African savanna elephant (*Loxodonta africana*) impacts on vegetation in a fenced area and the broader implications for elephant conservation

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Abstract

The first chapter assessed whether a monitored population of African savanna elephants (*Loxodonta africana*) impacted tree species in the small, fenced Karongwe Private Game Reserve (KPGR), South Africa and to determine levels of tree recovery. Trees in high-use areas were significantly less likely to show signs of debarking and push over. Tall trees were significantly more likely to be impacted by elephants, being associated with heightened risks of debarking and branches being broken but lower risks of being pushed over. Trees close to the fence line were not more impacted than trees near the centre of the reserve. The level of use, distance to the fence and tree height were not significant predictors of tree recovery indicators. Future mitigation efforts should focus on trees with high levels of impact and low levels of recovery. The second chapter considered how elephant impact influenced secondary damages to trees and how this effected tree recovery levels. Secondary damage was identified as insects, where wood borers and termites were considered. Irrespective of tree height, termites were found to be more likely to colonise damaged trees without signs of recovery andwood borers were more likely to colonise damaged trees showing signs of recovery. Therefore, carefully considering management approaches for elephant-induced termite and wood borer impact on trees should be applied in this fenced reserve. Following this, the third chapter considered an alternative method for identifying tree height in the KPGR, using aerial photographs with 3-D photogrammetry. Initial findings here indicate that this method was successful at identifying tree height within this fenced environment. This method should be repeated in such environments in conjunction with other mapping agencies. Lastly, the fourth chapter investigated school children's perceptions of elephants and elephant conservation at different geographical locations. Different levels of exposure to elephants were significant in influencing school children's perceptions. More research is required to enhance environmental education practises to support elephant conservation across different locations.

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Author's declaration

I (KT) confirm that the research presented within this thesis is my own.

The following research papers were submitted or prepared for publication in collaboration with Genoveva Esteban (GE), Andrew Ford (AF), Nathalie Pettorelli (NP) as my core supervisory team. External collaborators Kayla Zoon (KZ) and Angelo Poupard (AP) contributed to studies within this thesis. For Chapter 2 and 3, KZ aided with data collection. AP and AF provided some analyses in Chapter 2 and 4, respectively. KT led the writing of the manuscript:

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1 Introduction

1.1 Organisation of the Thesis

The thesis is presented in an integrated format, whereby material is incorporated in a style suitable for publication in a peer review journal. The first chapter outlines the main themes of the thesis: African savanna elephant (*Loxodonta africana*) impacts on vegetation and the broader implications for elephant conservation. The study areas, aims and objectives of the research project are then introduced. Data chapters 2, 3 and 4 are each presented as original and complete pieces of research, i.e., manuscripts. The final data chapter (chapter 5) is presented as a chapter that will be later condensed into a manuscript for publication. Chapter 6 discusses the implications of this research, future research directions and provides concluding remarks. The complete list of references is provided after the final chapter, to avoid replication and improve readability. Appendices containing data collected are included at the end of the thesis (Appendix 4).

1.2 African elephant conservation status

African elephants (*Loxodonta africana* and *Loxodonta cyclotis*) are found across the African continent at different population densities (Chase et al. 2016; Blanc et al., 2007, 2008; Thouless et al., 2016). After decades of deliberating whether African elephants should in fact be classified as two species, the International Union for Conservation of Nature (IUCN) has now listed African savanna elephants (*L. africana*) as ‘Endangered’ and the African forest elephant (*L. cyclotis*) as ‘Critically Endangered’ (Gobush et al., 2021). This is significant as before the latest status announced this year (2021), the IUCN listed all African elephants as ‘Vulnerable’. The decision was made by the IUCN to treat savanna elephants and forest elephants as separate species, based on genetic evidence on elephant populations (Roca et al., 2015; Mondol et al., 2015). Forest elephants are found in tropical forests in Central Africa and West Africa, and rarely overlap with the range of savanna elephants (largely East and Southern Africa) (Roca et al., 2007; Ishida et al., 2011; Mondol et al., 2015; Palkopoulou et al., 2018; Kim and Wasser, 2019). Additionally, forest elephants are smaller, gestate longer, have oval ears and smaller tusks. Savanna elephants live in large family units (known as breeding herds) have larger ears and different shaped skulls to forest elephants (Figure 1.1).

Figure 1.1 African savanna elephant (*L. africana*) (top image) and African forest elephant (*L. cyclotis*) (bottom image). Top image taken by the author (2018) and bottom image taken by Frank af Petersons, Save the elephants (Gobush et al., 2021).

This scientific development is extremely important mainly for the conservation implications it will have. The new IUCN assessment (2021) has found that in the last 31 years, the population of forest elephants has decreased by more than 86%, while the population of savanna elephants has decreased by at least 60% in the last 50 years (Gobush et al., 2021). The causes of these declines have been attributed to ivory poaching, habitat loss, and land fragmentation (Lemieux and Clarke, 2009; Thouless et al., 2016; Wittemyer et al., 2014). These alarming new statistics only increase the need for continued research on these sentient animals (Reinwald et al., 2021). It is important to acknowledge here that decreasing populations of savanna elephants is not spatially uniform across the continent, and great variability in elephant populations is evident across Africa. Therefore, conservation of both savanna and forest elephants needs to be carefully tailored to location. Considerable caution and local knowledge are required when applying this information into policy and management, and further actions are needed to conserve both species and reduce such unsustainable rapid declines.

1.2.1 Milestones in elephant conservation

Acknowledging the decline in elephant populations has historically given rise to many conservation projects, driven by international policies, as a result of poaching and conflict (Thouless et al., 2016; Chase et al., 2016). African elephants are part of the 'Big Five': the most dangerous and toughest animals to hunt in Africa (Capstick, 1983; Du Toit, 2001). Management of elephant culling was undertaken up until the early '90s, but this method has largely ceased today (Carruthers et al., 2008). However, in some countries game hunting of African savanna elephants is still legally permitted, and it is important source of income for those countries (Naidoo et al., 2016).

In 1989, when both African elephants were considered a single species, the African savanna elephant was listed in the Convention on International Trade in Endangered Species of Wild

Flora and Fauna (CITES). CITES-approved sales of national ivory stockpiles took place in 2002 and 2008, for Botswana, Zimbabwe and Namibia and later South Africa to two buyers: Japan and China. At this time, the demand for ivory in Japan decreased whilst demand in China grew, causing ivory prices to increase dramatically in China and Africa (Wittemyer et al., 2011, 2014) and debates around the benefits and consequences of these sales are highly divided (Stiles, 2004; Bennett, 2015; Biggs et al., 2017). This opening of the legal ivory market in China raised concerns by conservationists that this would lead to a rise in poaching. Added to this, illegally trafficking of ivory occurs today, and there has been a significant increase since 2006 (Underwood et al., 2013; Milliken, 2016).

Empirical research conducted by Monitoring the Illegal Killing of Elephants (MIKE) and the Elephant Trade Information System (ETIS) of ivory seizures between 2009-2013, affirmed that poaching levels of elephants and ivory trafficking occurred at alarming rates, and elephant populations across the continent went into net decline (CITES, 2018, 2019). At this time, growth of the consumer class in China increased the demand for ivory, driving poachers to increase harvesting ivory for money (Vigne and Martin, 2017; Meijer et al., 2018) and CITES recognised that elephant poaching has, again, reached an unsustainable level.

Following this, the Great Elephant Census was conducted in 2014, spanning 18 countries and 295,000 miles (Chase et al., 2016). Results released in 2016 revealed that there had been a 30% drop of savanna elephants in seven years. At a national level, National Ivory Action Plans (NIAPs) have been developed to combat illegal ivory trade, where the African savanna elephant is protected at different levels. As half of the species range is outside of protected areas (Taylor, 2009) and the level of protection is an important predictor of the species presenceand density (de Boer et al., 2013), providing protection is critical but fundamentally challenging because of these factors. However, conservation measures are vital, as Chase et al., (2016) demonstrated in areas where protection measures fail, elephant populations reduced by 70% within a 10-year period.

Savanna elephant reintroductions within fenced reserves across South Africa has proved successful in maintaining and increasing elephant population numbers over the last 25 years (Blanc and Barnes, 2007; Chase et al., 2016). Given the recent change in status of savanna elephants, this population increase is crucial for conserving elephants that are generally in decline. However, this population increase has raised concerns with regards to the suitability of these constrained areas for increasing elephant numbers. This thesis will consider a small, fenced reserve with high elephant density (Karongwe Private Game Reserve (KPGR), South Africa), to gain insights into the impacts of elephants on vegetation in response to their habitat use.

1.3 Importance of elephants

Elephants are among the most intelligent animals, with complex consciousness and strong emotions (Bates, Pool and Byrne, 2008). Their societal structures of large networks with hierarchical organisation may be one of the most elaborate of any vertebrate (Irie and Hasegawa, 2009). They have a flexible, fission-fusion society which means that they can differentiate between hundreds of individuals (Byrne and Bates, 2011). Elephant herds are led by matriarchs, which communicate with each other using low-frequency ultrasound calls (Payne et al., 1986) over distances of more than 1 km (Garstang, 2004). There is also increased evidence demonstrating sophisticated cognitive abilities in elephants (Irie and Hasegawa, 2009). Studies have shown that they can recognise their own reflection in a mirror (Plotnik et al., 2006), and are able to learn various commands by jungle dwellers (Rensch, 1957). Furthermore, they are unique in terms of having a prehensile trunk, which is used (amongst other purposes) for feeding, modifying objects, greeting other elephants and in conflict with other elephants (Hart and Hart, 1994).

African and Asian elephants are important ecologically as they are ecosystem engineers, promoting diversity of both habitats and species of flora and fauna (Bond, 1993; Jones et al., 1994). They play a key, ecological role in maintaining the linkages in the food web and their extinction would cause changes in both forest and savanna ecosystems (Western, 1989). Elephants are also important agents of seed dispersal, increasing habitat mosaics and diversifying mammalian communities (Bunney et al., 2017; Cochrane, 2003). Studies have shown that with few elephants present, vegetation can become homogenous, and woodland can become dense and encroaching which indirectly shapes the remaining wildlife community (Fritz et al., 2002). Elephants play an essential role in creating forest gaps, which helps diversify forests enabling vegetation to grow in otherwise canopy shadowed areas, in turn supporting other vertebrate feeding (Western, 1989; Valeix et al., 2011). Their distinct feeding and movement patterns shape the faunal and floral diversity of savanna and forest ecosystems(Ben-Shahar, 1993; de Beer et al., 2006). Elephant presence within savanna ecosystems is therefore essential for many species, and their removal will lead to cascading effects on manyecological processes (MacGregor et al., 2004).

Elephants are not only ecologically important; they are economically and culturally significant. As noted earlier, their behaviour and cognitive abilities make them a valuable species, and popular to many people globally. In areas across Africa, elephants are economically important as they are a species of interest for tourists, where ecotourism benefits local communities (Jones and Barnes, 2007; Libanda and Blignaut, 2007). Novelli et al. (2006) argued that this knowledge may contribute to shaping societies attitudes towards elephant conservation. The economic value of wildlife tourism in Africa, including elephants as a key species, is a significant proportion of their Gross Domestic Product (GDP) (Naidoo et al., 2016). The

COVID-19 pandemic has shown just how essential tourists are for wildlife conservation and the people who are reliant on that income across Africa (Lindsey et al., 2020). Newsome (2020) suggested that longer-term recession of wildlife tourism will lead to increased poaching and losses of wildlife. This only exacerbates the need for sustainable elephant conservation, for tourist dependent industries, local communities, and sustainable development across many African countries.

1.4 Savanna ecosystems

African savanna elephants (*Loxodonta africana*) are keystone species for savanna ecosystems (Western, 1989), helping promote diversity of both habitats and species (Brooks and MacDonald, 1983; Owen-Smith, 2006; Campos-Arceiz and Blake, 2011). African savanna ecosystems are comprised of both woody (trees and shrubs) and herbaceous (grasses) vegetation that determine the functioning of these ecosystems (Bond, 2008; Shannon et al., 2011). Abiotic drivers such rainfall and soil type influence the composition and structure of such savannas (Levick et al., 2009). Direct disturbance agents such as fire and herbivory can also contribute to changes in savanna structure (Levick et al., 2009) and ultimately ecosystem change (Shannon et al., 2008; Midgley, Lawes and Chamaillé-jammes, 2010).

Abiotic drivers such rainfall and soil type influence the composition and structure of such savannas (Levick et al., 2009). Direct disturbance agents such as fire and herbivory can also contribute to changes in savanna structure (Levick et al., 2009; Straver et al., 2009) and ultimately ecosystem change (Shannon et al., 2008; Midgley, Lawes and Chamaillé-jammes, 2010). Fire can be damaging to an ecosystem, but it can also benefit the regeneration of certain flora species that have fire resilience adaptations such as post-fire seeding and resprouting (Govender et al., 2006). Species that are not resilient are therefore particularly vulnerable to any fire events (Bond et al., 2001). Fire is a non-selective ecological driver, which can cause a reduction in woody biomass by removing small seedlings, and larger well established woody tree species (Govender et al., 2006; Mapaure, 2013; Aleper et al., 2008). However, if the scale and frequency of fires are managed effectively then an ecosystem will recover. The influence of fire and herbivory on vegetation change is difficult to interpret, as complex feedback relationships exist (Holdo et al., 2009; Midgley et al., 2010).

