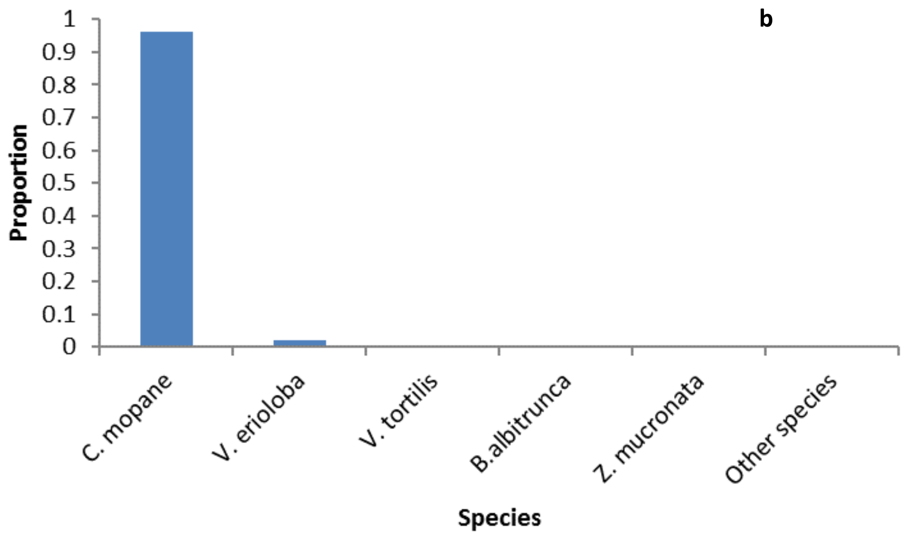


Figure. 2 The relative abundance of the wood species found inside (a) and outside (b) MIA International Airport

2. Regeneration status

Assessment of the regeneration structure of woody species inside MIA produced four regeneration patterns (Figure 3). The first pattern showed high number of individuals in the lower height classes and a gradual decline towards the highest classes (Figure 3a, b, c and d). Such a 'reverse J shaped' pattern was expressed by *C. mopane, V. erioloba, Grewia bicolor, Phyllantus reticulatus, D. angustifolia* and *V. tortilis.* The species in the second pattern showed absence of individuals in the lowest height class i.e. seedlings and missing of individuals in the highest height classes (Figure 3e, and f). This pattern was illustrated by *B. albitrunca, Combretum mossambicense, J. curcas, R. communis, Ziziphus mucronata* and *Berchemia discolor.* The third pattern was composed of species that showed high number of individuals in the first height class and low number of individuals in the upper height class, with missing of individuals in the middle height class (Figure 3g and h). Members of this pattern were *L. leucocephala* and *Screlocarya birrea*. The fourth pattern showed hampered seedling recruitment and lack of regeneration in the higher height classes (Figure 3i and j). This pattern was exemplified by *Philenoptera nelsii* and *Senegalia mellifera*. The fifth pattern showed species with one middle or higher height class (Figure 3k and l). This pattern was represented by *A. altissima* and *D. cinerea*.