Large herbivores that are found within savanna ecosystems include species such as white rhinoceros (*Ceratotherium simum*), African savanna elephant and giraffe species (*Giraffa* spp.). Of these, the African savanna elephant has been suggested to be the most prominent herbivore that can influence savanna vegetation structure (Owen-Smith, 1992; Kerley et al., 2006). Their feeding and movement behaviours can affect woody vegetation structure composition (Shannon et al., 2008) and resultantly cause an increase in shrubland. Therefore, the rate and extent at which savannas are being altered from woodland to shrubland because of large herbivores is of concern to specific countries, especially within the southern Africa states. Added to this, large herbivores can prove difficult to manage at various spatial extents due to their size, and their long-term impact on vegetation is not fully understood (Scholtz et al., 2014).

1.4.1 Elephant vegetation selectivity

Elephants can have a significant influence on ecological processes (Oliveras and Malhi, 2016), as they can alter the structure and composition of landscapes (Dublin et al., 1995; Cumming et al., 1997; Laws 1970). Elephant impact on woody vegetation can lead to a reduction in the number of trees within savannas, which can also lead to the extirpation of some woody plant species (O'Connor et al., 2007). Their feeding and movement activities influence vegetation structure, as they debark trees, break large branches, and often uproot trees (Coetzee et al., 1979; Mosugelo et al., 2002; O'Connor et al., 2007; Owen-Smith and Chafota, 2012). African elephants select tree species with high concentrations of nutrients (Holdo, 2003), and large volumes of foliage (Boundja and Midgley, 2010; Levick and Asner, 2013). Their feeding activity may not directly lead to tree mortality, but if the main stem is broken, the tree has been uprooted or more than 50% of the stem has been debarked, then these susceptible trees are more likely to die (O'Connor, Goodman and Clegg, 2007).

In addition, certain tree species are resilient to elephant impacts and respond with coppicing to hedge level growth (such as mopane, C*olophospermum mopane*) benefitting many browsing species such as mesoherbivores (Lewis 1991; Styles and Skinner, 2000). Depending on the severity of the impact some tree species can persist through time, but impact may increase vulnerability to other indirect disturbance agents such as fire (Croze, 1974; Leuthold, 1977; Pellew, 1983; Lock, 1993; Dublin, 1995; Western and Maitumo, 2004).

The cognitive behaviour of elephants means that they are highly selective in their foraging behaviours, where plant species selectivity and size are both considered (Vesey-Fitzgerald, 1973, Landman et al., 2008). Their selective behaviour means that only specific targeted species are impacted, compared to that of other disturbance agents (Dohn et al., 2017). They select trees with large volumes of foliage to gain maximum energy output, and the level of impact has been suggested to depend on tree characteristics such as height and canopy width (Boundja and Midgley, 2010; Levick and Asner, 2013, Howes et al., 2020). Additionally, elephants have shown preference for marula (*Sclerocarya birrea*) trees greater than 6 m in height, where they can feed on the canopy foliage (Cook et al., 2017). This selective feeding behaviour has been shown to be the cause of large tree (≥ 5 m) mortality across savanna biomes (Vanak et al., 2012; Helm and Witkowski, 2013). Research around this topic has been at the forefront of savanna ecology as concerns have been raised with the level of tree replacement of large woody tree species (Laws, 1970; Shannon et al., 2008).

1.5 Vegetation patterns within fenced reserves

Elephant reintroductions to fenced reserves are possible due to their suitable conditions for translocated elephants from larger reserves (Gaugris and Van Rooyen, 2010; Mackey et al., 2006; Thouless et al., 2016). Fenced reserves play an integral role in conservation as they aid in the decrease of human-wildlife conflict, poaching and the spread of diseases from livestock (Boone and Hobbs, 2004; Pirie et al., 2017). However, within fenced reserves, suitability of land, elephant densities and vegetation sustainment are often met with apprehensions (Lombard et al., 2001; Stretch et al., 2002; Caughley, 1976). Fences can influence the movement patterns of wildlife, as species that are constrained cannot move to areas with more abundant resources (Hopcraft et al., 2010). This can be especially important during the dry season when there is lower levels of forage available and water availability can become reduced (Oates and Rees, 2013; Skarpe, 1992; Tefempa et al., 2008). This can in turn effect large herbivore distributions within these confined spaces (Chamaille-Jammes et al., 2007; Redfern et al., 2003).

Hence, understanding how large herbivores utilise landscapes is important for reserve management. Concerns on the loss off trees ≥ 5 m tall across Africa's protected areas has been partly attributed to impacts by savanna elephants, which in turn is likely to be influenced by the proximity of fences and artificial water points (AWP). Large savanna trees (≥ 5 m) are considered important in savanna structures, as they provide resources (Dean et al., 1999) and enhance spatial heterogeneity (Manning et al., 2006). The future of the large trees persisting within fenced reserves is often thought as unsustainable due to elephants browsing behaviours within these confined spaces (Slotow et al., 2005). For example, Cook et al. (2017) found that within the Jejane Private Nature Reserve (JPNR), South Africa, elephant reintroductions lead to increase of the annual mortality rates of marula trees. Cook et al. (2017) stressed the lack of seedling regeneration as a result of elephant impact, which needs to be further quantified.

1.5.1 Elephant impact to vegetation in South Africa

An increase in elephant population density results in an increased demand on resources, where under natural conditions (free roaming and no land use restrictions), this increase would cause a range expansion or distribution shift. However, this is not the case throughout South Africa where there are high elephant population densities in confined spaces (Landman et al., 2008). This is due to suitable areas contracting because of human encroachment, and protected areas and fenced game reserves have been designated by management approaches (Lehmann et al., 2008; Lombard et al., 2001). There is increasing pressure on managed fenced reserves to support elephants sustainably, as there is little known on the long-term effects of maintaining elephants on vegetation within these fenced areas at different spatial and temporal extents.

Historically, studies on elephant impact in South Africa have been based around the Kruger National Park (KNP) to determine the decline in woody species and reduce the impacts of elephants (Eckhardt, Wilgen and Biggs, 2000; Levick et al., 2009). KNP is a renowned stronghold for African savanna elephants, and it is the largest protected area in South Africa (~20 000 km²). Elephant populations have significantly increased over the last 20 years, where 17 086 elephants were resident in 2015, growing at 4.2% per annum (Ferreira and Simms, 2017). Van Wyk and Fairall (1969) stated that the most important tree species in KNP were red bush willow (*Combretum apiculatum*), clusterleaf (*Terminalia sericea*), knob thorn (*Sengalia nigrescens*), marula and mopane (*Colophospermum mopane*). These five tree species constituted about 80% of the tree species population within this area. The potential impact of elephants on marula trees within the KNP, due to their ecological significance, resulted in a research project in 1979 to determine the extent of this (Coetzee, et al., 1979). This study indicated that the impact at the time of study did not threaten the marula population. Contrary to these outcomes, a later study by Trollope et al. (1998) recorded declines in the woody vegetation of between 1960 and 1989, suggesting that this could be due to the extreme increase in elephants during this time as well as other environmental factors.

There have been extensive studies on the impact of elephants to tree species in open (unfenced) reserves (Holdo, 2003; Morrison, Holdo and Anderson, 2016). However, there are relatively few including Gaugris and Van Rooyen (2010), Kerley and Landman (2006) and Howes et al. (2020) that have focused on the impact that elephants have on tree species within small (< 200 km^2) fenced reserves. Additionally, these studies have not considered the recovery levels of trees at different heights, after impact from elephants occurs. The recovery levels on tree species after elephant impacts occurs has also not been addressed in other studies within fenced areas, that focus on a single species (Gadd, 1997; Jacobs and Biggs, 2002). Thus, it is essential that we can determine recovery levels, such as coppicing and regrowth of trees after elephant impact occurs, so that reserve managers can apply appropriate mitigation strategies to sustain tree species to support elephant survival. This thesis aims to contribute to this gap in knowledge.

At a small reserve extent (< 200 km^2), the impact that elephants have on marula tree populations has been recorded in South Africa (Gadd, 1997; Weaver, 1995; Cook et al., 2017). Gadd (1997) found that marula trees were significantly impacted by elephant browsing, and recruitment and regeneration of these trees were weak. Weaver (1995) found that elephant impact was significant in both marula and knob thorn trees. Various studies on the effect of elephants within enclosed reserves have been conducted, but the density of elephants relative to the reserve size differs greatly, and one single tree species is often considered (Ruess and Halter, 1983; Jacobs and Biggs, 2000; Coetzee et al., 1979).

1.5.2 Secondary impacts to vegetation

Elephant impact to vegetation has to date, been focussed on the abundance of large trees due to their environmental and economic significance (Shannon et al., 2008). Elephants can cause branch breaking and debarking, which has been used to determine levels of non-severe to severe impact (Boundja and Midgley, 2010; MacGregor and Connor, 2004; Seloana et al., 2017), often derived from the Walker eight-point scale (Walker, 1976). Walker's (1976) method is used to record vegetation composition and utilisation. The types of elephant impact can enhance tree susceptibility to secondary impacts such as termites (*Coptotermes* species), woodborers (*Cerambycidae* species) or other insects, which may shorten trees' life span (Hatcher, 1995).

Termites can penetrate trees through fractures in the bark (Gould et al., 1993) and establish secondary nests inside the tree's cavities (Harris, 1968). This can occur more readily once the tree bark has been stripped by elephants (Helm et al., 2011) (Figure 1.2). Additionally, wood borer damage to trees is characterised by the woodboring activity of larvae and adult beetles in the stems and branches of damaged or stressed hosts (Halperin and Geis, 1999; Peters et al., 2002; Nair, 2007). Adult mortality of marula trees has been suggested to be attributed to rapid invasion by wood borers after bark stripping occurs and the sapwood is exposed (Helm et al., 2011; Coetzee et al., 1979; Guy, 1989; Jacobs and Biggs, 2002). This secondary impact may therefore hinder the trees' ability to recover, effecting the survival of trees within savanna ecosystems (Holdo, 2007). Therefore, it is important that we understand how tree species recover after secondary damage occurs, which has not yet been identified.

To date, there are relatively few studies that have considered the effects of elephants on invertebrates. Disturbance from elephants has been shown to influence dung beetle species diversity and biomass (Botes et al., 2006). Trees that are toppled by elephants may also provide refugia for species such as ground dwelling invertebrates (Govender, 2005). Musgrave and Compton (1997) considered the composition of phytophagous insect communities within Addo Elephant National Park (AENP), finding on average greater levels of impact on plants which were browsed by elephants. This was suggested to be caused by the change in nutrients as a result of severe pruning, causing rapid regrowth which is more palatable than unbrowsed material. However, the Kaffrarian succulent thicket habitat in AENP is unique in terms of plant cover, consisting of mainly evergreens (Stuart-Hill, 1992). Therefore, there is still a need to examine the effects on other different types of woody vegetation. The direct relationship between elephant impact and the subsequent secondary impact and tree recovery levels have yet to be fully understood. This thesis will aim to identify this gap in knowledge, to contribute to sustainable management approaches of elephants and vegetation within fenced reserves.

Figure 1.2 Field recordings of elephant impact and secondary damage to tree species within the KPGR (2019)

1.5.3 Methods to determine elephant impact

To date studies on elephant impact have used field-based methods for data collection on trees biophysical and vertical structural parameters (Nkosi et al., 2019) (Figure 1.3). Historically, field-based methods have used in ecological studies to provide detailed ecological data at small extents (Simms, 2009; Buchanan et al., 2013) which are often focused on specific tree species. For example, Cook et al. (2019) considered elephant impact over time on marula trees, using field-based methods in an area where elephants were excluded, and later reintroduced to a site within the KNP. This attempt to address the vegetation change over a fixed time, was dependent on accurate, replicable data acquisition, which is often not the case on large spatial areas, and in turn can hinder research attempting to address temporal changes to vegetation. Added to this, field-based methods are impractical and costly to implement for large data sets that are required on a regular basis to develop effective assessments for conservation management outcomes.

Figure 1.3 Field recordings of elephant impact to *Vachellia robusta* tree within KPGR, South Africa (2018). A staff with known height is used to determine tree metrics via *VolCalc* (Barrett and Brown, 2012)

Remote sensing techniques offer an alternative approach, that are not only cost-effective for application in large areas (Duro et al., 2007), but can also enable detailed ecological insights depending on the technique that is applied. Remote sensing methods at a 2-D scale using aerial photography, have been used to determine South African vegetation imaging landscape for many years. Mutanga and Ahmed (2016) identified that studies have focused on long term vegetation cover changes (Eckhardt, Van Wilgen, and Biggs, 2000; Russell and Ward, 2014), bush encroachment (Hudak and Wessman, 1998; Sirami, Seymour, Midgley, and Barnard, 2009; Wigley, Bond, and Hoffman, 2010), and biodiversity (Cumming et al., 1997).

Monitoring long-term savanna woody cover dynamics is possible using remotely sensed imagery, which could offer opportunities for conservation authorities.

To date, texture analysis has been applied to analyse woody vegetation using aerial photographs and satellite images (Asner et al., 2003; Hudak and Wessman, 1998). In many cases, optical imagery is used which can have limitations if imagery has clouds, shadow, low spatial variability and being 2-D in nature which may be insufficient for providing the necessary information to determine tree metrics (Kachamba et al., 2016). To derive tree metrics at a 3-D scale in savanna ecosystems, airborne laser scanning (ALS) methods have been used with light detection and ranging (LiDAR) scanners within the Kruger National Park (KNP) (Asner et al., 2009; Levick et al., 2009). ALS techniques are increasingly being used for the measuring and monitoring of 3-D vegetation structure (Lefksy et al., 2002), within these heterogeneous savanna ecosystems (Asner et al., 2009; Johansen et al., 2010; Levick et al., 2009; Levick and Rogers, 2008; Levick and Asner, 2013; Davies, Gaylard and Asner, 2018). However, ALS applications are extremely expensive to disseminate on large temporal and spatial extents, so alternative methods are required to identify and analyse 3-D tree structures.

The performance of 3-D photogrammetry applied to aerial photographs for the retrieval of savanna tree attributes, has not been studied extensively. There is potential for using aerial photography to derive 3-D vegetation dynamics to quantify tree heights at a landscape scale which could provide an economically viable approach. The use of aerial photographs within savanna ecosystems could potentially offer an opportunity to utilise an accessible resource to inform best practises for management approaches. Therefore, this thesis will address this gap in knowledge.

1.6 Approaches to elephant management

The optimal size of nature reserves has been the subject of debate for many years (Soule and Simberloff, 1986; Noss and Cooperrider, 1994; Shafer, 1995; Soule and Terborgh 1999; Margules and Pressey, 2000). Small game reserves (< 200 km^2) can help to protect and conserve ecological spaces and the species within them. Evidence suggests that privately owned conservation areas can protect biodiversity and are profitable (Mitchell et al., 2006; Kramer et al., 2002).

The need for private game reserves has increased over recent decades due to land becoming increasingly fragmented as a result of human development (van Hoven, 2015). This has meant that there is an increased need for small (< 200 km^2) enclosed reserves. As these areas are enclosed, reserve mangers need to effectively monitor fauna populations. This is especially important for elephants, who are unable to immigrate and emigrate to other areas in response to resource distribution within these fenced areas. Added to this, the movement patterns of elephants have been shown to be influenced by the proximity of the fence line, suggesting an increase in habitat utilisation within the centre of a reserve (Vanak et al., 2010). The direct effect of fences in relation to herbivore behaviour within small, fenced reserves has yet to be identified and needs further investigation (Hayward, 2009) which we will consider in this study. A greater understanding of elephant impact to vegetation within enclosed, small reserves is needed, to support to the conservation of elephant populations within South Africa.

Management approaches for reserves varies spatially as there are many factors that can influence the utilisation of trees and the level of elephant impact (Ntumi et al., 2005; Henley and Cook, 2019). Currentmethods include monitoring elephant's spatial movement activities, for both high- and low- level impacts (Loarie et al., 2009). Within South Africa, African savanna elephants have co- existed on managed fenced reserves (Asner et al., 2016). However, concerns over their impacton large trees, has seen a significant rise over recent years, and management has focussed on protecting endemic species and maintaining the natural system to an ‘ideal’ state (Kerley et al., 2010; Cumming et al., 1997). The ideal state has been based on historic records as well as tourist perceptions (Lomard, 1995).

Factors that impact management decisions include the presence of fences and AWPs (Hisocks, 1999). Elephants have sophisticated cognitive abilities and a significant memory capacity, where they follow a natural migratory pattern passed down from generations of matriarchs when they can roam freely. Fences often prevent this behaviour, and roads can act as pathways which they use to move through an area (Cushman, Chase and Griffin, 2010). During the dry season, AWPs serve as a permanent refuge within confined areas when natural resources dry up. These abiotic management methods can cause elephants to be confined within smaller areas, limiting resource distribution and overutilisation of certain plant species (Loarie et al., 2009).

Recent research has demonstrated how mitigation approaches to elephant management has changed from directly managing elephant numbers by invasive methods, to elephant distributions being managed in relation to gradients of their impact on vegetation (Cook and Henley, 2019; Henley and Cook, 2019). This method considers solutions to large-scale landscape manipulation, promoting interconnectivity and reducing fragmented landscapes. Protected areas such as the KNP is using this mitigation strategy across certain areas to protect large trees (≥ 5 m) from elephant damage, but this landscape scale approach is a viable option for this site due to its size(~20 000 km^2) and is not viable for smaller reserve extents. Mitigation measures for small reserves need to consider a combination of options such as translocations and contraceptive programmes, but there is a significant lack of knowledge of the implications that these measures have long term on a small-scale reserve (Duffy, 2002). Added to this, the long-termimplications of these mitigation methods on elephant’s societal change have not yet been evaluated (Nyakaana et al., 2001; Wittemyer et al., 2009).

Even though many of the challenges faced by elephants are similar, the approaches to their conservation and management vary greatly. Within South Africa, savanna elephants are numerous, and populations are growing. Their populations are managed within Private Nature Reserves and National Parks, where natural mortality may not suffice to control elephant numbers and meet conservation goals (Woolley et al., 2008). Therefore, management is required to regionally monitor elephant populations (Owen-Smith et al., 2006). Translocating elephants is an option, but this is only possible with areas of suitable habitat and elephant numbers in the area is appropriate. Management methods in areas where high elephant densities are found include culling, contraception (Fayrer-Hosken et al., 2000; Delsink et al., 2006), or creating habitat corridors and increasing available areas within proximity is also effective (Osborn and Parker, 2003).

1.7 People and elephant conservation

African elephant population declines have historically given rise to many conservation organisations, both *in-situ* and *ex-situ*. In-situ research-based organisations such as non-governmental organisation (NGOs), are often reliant on funding from international funders and donors to support research and conservation practises. Long standing elephant conservation organisations such as ‘Save the Elephants’ have been at the forefront of elephant conservation. Partnering both research on African elephants and frontline monitoring has enabled this organisation and many organisations alike to work with and directly conserve elephant populations. Rangers, conservationists, and anti-poaching organisations, are at the frontline of elephant conservation, tirelessly protecting and monitoring these animals. This includes anti-poaching patrols, monitoring fence lines and anti-snare procedures.

Approaches to elephant conservation differ between cultures, where community involvement has been applied across savanna environments (Sitati, 2012; Sitati and Wapole, 2006; Parker and Osborn, 2006). Community involvement views local participation as a prerequisite to sustainable conservation (Ashrnafi and Leader-Williams, 2005). Local knowledge holds intrinsic values and importance to science and conservation. With community knowledge associated with their immediate environment, this can prove vital to improve ongoing ecological research and conservation programmes. Therefore, community involvement is essential for passing on valuable knowledge to future generations effectively to people both *in-situ* and *ex-situ* for effective elephant conservation.

1.7.1 Environmental education

The ability to conduct relevant scientific research on conservation issues is important to determine the extent of how ecosystems will be affected. This information is key to enable effective communication with decision makers and stakeholders, but this alone is not sufficient to solve complex conservation issues (Kansky and Knight, 2014). Environmental education (EE) is a key conservation strategy that can be applied to important conservation topics (Kapur, 2017). This method provides environmental awareness information that can influence individuals and communities, to students of all levels. EE can be carried out at all ages, however EE practises targeted at school children is important, as they are not likely to have fully formed opinions or attitudes about the environment (Pelletier et al., 2004). Studies have highlighted the importance of targeting children, for nurturing positive environmental behaviours and help spread positive effects of EE programmes to a wider demographic (Rakotomamonjy et al., 2014; Damerell et al., 2013).

Environmental education is engrained in conservation programmes such as protecting nature and wildlife (Athman and Monroe, 2001; Fraser et al., 2015). This is especially important when considering endangered species that need effective conservation, as these species would likely not survivewithout intervention strategies. Elephants are one such species, which have been described earlier in this chapter. They are faced with challenges such a land fragmentation, poaching and habitat destruction, causing population numbers to decline (Leimgruber et al., 2003; Nelson, Bidwell, and Sillero-Zubiri, 2003). Understanding children's perception of elephant conservation could improve conservation education delivery, enhancing children's connection to elephants which is crucial for their long-term conservation (Ardoin and Bowers, 2020).

Environmental education programmes based on environmental issues need to be carefully applied depending on howschool children perceive concerns around elephant conservation. This can only be achieved ifwe have a clear understanding of school children's perception, *in* and *ex situ* of elephants whichwill likely be influenced by the level of exposure to elephants. This has yet to be identified, where studies have often focussed on adults within local communities and their response to Human Elephant Conflict (HEC) (Hart and O'Connell, 1998; Bandara and Tisdell, 2003; Raihan Sarker and Røskaft, 2010; Western et al., 2015). This is important to establish, howeverdetermining how school children perceive elephants is an essential method in supporting longterm management of elephants. By understanding school children's perceptions, we can betterunderstand their attitudes towards elephant conservation and provide support and guidance to critical areas.

1.8 Project Rationale

A greater understanding of elephant impact to vegetation within enclosed, small reserves is needed, to determine the long-term sustainability of vegetation and ultimately, how this understanding can contribute to the conservation of elephant populations within South Africa. There have been various studies on the impacts that elephants have on vegetation at this scale, but these have been limited to single species and lack important information on the recovery of tree species that exhibit elephant impact. Determining the level of tree recovery after elephant impact occurs is essential to be able to maintain vegetation with elephant presence in enclosed areas. Additionally, the fenced nature of enclosed reserves has also been overlooked as a potential determinant of impact levels in many studies which requires further investigation. Therefore, the levels of impact and recovery in response to elephant habitat use and fence line effect is the focus of Chapter 2.

Added to this, the increasing elephant densities in fenced reserves (Skarpe et al., 2004; Shannon et al., 2008) and the decreasing numbers of large trees (Ben-Shahar, 1993; Eckhardt et al., 2000; Moncrieff et al., 2008), has resulted in a need for improved knowledge of how elephants and other subsequent disturbances can result in tree death (Holdo, 2005). Tree species are faced with several biotic constraints such as insects (Wargo, 1996; Hakeem et al., 2012), and this secondary impact partnered with the lack of tree recovery, has been overlooked in many studies focussed on elephant impact within fenced reserves. Therefore, there is need to determine how insect presence relates to tree impact and how this affects tree recovery. This is the focus of Chapter 3.

To be able to effectively predict the effects that elephants have on vegetation, field data collection and statistical analysis techniques have been used in this PhD research to provide quality data visualisation and management. Mixed-effect models using statistical analyses programmes have been used effectively to predict tree species response in previous studies considering for elephant impact. However, multi-model analyses on multiple tree species need to be explored further to determine the effects of elephants and vegetation recovery (Chapter 2), considering for the secondary effects of elephant impact (Chapter 3).

Field based methods used to monitor impact are valuable, however distance-sampling techniques including remote sensing can be applied to determine tree metrics. To date, most remote sensing studies concerning elephant impact have utilised coarse scale remote sensing methods including multispectral images such as Landsat and "Satellite pour l'Observation de la Terre" (SPOT) images (Munyati and Sinthumele, 2016). However fine scale, remote sensing techniques are limited and determining the 3-D structure of trees has relied on ALS, and a combination of aerial imagery and high-resolution satellite imagery (Asner et al., 2009; Levick et al., 2009). The performance of 3-D photogrammetry applied to aerial photographs for the retrieval of savanna tree attributes and vegetation height at a reserve extent has not been studied extensively. This thesis will apply some of these methods and explore the efficacy of using 3-D photogrammetry from aerial photographs to determine vegetation height at a reserve extent. This is the focus of Chapter 4.

Determining how elephants impact vegetation on a temporal and spatial extent is important in achieving direct elephant conservation by maintaining areas with suitable elephant numbers and adequate vegetation. However, elephants are threatened by habitat fragmentation because of human encroachment. This in turn increases human elephant conflict (HEC), where people living near elephants cancome into conflict with elephants, and therefore attitudes towards elephants can often be negative. Communities living near elephants and wildlife conservation areas need improved education to become engaged with conservation practises and value viable careers in conservation. Additionally, participation in *ex situ* education programmes is important for increasing awareness and encourage funding for elephant conservation (Makecha and Ghosal,2017). This will improve understanding of conservation, methods of mitigating HEC, and will also encourage opportunities within the wildlife tourism industry, ultimately supporting elephant conservation.