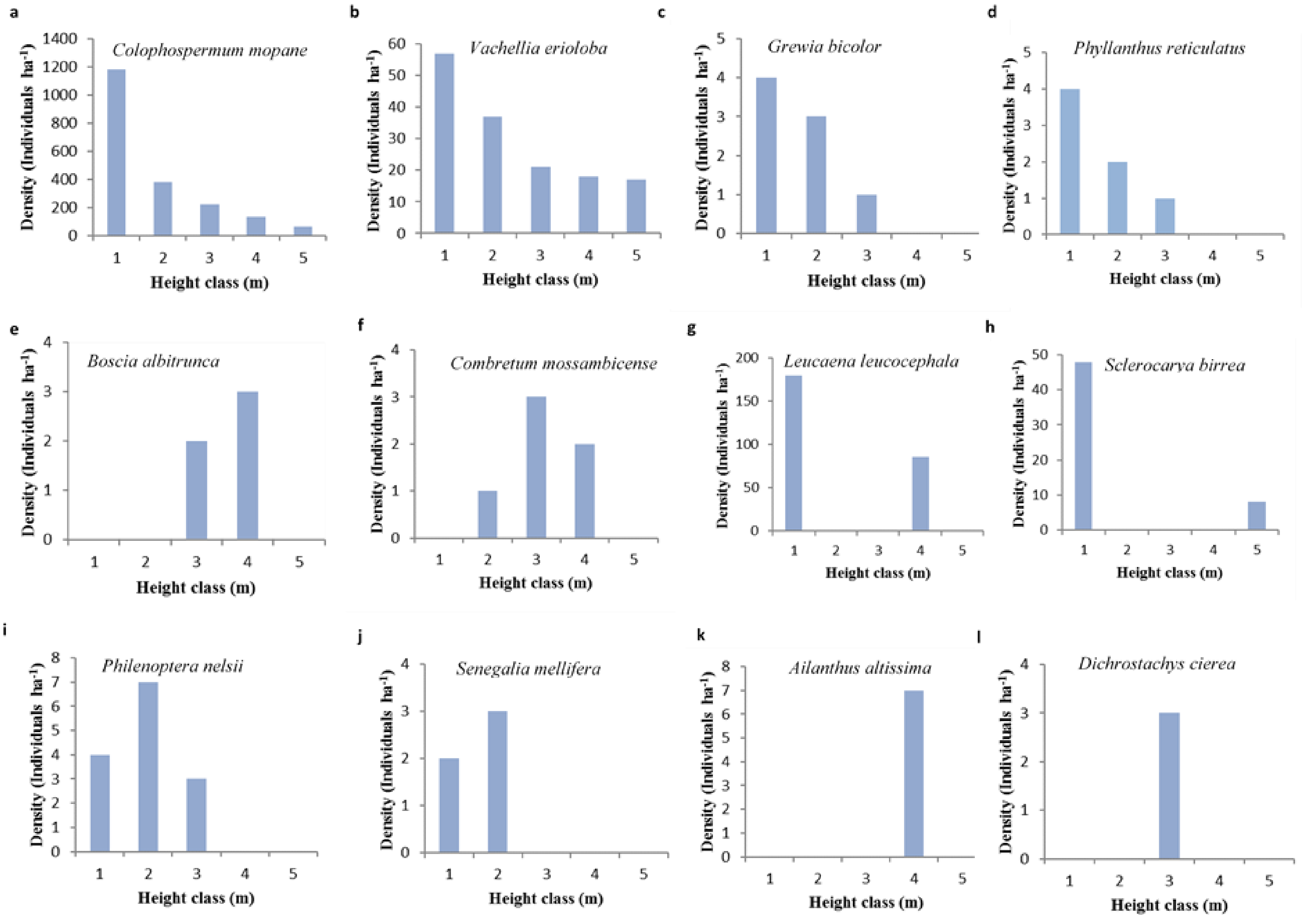


Figure. 3 Population structure of woody species inside Maun International Airport. Height class: 1 = 0–0.5; 2 = 0.5–1; 3 = 1–2; 4 = 2–4; and 5 = > 4 m

The distribution of the woody species outside MIA was categorized into four regeneration patterns based on the height classes profile. The first group showed high number of individuals at the lowest height classes and a progressive decline towards the middle and upper height classes (Figure 4a, b, c and d). This group was represented by *D. cinereal, Z. mucronate, V. erioloba* and *V. tortilis*. The second group showed interrupted 'reverse J shaped' pattern i.e. high number of individuals in the lowest height class and hampered regeneration in the subsequent middle and upper height classes (Figure 4e). This pattern was exhibited by *C. mopane* as the sole species. The third group showed missing of individuals in the lowest height classes (i.e. seedlings) and in the upper height classes (Figure 4 f, g and h). To this group belong *D. angustifolia*, *T. prunioides* and *B. albitrunca.* The species in the fourth group showed dominance of individuals in a single height class (Figure 4i, j, k and l). This group was formed by *B. discolor, C. hereroense, P. nelsii, S. mellifera, H. petersiana* and *P. violacea*.