There has been little focus on determining how school children perceive elephants and elephant conservation, both *in situ* and *ex situ* (Makecha and Ghosal, 2017) School children are a key demographic, as they are not likely to have fully formed opinions or attitudes about the environment (Pelletier et al., 2004). Additionally, understanding how school children perceive elephant conservation could improve conservation education delivery, enhancing children’s connection to elephants which is crucial for their long-term conservation (Ardoin and Bowers, 2020). Chapter 5 of this thesis will therefore also consider how school children perceive elephant conservation at different geographic locations (U.K., Kenya and South Africa) to determine how elephants and elephant conservation are perceived.

1.8.1 Study areas

Both fieldwork data collection and distance-sampling techniques were conducted on Karongwe Private Game Reserve (KPGR) in Limpopo, (South Africa) for Chapters 2, 3 and 4 (Figure 1.4). KPGR is a small, fully fenced 7,960-hectare reserve within the savanna biome in the Limpopo Province of South Africa (S24.227061, E30.603302) and has a mean annual rainfall of 790 mm (Low and Rebelo, 1998). Temperatures range from 0 ºC to 45 ºC, with an average of 22 ºC. KPGR falls within a summer-rainfall area where rainfalls mainly between October and April.

The reserve originally consisted of 10 individual private farmlands, but the fences were removed in 1999 and various game species were introduced, including African savanna elephant, lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinoyx jubatus*), and white rhinoceros (*Ceratotherium simum*), to establish a game reserve. The reserve is bordered on all sides by public roads, all of which are within 50 m of the fence line. The western fence line (19.1 km) runs along the paved R36 route, while gravel roads run parallel along the eastern (14.5 km) and northern (11.9 km) fence lines. The R36 acts as the main passage between Hoedspruit and Tzaneen, the two larger cities in the vicinity of the reserve.

Within the KPGR the altitude above mean sea level (AMSL) varies from 489 m in the east to 520 m in the west to (Lehmann et al., 2008) and therefore drainage predominantly flows from west to east. Makhutswi River in the north is the only perennial river. The Kuvyenami and Mafunyane Rivers drain the centre, and the Korongwe and Mathumi Rivers drain the south of the reserve. All these rivers join up with the Olifants River. There are also large and small koppies (rocky outcrops) are distributed around the reserve.

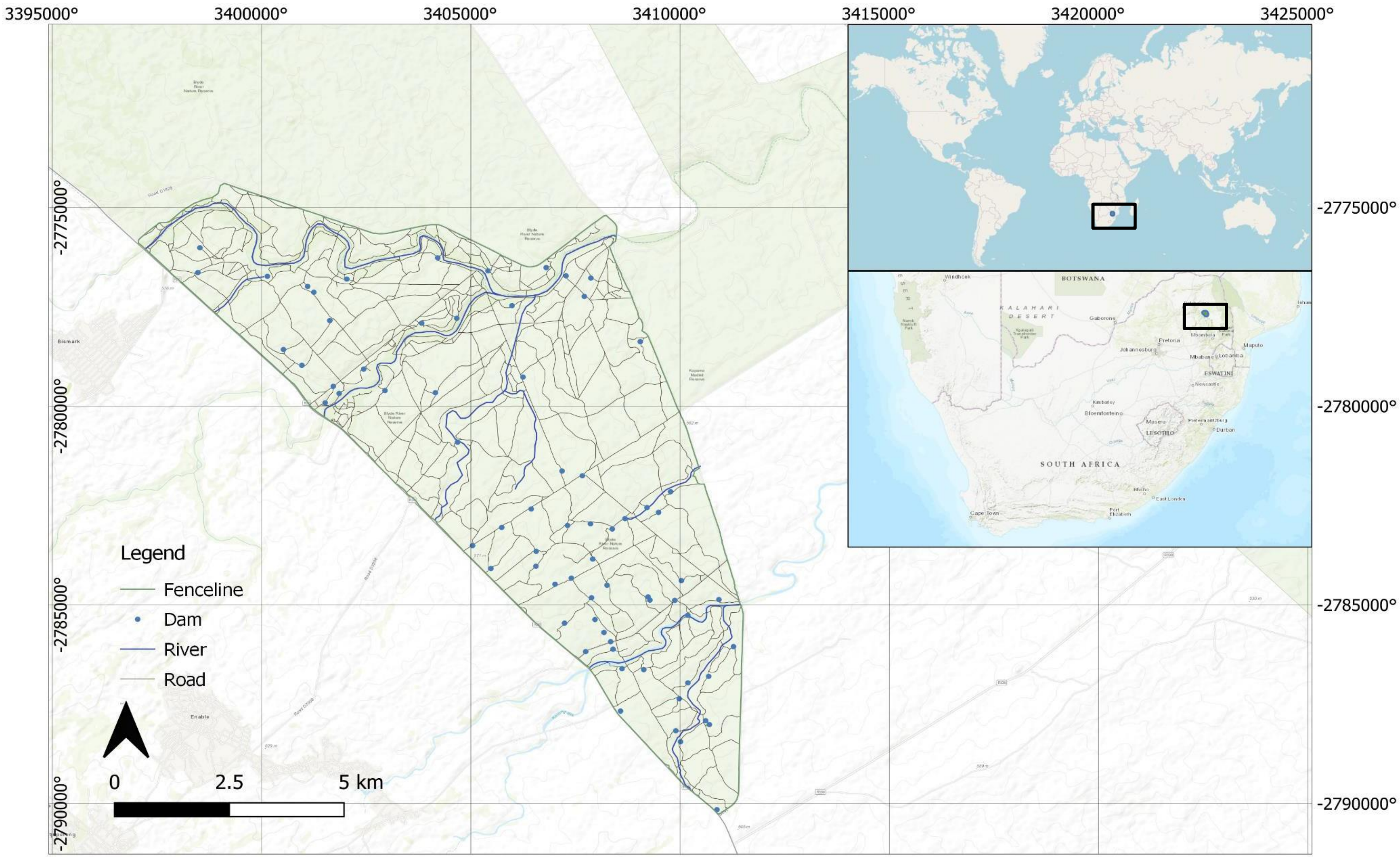


Figure 1.4 Location of Karongwe Private Game Reserve (KPGR) in Limpopo, South Africa. (Map compilation by the author using data via ESRI. Projection: Geographic. Datum: WGS84)

1.8.2 Vegetation type

KPGR is within the savanna biome (Rutherford and Westfall, 1994) within the Mixed Lowveld Bushveld (Low and Rebelo, 1998) (Figure 1.5) The vegetation patterns across the reserve are bush on the uplands, open tree savanna in the bottomlands, and there is dense riverine woodland on the riverbanks (Lehmann et al., 2008). The shrub layer and grass layer are moderately developed (Low and Rebelo, 1998). Across the reserve, there are many dolerite intrusions and areas covered by gabbro. Basement gneisses and granite underlie this region (Low and Rebelo, 1998). Knob thorn and marula trees dominate this savanna biome, and *Combretum* spp. are also prevalent.

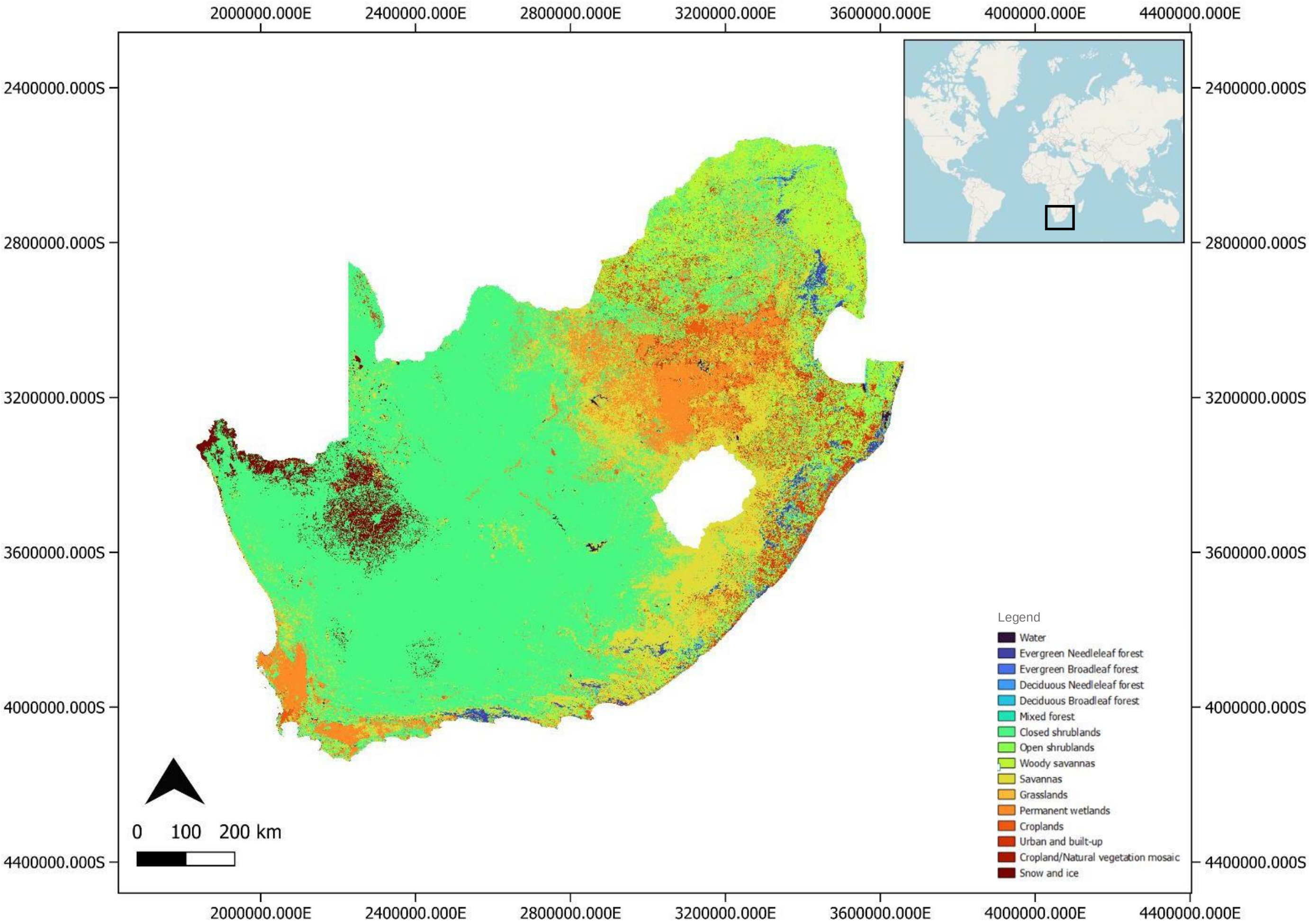


Figure 1.5 Land cover classification of South Africa (Map compilation by the author using data via MODIS and IPUMS. Projection: Geographic. Datum: WGS84)

1.8.3 Elephant population on KPGR

The elephant population on KPGR has increased since their reintroduction in 1999. They were first introduced in 1999 when management released one adult male and four adult females, all of which still live on KPGR. Four more elephants have since been introduced to the reserve and 19 elephants were born, of which five have died and two have been relocated. From 2011, the elephant population has consisted of one stable family unit (n = 18), defined as all adult females, all subadults and juveniles of both genders (Poole, 1989) plus three adult bulls until 2015 (one adult bull was translocated) (Table 1.1). Two male elephants were administered with the gonadotrophin releasing hormone (GnRH) vaccination in 2012. GnRH vaccinations is a non-invasive contraceptive measure for managing wildlife populations, where fertility control is warranted in smaller, fenced game reserves with populations in high densities (Lueders et al., 2017). In 2016, both males were no longer administered with contraception, and an elephant birth in 2019 brings the total population to 21 elephants (20 elephants at the time of field study for Chapter 2, 3 and 4). Like other elephant populations, the family unit (from now on to be referred to as the breeding herd), remained together, while the three adult bulls occasionally associated with each other and the herd since their reintroduction (Poole, 1989; Western and Lindsay, 1984). More recently, the adult bulls have been seen to associate with the breeding herd, and field observations now rarely observe the breeding herd and bull elephants separately (Appendix 3: Figure A.3; see also Chapter 6). Owen-Smith et al., (2006) suggests that an effective elephant population density is 0.28 km^{2}, and therefore, KPGR should support 22.28 individuals.

Table 1.1 Elephant populations on Karongwe Private Game Reserve (KPGR, South Africa) since their introduction in 1999. Since 2016, E1 and E3 were no longer administered with the GnRH vaccination.

Animal Name	Sex	D.O.B	Translocated from	Reintroduction date	Removed/translocated date
Gattis	M	1990	Kapama	24-Jul-99	13-Apr-04
Madala	M	1978	Kapama	24-Jul-99	13-Apr-04
E2 - Mr M	M	1982	Kapama	24-Jul-99	Oct-15
E1 - Fumbe	**M**	**1980**	**Kapama**	**24-Jul-99**	
E3 - Flippy	**M**	**1986**	**Magudu, KZN**	**Jul-99**	
E4 - Tsuku	F	1987	Magudu, KZN	Jul-99	
E5 - Nick	F	1985	Magudu, KZN	Jul-99	
E6 - Telipha	F	1987	Magudu, KZN	Jul-99	
E7 - Duma	F	1985	Magudu, KZN	Jul-99	
Pula	M	05-Oct-00			Aug-08
Mafunyane	M	23-Oct-00			Aug-08
E7.1 - Lavara	F	13-Jul-00			
UK	M	05-Jul-02			Feb-10
UK	M	29-May-03			Feb-10
E5.1	F	29-Jun-03			
E4.1	M	28-Oct-03			
E6.1	F	14-Aug-04			
E7.2	UK	12-Aug-05			
E4.2	F	08-Apr-06			
E5.2	F	26-Jun-06			
E7.3	F	Nov-07			
UK	UK	Nov-07			
E4.3	F	Dec-08			
E5.3	UK	Jan-09			
E6.2	F	Feb-09			
E7.4	UK	May-09			
E7.1.1	UK	Dec-11			
E5.1.1	UK	Dec-11			
E5.4	UK	25-Oct-19			

1.8.4 Environmental education

We indicated earlier to the importance of school children's perceptions of elephants and how that can influence the likelihood of them wanting to protect elephants. This thesis will also aim to contribute to the understanding and perception that school children have with elephants at different geographic locations. We selected school children as our research demographic, as understanding children's perception of elephant conservation may facilitate improved methods of conservation education delivery (Ardoin and Bowers, 2020). Schools were selected based on their location with regards to elephant presence or absence and in different countries (Table 1.2; see chapter 5 for full details).

Table 1.2 Selected study site locations

Study location	Elephant exposure	Land use
England: Wrenn School, Wellingborough	In captivity (zoos)	Urban environment
Kenya: Brainhouse School, Mathare North, Nairobi	Predominantly open reserves	Rural and urban environment
South Africa: Diputhi School, Limpopo	Fenced reserves only	Mostly rural environment

1.9 Research aims and objectives

Using African savanna elephants (*Loxodonta africana*) as the study species, the main aim of this thesis is to:

- ***Quantify the patterns of the direct and indirect impacts elephants have on vegetation and determine the levels of tree recovery using field data collection.***

Additional aims are to:

- ***Explore distance sampling methods for detecting tree attributes within a fenced reserve.***
- ***Quantify the extent at which school children perceive elephant conservation, considering for their importance at an economic and environmental level, and their perception of wildlife conservation careers.***

The research objectives (O) are:

O1. Assess how field data collection and modelling approaches used for studying elephant impact on tall trees (> 5 m height) can be applied and expanded to additionally identify the recovery levels of multiple tree species within a fenced reserve;

O2. Identify how field data collection and modelling analyses can be used to determine the secondary effects of elephant impact on trees > 2 m, and how this influences tree species recovery level;

O3. Determine the ability of photogrammetric point clouds derived from conventional aerial survey for estimating tree heights;

O4. Identify whether school children in countries with and without elephant presence perceive elephants as a threat or as an animal that they value both economically and environmentally.

The research objectives are met in the data chapters as follows:

Chapter 2: Modelling the impact of elephants on vegetation within a fenced reserve, using impact and recovery levels to assess the influence of these variables on tree height, identified elephant range use and fence line (O1)

Chapter 3: Investigating how insect presence can affect the level of recovery on different tree species at various heights after elephant impact occurs, using modelling approaches (O2)

Chapter 4: Applying 3-D photogrammetry from historical aerial photographs to test how effective this method is in identifying tree height for elephant impact studies (O3)

Chapter 5: Quantifying how children perceive elephant conservation through questionnaires across locations with elephant presence and elephant absence (O4).

Chapter 2

2. Impacts of African savanna elephants (*Loxodonta africana*) on tall trees and their recovery within a small, fenced reserve in SouthAfrica

- *Objective 1: Assess how field data collection and modelling approaches used for studying elephant impact on tall trees (> 5 m height) can be applied and expanded to additionally identify the recovery levels of multiple tree species within a fenced reserve.*
- *Main findings: Trees in high-use areas were significantly less likely to show signs of debarking and push over. Tall trees were significantly more likely to be impacted by elephants, being associated with heightened risks of debarking and branches being broken but lower risks of being pushed over. Trees close to the fence line were not more impacted than trees near the centre of the reserve. The level of use, distance to the fence and tree height were not significant predictors of tree recovery indicators. Therefore, we suggest that future mitigation efforts should focus on trees with high levels of impact and low levels of recovery.*

2.1 Abstract

African savanna elephants (*Loxodonta africana*) can have detrimental impacts on trees due to their feeding habits. To date, studies exploring elephant impact on trees and their recovery levels within small reserves restricted by fences, have lacked focus in determining elephant high-use areas, the direct effect of tree recovery. The aim of this study is to assess whether elephants cause significant impact on several tree species in the small fenced Karongwe Private Game Reserve (KPGR) and to determine levels of tree recovery. We analysed the level of impact using vegetation transects, where all trees ≥ 5m in height were surveyed (n=634 trees). Elephant location data were used to identify high- and low-use areas. Thirty-two tree species were recorded, with 5 species accounting for 80%; these were used for further analysis. Trees in high-use areas were significantly less likely to show signs of debarking and push over. Tall trees were significantly more likely to be impacted by elephants, being associated with heightened risks of debarking and branches being broken but lower risks of being pushed over. Trees close to the fence line were not more impacted than trees near the centre of the reserve. The level of use, distance to the fence and tree height were not significant predictors of tree recovery indicators. Therefore, we suggest that future mitigation efforts should focus on trees with high levels of impact and low levels of recovery.

Keywords

Karongwe Game Reserve, *Loxodonta africana*, Tree impact, Tree recovery, Space use, Elephant density, Fence

2.2 Introduction

African savanna elephants are keystone species for savanna ecosystems (Western, 1989), helping promote diversity of both habitats and species (Brooks et al., 1983). Elephant populations have been declining in range and numbers for decades due to ivory poaching, habitat loss and land fragmentation (Lemieux and Clarke, 2009; Thouless et al., 2016). African savanna elephant populations have decreased by at least 60% over the last 50 years, according to the latest IUCN assessment (Gobush et al., 2021). To counteract these trends, countries such as South Africa have engaged in major elephant reintroductions to protected areas, many of which include conversion of agricultural land to fenced reserves (Lehmann et al., 2008; Lombard et al., 2001). This method has proved successful in maintaining and increasing elephant population numbers; however, suitability of land, elephant densities and vegetation sustainment is often met with concerns (Stretch et al., 2002; Caughley, 1976).

In an open ecosystem without land use restrictions, elephant herd size varies depending on resource availability (Young et al., 2009). The impact of elephants on tree species in open reserves (unfenced) has been well studied (Holdo, 2003; Morrison, Holdo and Anderson, 2016). Tree species composition of an area has been shown to change when elephants are present in high enough densities to modify their habitat (Cummings et al., 1997). To determine the level of elephant impact, research has focussed on high profile species such as marula trees (*Sclerocarya birrea*) (Gadd, 1997; Weaver, 1995; Jacobs and Biggs, 2002; Wiseman et al., 2004). Trees with larger stems (> 10 cm in diameter) are more likely to be selected by elephants for debarking, whilst smaller trees are more likely to be toppled (Boundja and Midgley, 2010; Ihwagi et al., 2012; Ssali et al., 2013). Gaugris and Van Rooyen (2010), Kerley and Landman (2006), Landman et al. (2008) and more recently Howes et al. (2020), have documented the impact that elephants have on small reserves, where natural elephant feeding behaviours are restricted by fences.

Spatial restriction of elephants within fenced reserves can exacerbate their impacts on their habitat (Laws, 1970; Hoare, 1999; Baxter, 2005). Fencing may cause elephants to become sedentary, reduce seasonal movement, prolong, and concentrate feeding impacts (Cumming et al., 1997; Lombard et al., 2001; Guldemond et al., 2008). Fencing acts as a fixed boundary, where the confinements of elephants could deprive access to seasonal habitat, in turn increasing encounters of selected tree species (O'Connor et al., 2007). The potential for elephants to utilise the same patches of vegetation increases in small, fenced reserves, because of their inability to distribute themselves effectively in response to resource availability (Slotow et al., 2005; Mackey et al., 2006; de Boer et al., 2015). Additionally, the fence line itself can prove problematic in extensive areas, as they may cause elephants to bunch up against the fence line (Loarie et al., 2009). Movement patterns of elephants have moreover been shown to be influenced by the proximity of the fence line, with studies suggesting increased habitat use within the centreof the reserve (see e.g. Vanak et al., 2010).

Elephant impact on vegetation is known to be affected by their feeding behaviours. Potential impacts of elephants on vegetation include broken branches, the main stem being broken, debarking, the tree being pushed over, and the elephant causing the death of the tree (Table 1). Recovery levels are generally determined as the ability of individual trees to survive after elephant browsing occurs. Bark recovery (Wigley et al., 2019), coppicing (Jacobs and Biggs, 2002) and sprouting (Bond and Midgley, 2001) are generally used as indicators of tree recovery. Elephants consume both woody vegetation and grasses, and they characteristically select vegetation depending on seasonal availability (Buss, 1961; Laws, 1970; Owen-Smith, 1988; de Boer et al., 2000). They typically feed on tree species with high nutrients in their leaves (Holdo, 2003; Jachmann, 1989; Wiseman et al., 2004, Novellie et al., 1991) and select trees with large volumes of foliage to gain maximum energy output; the level of impact has been suggested to depend on tree characteristics such as thetrees height and canopy width (Boundja and Midgley, 2010; Levick and Asner, 2013, Howes et al., 2020; Thornley et al., 2020). Private wildlife reserves are often set on degraded livestock areas, which can force elephants to utilise woody vegetation year-round due to poor grazing conditions (O'Connor, 2007; Smallie and O'Connor, 2000). It is however important to acknowledge that conflicting views remain on elephant vegetation preferences and their nutritional characteristics (Scholes and Mennell, 2008). An increase in bark and roots being consumed may indicate nutritional stress, which may in turn result in greater impact on woody vegetation (Guy, 1976; Barnes et al., 1994).

Therefore, the ability for individual trees to recover after being impacted by elephants, is essential to maintain species within the reserve (Moe et al., 2009; Kohi et al., 2011; Scogings et al., 2012). The resilience of tree species depends on whether that species possesses recruitment and regeneration rates that match the rate of mortality over time (O'Connor et al., 2007, Thomson, 1975; Lock, 1977; Cumming, 1981). Once impact has occurred, trees can recover through coppicing, regrowth as well as seedling regeneration, but the success of this is dependent on the level of impact to the tree. Adults of some species such as mopane (*Colophospermum mopane*) have high coppicing ability (Lewis, 1991; Ben-Shahar, 1996; Styles and Skinner, 2000), while other species have weak regrowth ability (e.g., umbrella thorn (*Vachellia tortilis*)) (MacGregor and O'Connor, 2004). Most *Vachellia* and *Senegalia* populations heavily impacted by elephants have persisted through time on account of their regeneration ability (Croze, 1974; Leuthold, 1977; Pellew, 1983; Lock, 1993; Dublin, 1995; Western and Maitumo, 2004). Studies on marula trees determined that even though impacts from elephants were high, mortality rates were low as affected trees did show signs of recovery (Gadd, 2002). Small and medium-sized herbivore species including small browsers such as impala (*Aepyceros melampus*) and rodents have been suggested to prevent seedling recruitment in marula trees, due to high utilisation and seed predation (Haig 1999; Helm et al.,2009; Helm and Witkowski, 2012). Elephants may kill regenerating stems through over- browsing, which may be exacerbated in fenced reserves (Moseby et al., 2018). There is a need to determine the recovery levels on impacted individual trees across fenced reserves with elephant presence, so reserve managers can apply appropriate measures to maintain sustainable populations of tree species while securing elephant survival. In this study, we attempt to determine levels of tree recovery following elephant induced impact whilst considering habitat use and fence line effect. While doing so, we test the following hypotheses:

(H1) Impacts will be more prevalent on tall trees (≥5 m) within high use areas, and low levels of recovery will be displayed on these trees

(H2) Trees close to the fence line will be less impacted than trees further from the fence line, which will display lower levels of recovery