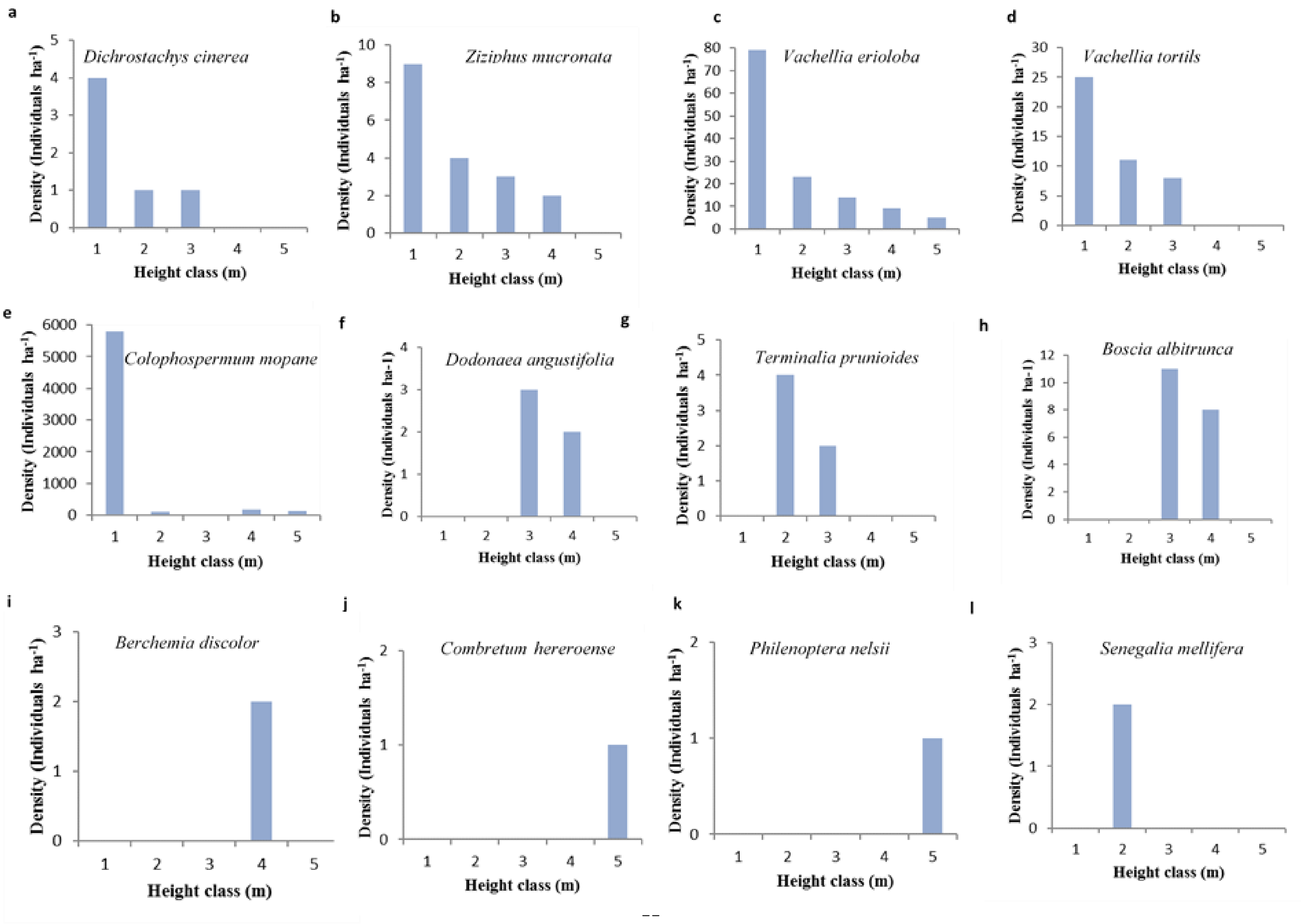


Figure. 4 Population structure of woody species outside Maun International Airport. Height class: 1 = 0–0.5; 2 = 0.5–1; 3 = 1–2; 4 = 2–4; and 5 = > 4 m

Discussion

The study revealed a substantial difference between the inside and outside of MIA in terms of species diversity, evenness and regeneration status of the woody species. The Shannon Diversity Index (*H'*) of the woody species inside was five times greater than outside MIA. This can be attributed to species richness, evenness and anthropogenic disturbances. There were more woody species and better equitable distribution of individuals of different species inside compared with outside MIA. Furthermore, continuous harvesting of woody species for fuelwood and construction as well as annual fires account for lower species diversity outside MIA. The site is also part of communal rangelands and, therefore, subjected to heavy browsing and overgrazing mainly by domestic animals, but also wild animals.

The diversity and evenness observed inside and outside MIA are lower than those recorded from open areas in Botswana e.g. in Shorobe (*H'* = 2.18 and *E* = 0.6) and Xobe (*H'* = 1.5 and *E* = 0.5) (Neelo et al. 2013) and also from an exclosed woodland in Island Safari Lodge (*H'* = 2.16 and *E* = 0.6) and Okavango Research Institute compound (*H'* = 2.42 and *E* = 0.75) (Teketay et al. 2018). These findings are also in agreement with other studies on other exclosures (Mulugeta 2014; Kasim et al. 2015; Asmare and Gure 2019). The lower diversity recorded for MIA could be explained by its historical use for human settlement or residential purposes. It can be argued that during its time as a residential area, most woody species inside MIA were frequently harvested for fuelwood and construction. Regeneration of woody species subjected to such disturbances is influenced by a number of factors (Teketay et al. 2018). When a deforested site is excluded from anthropogenic disturbances and herbivory impacts, as was the case with MIA, vegetation regenerates quickly through seedling recruitment from soil seed bank and coppicing from stumps (Teketay 2005). Soil seed bank is recognized as the main pathway of regeneration of most woody species (Whitmore 1996). In the current study, large numbers of seedlings were recorded for the dominant species (*C. mopane*) inside and outside MIA, suggesting that seed rain is the major regeneration strategy. For other woody species with low numbers of seedlings, it implies they are probably still at an initially recovery stages.