2.3 Method

2.3.1 Study site

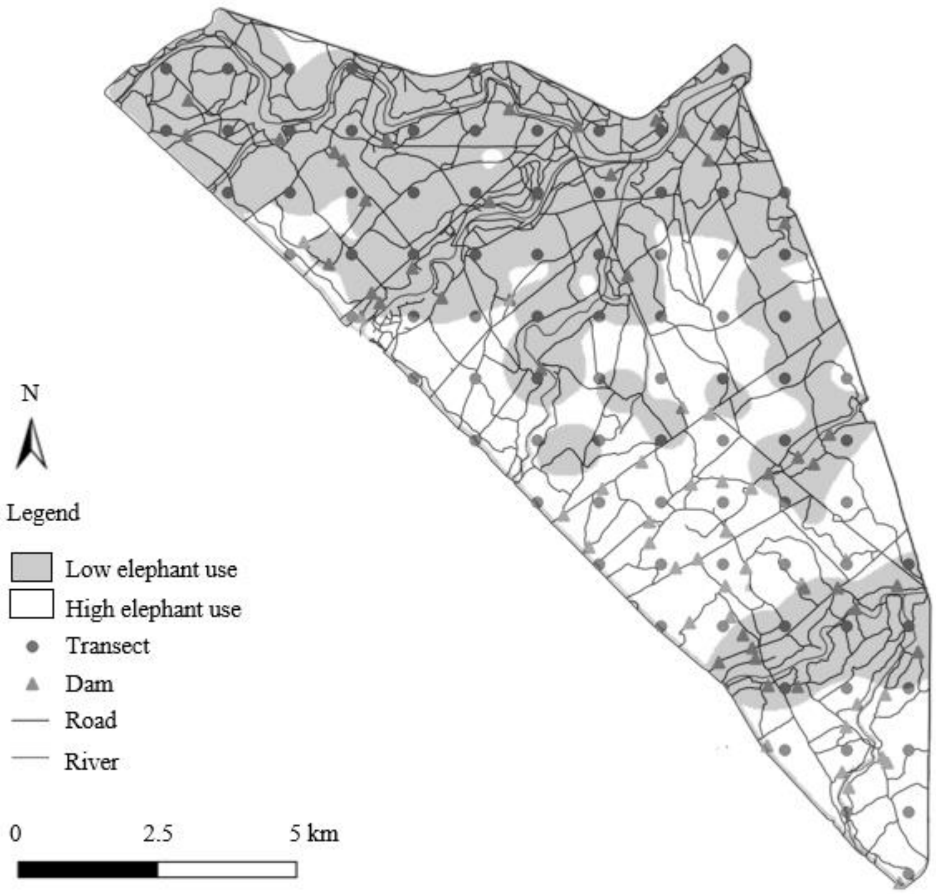
The study was carried out in Karongwe Private Game Reserve (KPGR), a 7,960-hectare fenced private reserve in the Limpopo province of South Africa (S24.227061, E30.603302). The reserve consists of two savanna vegetation types: Granite Lowveld and Tzaneen Sour Bushveld type (Mucina and Rutherford, 2006). Average daily temperatures range from 5-17 ºC in winter (June to August) and 17-28 ºC in summer (December to February). The altitude varies from 489 m to 520 m above sea level (Lehmann et al., 2008).

The reserve originally consisted of 10 individual private farmlands, but division fences were removed in 1998 and a Reserve was established. KPGR is bordered by public roads, which are 50 m from the fence line. The western fence line (19.1 km) runs along the paved R36 route, while gravel roads run parallel along the eastern (14.5 km) and northern (11.9 km) fence lines.

Elephants were translocated to KPGR in 1999 from Kapama Game Reserve and Maggudu, Kwaza-Zulu Natal (7 individuals). Since 2011, the elephant population has consisted of one stable family unit of adult females, both male and female subadults and juveniles. There are also two bulls present on this reserve. Owen-Smith et al. (2006) suggests that an effective elephant population density is 0.28 km^2, so based on this estimation, KGPR could support 22.28 elephants. KGPR currently supports 20 elephants.

Elephants within KPGR are never more than 3 km from an artificial water point: there are 70 dams across the reserve; some are pumped when the water level is low. Distance to the water was therefore not considered as a limiting factor of elephant distribution or an explanatory variable likely to shape tree damage; it was therefore not included in our models (Harris, Russell, van Aarde, and Pimm, 2008; Shannon et al., 2006) (Figure 2.1).

Figure 2.1. Spatial distribution of water points, vegetation transects and elephant utilisation distribution across Karongwe Private Game Reserve (KPGR)



2.3.2 Data collection

Elephant locations were determined by sightings twice a day: AM drives (05:00) and PM drives (15:00), as part of a long-term study using visual recordings (data collection began in 1999). Sightings were recorded within 5 m of the observer, where the GPS recording was taken for the elephant. After locating the focal animal, the following parameters were recorded:

- Date
- Time
- Location
- Map coordinates (derived from GarminTM GPSMap® 60CSX - GNSS)

Vegetation data were collected between July and September 2018 using 84, 10 x 100 m transects distributed across the reserve (Appendix 1: Table A.1; 4: Table A.4.1). Sampled trees near the fence line were those who were found being within 100m of the fence line. Out of the total 84 performed, 29 transects were carried out in areas considered to be near the fence line. Navigation-grade GNSS co-ordinates were acquired at the start of each transect. Every tree of height ≥5 m and diameter breast height(DBH) of ≥15 cm was sampled for elephant impact and recovery (Coetzee et al., 1979; Staub et al., 2013). Our study considered >5 m trees as research to date has focussed on elephant impact on trees within this height class as they are often targeted by elephants, but these studieslacked insights on multiple tree species within a small, fenced reserves with high elephant density (Weaver, 1995; Biggs and Jacobs, 2002; Helm et al., 2009; Helm and Witkowski, 2012). When a tree met the necessary requirements, the following parameters were recorded:

- Species, height (m), DBH (cm)
- Elephant impact type (Table 2.1)

- Tree recovery type (Table 2.1)

Tree impact types were derived from the Walker damage scale (Walker, 1976) (Table 2.1). Elephant impact on trees was easily distinguished from that of other browsers due to their foraging behaviours. Elephants feed on woody vegetation by breaking off branches, toppling and bark stripping using their tusks (Coetzee, 1979; Boundja and Midgley, 2010), whereas smaller browsers are narrowly selective for new leaves, flowers and fruits at lower heights (Owen-Smith and Chafota, 2012). We also recorded levels of recovery for each tree.

Table 2.1. Scale used to record elephant browsing during field observations. Impacts and recovery levels on tree species were derived from Walker (1976).

Variable	***Observation***
Impact	Branches broken (A)
	Condition of the tree: Alive/Dead (B)
	Main stem broken (C)
	Main trunk debarked (D)
	Pushed over (E)
Recovery	Presence of coppicing (tree regeneration from stump) (F)
	Bark regrowth (G)
	Presence of sprouting (resprouting from stems) (H)

2.3.3 Data analysis

‘High-use’ and ‘low-use’ areas were determined using elephant location data collected in 2018. Habitat use is described as a categorical variable, with high-use areas including areas where elephants are within their home and core range and low-use areas including areas not within their home and core range. A utilisation distribution (UD) was created to provide a measure of the probability an elephant to be found at a given location (Worton, 1989); the 'heatmap' tool in QGIS was then used to perform a quartic (biweighted) kernel density estimation (KDE) using a discrete data set to produce a continuous UD. To define the home range of the elephants, 95% of volume contours of the KDE was extracted to remove the outliners. 50% of the space use distribution,determined the elephants kernel core range (CR) and was extracted for this study. 'High-use' areas of elephants were defined as merged recordings of elephants within the home range andcore range. 'Low-use' areas corresponded to areas where no elephant presence was recorded.

Data exploration determined that sample sizes were too small to effectively test our two hypotheses for the following impact and recovery variables: B, C, G and H (Table 2.2). Therefore, GLMMs (binomial distribution) were used to model the likelihood of a given impact type (A, D, E, Table 2.2) to be found on a particular tree as a functionof the height of that tree, its distance to the fence, and whether or not the tree was located in an are highly used by elephants (all fixed effects). Transect identity was modelled as a random effect. We also used this approach to model the likelihood of coppicing (F; Table 2.2) to occur on a given tree as a function of the height of that tree, its distance to the fence, and whether or not the tree was located in an area highly used by elephants (Table 2.2). A baseline model was constructed with all the possible interactions and main effects. Akaike information criterion (AIC) (Burnham and Anderson, 2004) and model averaging was used to select a combination of the top models. We limited the calculation of the conditional averages to models within 2 delta AIC of the best model. The conditional average for each model was used for further inference. All models were builtin R using the "lme4" package (Pinheiro and Bates, 2000; R Core Team, 2014).

Model assumptions were verified by plotting residuals for spatial dependency. We determined that the random effect approach is sufficient for spatial dependency by conducting a Moran's

I test on all models (Getis, 2008). Results confirm that spatial autocorrelation is absent (p-value > 0.05) in the residuals of all models.

Table 2.2 GLMM structure of dependent and independent variables (fixed effects) for all impact and recovery variables

Depedent varaible	***Independent variables***
Branches Broken (A)	Habitat Use + Height + Habitat Use: Height + Fence line
Debarking (D)	Fence line + Habitat Use + Height + Fence line: Height + Fence line: Habitat Use
Pushed over (E)	Habitat use + Height + Fence line
Coppicing (F)	Habitat Use + Height + Habitat Use: Height + Fence line + Fence line: Height + Fence line: Habitat Use

2.4 Results

634 trees were considered for analysis; these data were gathered on the five most common species in the reserve: knobthorn (*Sengalia nigrescens*) 30%; marula 19%; velvet corkwood (*Commiphora mollis*) 13%; red bushwillow (*Combretum apiculatum*) 11%; leadwood (*Combretum imberbe*) 5%. 570 (90%) of these trees expressed visible signs of elephant impact. Overall, levels of impact across the reserve were thus high, but levels of recovery were low in both high-use and low-use habitats (Figure 2.2).

In total 10% of trees were found to be dead. 13% of all sampled trees were found to be pushed over. 58% of trees exhibited branches broken and only 2% of sampled trees had their main stem broken. 10% of trees displayed debarking. 5% of trees showed signs of coppicing, 2% sprouting and 2% regrowth.

Debarking was more likely to occur on trees found in low-use areas; similarly, trees were more likely to be pushed over in low-use areas ($P=0.04$ and $P=0.03$, respectively). The likelihood of finding trees with branches broken was not influenced by elephant habitat use (all $P > 0.05$; Table 2.3).

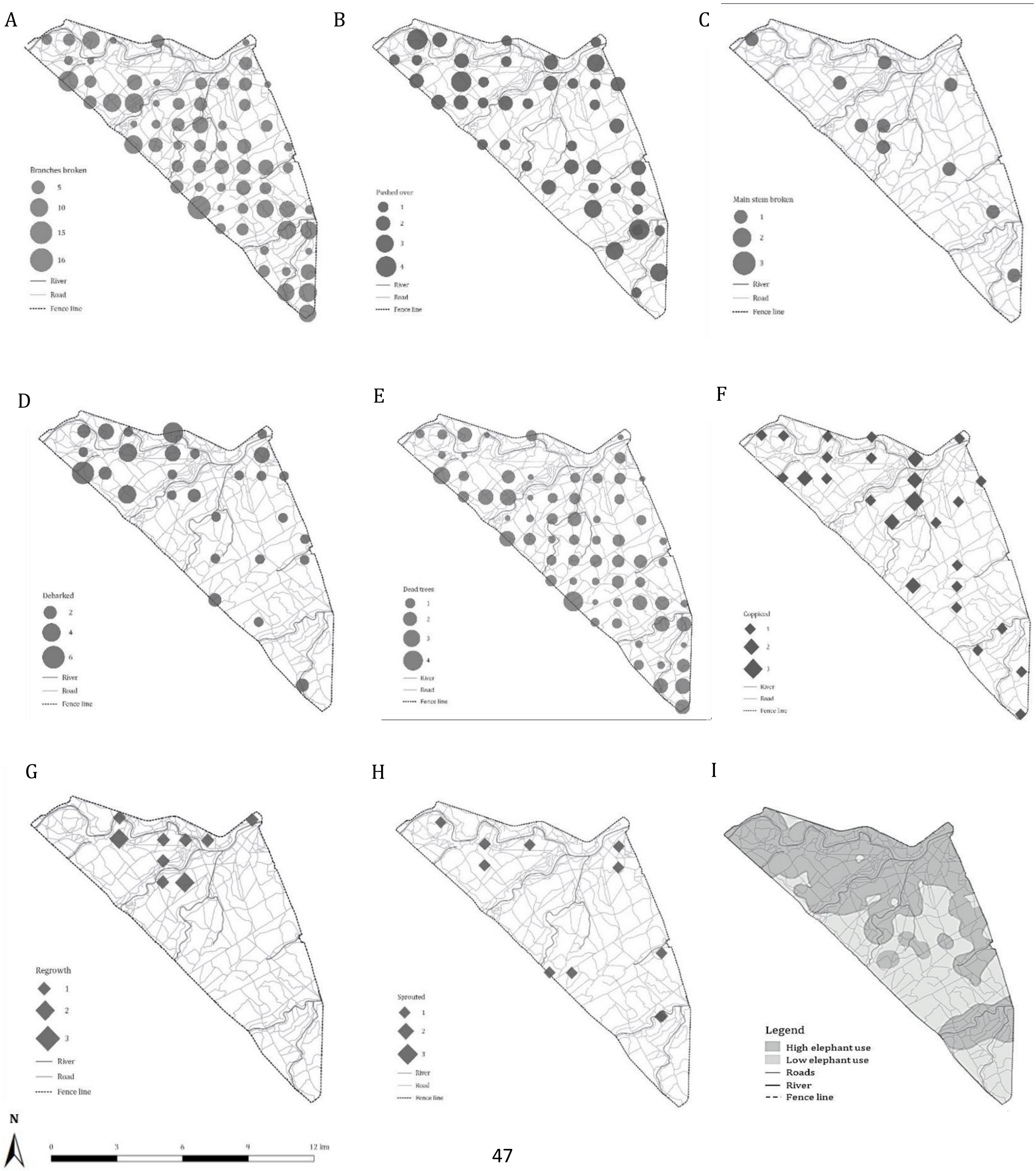
Taller trees were significantly more likely to show signs of debarking ($P=0.01$) and branches being broken ($P=0.01$). However, taller trees were less likely to be pushed over ($P=0.01$).

Trees within proximity to the fence line did not significantly experience less impacts from elephants than trees further apart from the fence line (all $P> 0.05$; Table 2.3). The level of use, distance to the fence and tree height were not significant predictors of tree recovery indicators.

Table 2.3. GLMM outputs of dependent and independent variables (fixed effects) for all impact and recovery variables on the best models.

Variable	***Fixed effects***	***GLMM coefficient (estimate)***	***SE***	***Z value***	***P value***
Branches broken (A)	Habitat use	0.63	0.96	0.66	0.51
	Height	0.19	0.07	2.80	**0.01**
	Habitat use: Height	0.18	0.14	1.25	0.21
	Fence line	-0.29	0.59	0.49	0.62
Debarking (D)	Fence line	3.17	2.46	1.29	0.19
	Habitat Use	-1.07	0.52	2.07	**0.04**
	Height	0.31	0.08	3.94	**0.01**
	Fence line: Height	-0.38	0.23	1.69	0.09
	Fence line: Habitat use	-1.54	1.49	1.03	0.30
Pushed over (E)	Habitat use	-0.74	0.35	2.12	**0.03**
	Height	-0.22	0.08	2.81	**0.01**
	Fence line	0.17	0.66	0.26	0.79
Coppicing (F)	Habitat use	2.61	2.89	0.89	0.37
	Height	-0.13	0.12	1.05	0.29
	Habitat use: Height	-0.70	0.42	1.68	0.09
	Fence line	4.80	4.59	1.05	0.29
	Fence line: Height	-0.75	0.64	1.18	0.24
	Fence line: Habitat use	-2.18	2.36	0.92	0.36

Figure 2.2 Spatial distribution of total impacts (●) and recovery (◆) on trees: A= Branches broken; B = Pushed Over; C= Main Stem Broken; D= Debarked; E= Alive; F= Coppiced; G= Regrowth; H=Sprouted and I= Total elephant habitat use during 2018



2.5 Discussion

This study shows that African savanna elephant impact on trees does not occur randomly. Contrary to our expectations, (1) the level of tree impact was not determined by the proximity to the fence line; (2) tree height and habitat use impacted differently risks of debarking, branches being broken, and tree being pushed over; (3) tree recovery could not be predicted from tree height, the level of elephant use in the area occupied by the tree, or the distance from the tree to the fence line.

The results regarding the level of impact in response to tree height were consistent with impact from elephants that have been seen on other sites across African savannas, when considering for impacts related to branches being broken and debarking. Tree height has beenshown to be a significant indicator of the presence of elephant impact (Makhabu et al., 2006; Mapaure and Mhlanga, 2000; Scogings et al., 2012), which has also been the focus of many studies (Biggs and Jacobs, 2002; Helm et al., 2009; Helm and Witkowski, 2012; Cook et al., 2017). Previous studies considering elephant impacts on marula trees, have shown that tall treesbetween 5-11 m high showed signs of impacts, and the greatest mortality was found in trees inthe 5-8m height class (Biggs and Jacobs, 2002; Helm et al., 2009; Helm and Witkowski, 2012;Cook et al., 2017).

However, our findings do not match previous observations that the containment of elephants increases impacts on trees within the areas they mostly utilise (Cumming et al., 1997; Lombard et al., 2001). Additionally, we identified that the likelihood of a tree being debarked or being pushed over was reduced in high-use areas, which was surprising as we expected habitat use to correlate with impact. This mismatch between expectations and observations could be a result of how habitat use was determined in this study, as we only considered elephant sightings for one year (2018). Further work is required to establish whether the reported patterns remain consistent once more information on elephant distribution is taken into account.

We also considered the distance from the fence line in relation to tree impact, as this had not been previously studied in a small, fenced reserve. Recent research has focussed on efforts to deter elephants from fences to prevent elephants breaking out of reserves, reduce crop raiding and human-wildlife conflict (Pozo et al., 2019; Changa'a et al., 2016; Ngama et al., 2016; King etal., 2011) but little is known about the edge-effect of fences on tree damage and recovery (Vanak et al., 2010). We found no significant relationship between distance to the fence line and all impact and recovery variables. This suggests that management plans aimed at focusing efforts on reducing the impacts of elephants on trees based on their distance to the fence line may not be evidence-based.

Furthermore, we analysed the level of recovery on impacted trees, as this had been largely overlooked in previous studies which focussed on impact in small, fenced reserves considering multiple tree species. We considered tree recovery an important factor, as the ability for trees to recover after being impacted is essential for the long-term sustainability of tree populations (Leuthold, 1996). Our results showed a significant lack of recovery on most sampled trees, including large trees within high-use areas, which is a concern in an area of high elephant density and high levels of impact. Previous studies have emphasised that if tree species are unable to recover from impact, severely impacted trees will not persist through time (O'Connor et al., 2007; Moe et al., 2009; Kohi et al., 2011; Scogings et al., 2012). Even if tree species do exhibit signs of recovery, they can become sterilized if no seeds are produced (Midgley et al., 2020). Added to this, there are numerous factors that could compromise recruitment of large trees such as fire and excessive herbivory from smaller antelope whose densities have increased as a result of increased abundance of artificial water points (AWP) in private nature reserves. Therefore, including smaller trees, establishing seedling recruitment and tree survival rates is needed in future studies on elephant impact to determine if this impact to large trees unsustainable.

Current landscape conditions in parts of Africa, particularly in South Africa where fencing is more prevalent, limit space use and increase impacts in the savanna landscape (Loarie et al., 2009). We have attempted to address some of the explanatory factors likely to impact tree damage levels by elephants and tree recovery within this study, but there are limitations to our work. Our study is constrained both temporally and spatially, as we only collected data over one time period within one area. The study could be replicated in the wet and dry season as a comparison to determine how seasonality and water availability effectstree recovery. Tree impact could be recent, therefore there may not have been sufficient time to display signs of recovery that could be identified during the time of study. We only looked at trees >5 m in height and focussed on the five most common species. We then had to score impact binomially, which reduced our ability to explore how responses differ according to damage level. As demonstrated in Gadd (2002), tree species may be more vulnerable to mortality if a greater percentage of bark has been stripped. Therefore, future studies should consider scoring impact levels into quantitative formats, to discern from low level impacts andhigh levels impacts (Helm et al., 2009). This would aid in identifying areas where high levels of impact occur. Future research also needed to look at information over multiple years and other factors that might impact elephant movements, such as human- wildlife conflict areas and other anthropogenic disturbances that were beyond the scope of this study.

Management of elephants on small reserves such as the study site in question is challenging as there are multiple factors to consider. This is due to the size constraints of the reserve where expansion is not a viable option, which is the case in many reserves throughout South Africa with increasing elephant population numbers. Elephant bulls have been shown to cause greater impacts to vegetation compared to cows as they are larger bodied and have more destructive tendencies, especially when in musth (Greyling, 2004). The success of contraception as a management tool to control population numbers has been shown in several small reserves in South Africa, including the Greater Makalali Private Game Reserve and Tembe Elephant Park

(Bertschinger et al., 2018). Contraceptives were also administered to bull elephants in 2016 in the reserve considered in this study. Future studies should explore the impact of contraception on the behaviour of elephants in small reserves, considering any changes of behaviours and ultimately how these impacts on vegetation (Stretch et al., 2002).

Within the study site, the level of impact on trees was high but tree mortality was relatively low (10% of trees were dead). Trees exhibiting any signs of recovery was also very low (<3% for each recovery variable). If elephant impact continues at the rate that we have found on this reserve, then there is cause for concern as tree regeneration levels are low and ultimately mortality will increase. This suggests that elephant impact may be unsustainable in the long term, despite the elephant density falling within the carrying capacity estimate (Pienaar et al., 1966). Therefore, mitigation measures may be required to reduce elephant impact on tree species. Further research is needed to determine the severity of impact, regeneration and recruitment levels on individual tree species, so that mitigation measures can be put in place to reduce and manage levels of impact. Mitigation measures include wire netting, and beehive protection for individual trees as well as controlling elephant distribution in areas that are vulnerable to severe elephant impacts (Henley and Cook, 2019).

Our study has given an insight into impacts on trees by elephants and subsequent recovery, within a fenced reserve with high elephant density, but there is still a need to determine the long-term impacts of elephant on vegetation. We have stressed the need to focus mitigation efforts on trees with high levels of impact where recovery was not identified. A possible addition to this study would be to include trees of smaller height classes to see if impacts occur as readily to smaller trees and if so, how well they recover (<5 m in height). This has been suggested by anecdotal evidence, where elephants have shown an increase in preference for seedlings. We also suggest that future studies should consider the secondary effects of elephant impact, for example bark stripping makes trees more susceptible to further impacts (Campbell et al., 1996; Wigley et al. 2019). As reserves vary in elephant density, methods of population control and types of vegetation vary from one reserve to another, it is imperative that we establish new holistic management methods for the sustainability of fenced reserves and to ultimately support long-term elephant conservation.

Chapter 3

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3. The effect of insects on elephant-induced tree impact within a small, fenced reserve in South Africa

- *O2: Identify how field data collection and modelling analyses can be used to determine the secondary effects of elephant impact on trees > 2 m, and how this influences tree species recovery level*
- *Main findings: Secondary impact was identified as insects, where wood borers and termites were considered. Irrespective of tree height, termites were found to be more likely to colonise damaged trees without signs of recovery and wood borers were more likely to colonise impacted trees showing signs of recovery. Therefore, carefully considering management approaches for elephant-induced termite and wood borer impact on trees should be applied in this fenced reserve.*

3.1 Abstract

African savanna elephants (*Loxodonta africana*) have been recognised as ecosystem engineers, where their feeding habits have been shown to alter landscapes. Within small, fenced reserves, studies exploring elephant impact on trees and their recovery have overlooked secondary impacts that could be contributing to tree mortality. The aim of this study is to assess the significance of both elephant impact and secondary impact, and the subsequent tree recovery. We identified secondary impact as insects and considered wood borers and termites in this study. This was conducted in in the small fenced Karongwe Private Game Reserve (KPGR), South Africa. We analysed the level of damage, recovery and insect presence using vegetation transects, where all trees ≥2 m in height were surveyed (n=1278 trees). Forty tree species were recorded, with 5 species accounting for 77% of the dataset and used for further analysis.

Termites were found to be more likely to colonise impacted trees without signs of recovery. However, wood borers were more likely to colonise impacted trees showing signs of recovery. Termites and wood borer presence on impacted trees was not dependent on tree height. We suggest carefully considering management approaches for elephant-induced termite and wood borer impact on trees.

Keywords

Karongwe Game Reserve, *Loxodonta africana,* Tree impact, Tree recovery, Termite impact, Wood borer impact, Elephant density

3.2 Introduction

African savanna elephants (*Loxodonta africana*) are known to be capable of altering landscapes by changing species composition and reducing plant biomass (White and Goodman, 2009). Their ability to structurally modify vegetation has resulted in several studies on savanna trees, the impacts elephants can inflict to them (Ben-Shahar, 1998; Gandiwa et al., 2011; Asner et al., 2016), and the subsequent impact this may have on other tree species (Kerley and Landman, 2006; Hrabar and Du Toit, 2014; Joseph et al., 2018). The direct impact elephants have on vegetation is a particular concern in areas of high elephant density (Bounja and Midgley, 2009), such as fenced reserves, where increased impact can decrease savanna vegetation heterogeneity (Pringle, 2008). To date, literature has largely focussed on elephant impact with regards to the abundance of large trees, due to their significant environmental and economic value (Shannon et al., 2008). Types of impacts caused by elephants include breaking branches and stems (Nasseri, McBrayer and Schulte, 2011), as well as debarking (Calenge et al., 2002). Debarking has been shown to increase tree susceptibility to other associated impacts, such as disease infection (for example, heart rot of the stem and branches) (Shannon et al., 2011; White and Goodman, 2009; Helm et al., 2011). Tree impact can also enhance tree susceptibility to termites (*Coptotermes* species), woodborers (*Cerambycidae* species) or other insects, which may shorten trees' life span (Hatcher, 1995).