Woody species examined revealed substantial variations in their height-class distributions, which indicates different adaptation capacity of the species to the prevailing environmental conditions and disturbances. Six and four species inside and outside MIA, respectively, exhibited a 'reverse J' shape curve with continuous height-class distributions, which implies healthy regeneration (Teketay et al. 2018; Inoussa et al. 2017; Asmare and Gure 2019). It also confirms the role of the exclosure in conservation of natural resources.

The dominant species *C. mopane* displayed healthy regeneration inside and hampered regeneration outside MIA, suggesting that human impacts, such as cutting and logging are disrupting regeneration of this species. It is commonly used as fire-wood because it burns slowly and produces good charcoal (Tietema et al. 1991) as well as construction and fencing due to its resistance to rotting, termite and powder post beetle ((https://www.wood-database.com/mopane/ accessed on 02-07-2020).

Dichrostachys cinerea and two species of *Vachellia*, namely *V. erioloba* and *V. tortilis* exhibited healthy regeneration outside MIA despite pressure from anthropogenic activities and herbivory impacts. This indicates bush encroachment due to overgrazing and extensive use of these woody species (Neelo et al. 2015; Teketay et al. 2016). The leaves of *V. tortilis* and *V. erioloba* are nutritious (Tolsman et al. 1991; Moleele 1998), but the presence of thorns limit browsing by herbivores and, as a result, the species proliferate into trees and shrubs (Moleele and Perkins 1998). *Dichrostachys cinerea* is an aggressive invader particularly in overgrazed areas (Teketay et al. 2016). It is reported to be, most likely, stimulated by disturbances, such as fire and browsing (Wakeling and Bond 2007; Wigley et al. 2017).

Invasive woody species were only present inside MIA and showed either hampered regeneration (*L. leucocephala*) or hampered seedling recruitment (*J. curcas*, *R. communis* and *A. altissima*). The presence of invasive species is not surprising as the site was previously a residential area and local communities might have introduced them as ornamental trees. *Ailanthus altissima* (also known as prison tree and tree-of-heaven) is planted in most countries as an ornamental tree (Iverson et al. 2019). It is an 'aggressive invader' that spread from root sprouts and grows rapidly to produce large quantities of seeds (Call & Nilsen, 2005) that are wind dispersed (Bory and Clair-Maczulajtys 1980). *Ricinus communis* (also known as castor bean) is a fast-growing small tree that produces large quantities of toxic seeds (Kuete 2014) and has been rejected for use as biofuel crop due to its high invasive potential (Gordon et al. 2011). *Leucaena leucocephala* is a nitrogen-fixing tree-legume (Bageel et al. 2020) that grows vigorously to colonise disturbed vegetation. It has spread aggressively around the world (de Sousa Machado et al. 2020), and it is declared a category 2 weed across South Africa (Henderson 2001). *Jatropha curcas* has spread rapidly in Asia and Africa where it is promoted as an ornamental and hedge plant (www.cabi.org/isc/data sheet). It is classified as a high-risk plant (Gordon et al. 2011; Negussie et al. 2013). Its cultivation is prohibited in Australia (PIER 2008), South Africa (GISP 2008) and Hawaii in USA (USDA-NRCS 2008).

Edible fruit-bearing woody species displayed healthy regeneration (*G. bicolor*), hampered seedling recruitment (*B. albitrunca* and *B. discolor*) and hampered regeneration (*S. birrea*). Lack of seedlings in *B. albitrunca* and *B. discolor* implies that fruits of these species are consumed by humans and browsing animals. Fruits of *B. albitrunca* and *B. discolor* are widely eaten by animals, birds and humans (Heath and Heath 2009). The fruits of *S. birrea* and B. discolor are rich in vitamin C, which is higher than that of exotic species (Leaky 1999; Chivandi et al. 2012), signifying their importance as source of food. *Sclerocarya birrea* fruits have been traditionally used to make a 'beer' (Shackleton 2002). Fruits are also used to make 'Amarula' cream liquor, jams, wine, fruit juice and other products (Wynberg et al. 2002).

Conclusions/wider implications of findings

This study has demonstrated the important role exclosures play in enhancing woody species richness, diversity and evenness as well as facilitating regeneration of woody species. The study has highlighted that degraded woodlands and other similar ecosystems can be cheaply and conveniently restored through establishment of exclosures. Based on our findings, the following recommendations are provided for sustainable management of woodlands inside MIA:

I. plan for eradication of invasive woody species;

II. study the reproductive ecology of individual trees (seed production, dispersal and germination);

III. conduct research on herbaceous species richness, diversity, evenness and density; and

IV. initiate plan for management of bush encroachment.

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