Termites can indeed penetrate trees through fractures in the bark (Gould et al., 1993; N'Dri et al., 2011) and establish secondary nests inside the tree's cavities (Harris, 1968), increasing tree susceptibility to insect colonisations. This happens more frequently when bark is removed by animals such as elephants or porcupines (*Hystrix africaeaustralis*) (Helm et al., 2011). Termites seem to prefer older, stressed trees with low water content and gaps within the bark (Cowie et al., 1989; Gould et al., 1993; Werner et al., 2008). Within the Kruger National Park (South Africa), termites have been shown to prevent regrowth of marula trees (*Sclerocarya birrea*) (Coetzee et al., 1979) and affect tree survival (Cook and Henley, 2019). Additionally, termite presence can result in trees being hollowed out from the inside, which may exacerbate vulnerability to elephant's and other animals' impact (Werner et al., 2008).

Wood borer impact to trees is characterised by the boring activity of larvae and adult beetles in the stems and branches of impacted or stressed hosts (Halperin and Geis, 1999; Peters et al., 2002; Nair, 2007; Liu et al., 2008). Adult mortality of marula trees has been suggested to be attributed to rapid invasion by wood borers after bark stripping occurs and the sapwood is exposed (Helm et al., 2011; Coetzee et al. 1979; Guy 1989; Jacobs and Biggs, 2002). Structural impact caused by elephants and other herbivores, enables wood borers to substantially weaken the stem (Coetzee et al., 1979), exacerbating the original impact by reducing the trees' ability to recover (Guy, 1989). Recently, Vogel et al. (2014) found that the presence of insects on large, older trees with high elephant impact was negatively related to knob thorn trees' (*Sengalia nigrescens*) survival, indicating elephant impact could indeed be indirectly facilitating insect attack and shortening the trees lifespan.

The interactive effects of multiple disturbances on different woody savanna species, such as the subsequent impact of insects on trees impacted by megaherbivores, are currently not completely understood (Holdo, 2007; Migley et al., 2010). To date, studies have considered the importance of elephant impact on supporting arboreal species populations (Pringle et al., 2015) and the functional relationship between ant abundance and the benefits of protecting trees from elephant's herbivory (Palmer et al., 2013). Increasing elephant densities in fenced reserves (Skarpe et al, 2004; Shannon et al., 2008) and the decreasing numbers of largetrees (Ben-Shahar 1993; Eckhardt et al., 2000; Moncrieff et al., 2008), have resulted in a needfor improved knowledge of how elephants and other subsequent disturbances can result in treedeath (Holdo, 2005). Tree species are faced with several biotic constraints such as insects (Wargo, 1996; Hakeem et al., 2012), and this secondary impact partnered with the lack of tree recovery, has been overlooked in many studies focussed on elephant damage. This paper aims to address this knowledge gap, by investigating how insect presence relates to tree impact andaffects tree recovery. While doing so, this contribution will test the following hypotheses:

1) Insects are more likely to colonise trees damaged by elephants than trees not damaged by elephants.

2) Insects are more likely to colonise taller trees damaged by elephants than shorter trees.

3) Insects are less likely to colonise damaged trees that exhibit signs of recovery

3.3 Method

3.3.1 Study site

The study was carried out in Karongwe Private Game Reserve (KPGR), a 7,960-hectare fenced private reserve in the Limpopo province of South Africa (centred on 30.60° E 24.23° N). The reserve consists of two savanna vegetation types: Granite Lowveld and Tzaneen Sour Bushveld (Mucina and Rutherford, 2006). Daily mean ambient air temperatures range from 5-17° C in winter (June to August) to 17-28° C in summer (December to February). The elevation range is 489-520 m above mean sea level (Lehmann et al., 2008).

The reserve originally consisted of 10 individual private farmlands, but division fences were removed in 1998 and a Reserve was established. KPGR is bordered by public roads, which are as close as 50m from the fence line. The western fence line (19.1 km) runs along the paved R36 route, while gravel roads run parallel along the eastern (14.5 km) and northern (11.9 km) fence lines.

Elephants (7 individuals) were translocated to KPGR in 1999 from Kapama Game Reserve and Maggudu, Kwaza-Zulu Natal. Since 2011 the elephant population has consisted of one stable family unit of adult females, both male and female subadults and juveniles. There are also two bulls present on this reserve. Owen-Smith et al. (2006) suggest that an effective elephant population density is 0.28km², based upon which KGPR could support 22.28 elephants. KGPR currently supports 20 elephants.

3.3.2 Data collection

Vegetation data were collected in June – October 2019, with 84, 10 x 100m transects to represent the vegetation type across the reserve (Appendix 1: Table A.1; 4: Table A.4.2). A navigation-grade GNSS (Garmin™ GPSMap® 60CSX) was used to acquire co-ordinate pairs at the start of each transect. Every tree of height ≥2 m and diameter breast height (DBH) of ≥10 cm was sampled for elephant damage and recovery (Coetzee et al., 1979; Staub et al., 2013). When a tree met the necessary requirements, the following parameters were recorded:

- Species, height (m), DBH (cm)
- Elephant impact type (Table 3.1)
- Tree recovery type (Table 3.1)
- Insect presence: Termites, Wood borers

Tree impacts were derived from the Walker damage scale (Walker, 1976) (Table 3.1) to determine the types of elephant impacts on each tree during data collection. Elephant impacts on trees is easily distinguished from that of other browsers due to their foraging behaviours (Jachmann and Bell, 1985). Impacts were recorded according to the methods used by Jacobs and Biggs (2002). The types of recovery were also recorded for each tree based on the types of recovery identified by Gadd (2002) (Table 3.1). All trees sampled were recorded using a binary scoring system for each parameter.

Table 3.1 Scale used to record elephant browsing impacts and recovery levels on tree species after Walker (1976).

Variable	**Observation**
Damage	Branches broken
	Condition of the tree: Alive/Dead
	Main stem broken
	Main trunk debarked
	Pushed over
Recovery	Presence of coppicing
	Bark regrowth
	Presence of sprouting

3.3.3 Data analysis

A total of 1278 trees were used in our analysis, on the five most abundant tree species: knobthorn (*Senegalia nigrescens*), marula (*Sclerocarya birrea*), velvet corkwood (*Commiphora mollis*), red bush willow (*Combretum apiculatum*), and leadwood (*Combretum imberbe*).

Data exploration was carried out following the protocol described in Zuur et al. (2010). Generalized linear mixed effect models (GLMM; binomial distribution) were used to model the likelihood of a given insect type to be found on any given tree, as a function of the height of the tree, the level of tree impacts, and the two-way interactions between covariates (all fixed effects). We also used GLMM to model the likelihood of a given insect type to be found on any impacted tree, as a function of the height of the tree, whether the impacted tree showed any signs of recovery, and the two-way interactions between covariates (all fixed effects). In all cases, transect identity was modelled as a random effect. Identified impact and recovery types were classified into 'ImpactScore' (0-5, depending on the number of types of impacts identified) and 'RecoveryScore' (0-3, depending on the number of types of recovery identified) for each observed tree (Table 3.1). We tested the model structure by adding the independent variables and then tested the main effects plus the interactions; the best models were used for further inference. All models were built in R using the "lme4" package (Pinheiro and Bates, 2000; R Core Team, 2014).

Model assumptions were verified by plotting residuals for spatial dependency. We determined that the random effect approach was sufficient for spatial dependency by conducting Moran's I test on all models (Getis, 2008). Results confirm that spatial autocorrelation is absent in the residuals of all models, and inference was taken from the best performing models (Moran's I for all models < 0.02; p-value < 0.05 for all models).

3.4 Results

Termites were more likely to be found on more impacted trees, ($P=0.02$). Tree height was less important as the impact score increased ($P=0.01$).

The likelihood of finding wood borers on trees, on the other hand, was not impacted by tree height or impact score (all $P > 0.05$).

We also found that recovery was significantly linked to wood borers presence: the higher the recovery score, the greater the chance of finding woodborers on impacted trees ($P = 0.03$). However, the likelihood of finding termites on impacted trees was not related to the tree's recovery score ($P > 0.05$). Both termite and wood borer presence were not affected by tree height of impacted trees ($P > 0.05$) (Table 3.2).

36% of sampled trees had no termite or wood borer presence. Trees that had termite presence had the highest level of impacts (60%) compared to wood borers (50%) and trees without insect presence (37%). Trees that had termite presence also had the highest level of recovery (31%). Trees with wood borer presence had similar levels of recovery compared to trees without insect presence (19% and 17%, respectively). The majority of impacts that were found on trees with and without insect presence were branches broken. Trees with termite presence had the lowest number of trees pushed over compared to trees with wood borer presence and trees without insects (15, 36 and 31, respectively).

Table 3.2 GLMM outputs of dependent (termites and wood borers) and independent variables (fixed effects) for both insects tested.

Variable	**Fixed Effects**	**GLM coefficient (estimate)**	**SE**	**Z value**	**P value**
Wood borer	Height +	-0.04	0.05	-0.66	0.49
	RecoveryScore	0.35	0.17	2.16	**0.03**
Termite	Height	-0.13	0.11	-1.21	0.23
	RecoveryScore	-0.68	0.76	-0.89	0.37
	Height: RecoveryScore	0.09	0.10	0.86	0.39
Wood borer	Height	0.08	0.06	1.39	0.10
	ImpactScore	0.64	0.39	1.63	0.10
	Height: ImpactScore	-0.07	0.06	-1.25	0.21
Termite	Height	0.09	0.07	1.29	0.19
	ImpactScore	1.14	0.47	2.41	**0.02**
	Height: ImpactScore	-0.17	0.07	-2.51	**0.01**

3.5 Discussion

Our results show that (i) termites are more likely to colonise impacted trees; (ii) wood borers are more likely to colonise impacted trees that are showing signs of recovery, and that (iii) insect presence on impacted trees did not depend on tree height.

Studies to date that have considered elephant impact on trees have overlooked the impact of insects. We show here that termites colonising damaged trees should be regarded as a significant contributor to secondary impacts. We also found that the effect of tree height was not related to insect presence, suggesting that insects do not colonise tall trees. This raises concerns, as management efforts to date on trees have focused on large trees as they are considered the most susceptible to elephant impact (Biggs and Jacobs, 2002; Helm et al., 2009; Helm and Witkowski, 2012; Cook et al., 2017). Howes et al. (2020) determined that tree impact by elephants in an enclosed reserve was non-lethal to trees, and that taller trees were less likely to suffer from elephant impact. However, once elephant impact on trees has occurred, it was not known how the level of insect damage impacts tree mortality. We have shown here that termite presence on impacted trees could be leading to increased mortality if thetree is unable to recover from elephant impact, as they were more likely to be found on impacted trees that did not show any signs of recovery.

It could also be conceivable that debarking may not be the main driver for subsequent insect impact. Debarking has been shown to increase tree susceptibility to other impacts including fires (Ihwagi et al., 2010) and diseases, and has shown to be attributed to cause direct mortality (White and Goodman, 2009). This method of elephant feeding has also been shown to make the tree more susceptible to termites, wood borers and other insect activity and ultimately, shortening the trees lifespan (Hatcher, 1995). However, our results show that termites are more likely to colonize trees that have a greater number of impacts, which could result in further impacts and increase likelihood of tree mortality. Added to this, our results showed that wood borer presence was likely to be found on trees that exhibited signs of recovery, suggesting that even trees showing signs of recovery may encounter further impacts from insects. We suggest mitigation methods should focus on the most susceptible trees that show high levels of impact, that are likely to incur further impacts from termites and considerwood borers presence on trees with recovery.

We stress that our study does not indicate the removal and prevention of insects at this stage. We are suggesting that more focus should be directed towards secondary impacts, as opposed to just considering elephant impact on its own in relation to tree mortality. Additionally, elephant feeding habits result in greater availability of food for termites and woodborers (Holdo and McDowell, 2004). In fact, within fenced reserves that limit wildlife migration between reserves, high densities of termite mounds (Macrotermes) are important to conservation as they are able to sustain wildlife population by sustaining nutritious forage availability across seasons. Trees species within proximity to termite mounds within savanna environments benefit as termite mounds can aid tree growth due their increased soil fertility as well as water availability (Davies et al., 2016). This can be crucial during the dry season when forage is limited (Davies et al., 2016). Studies have also suggested that within fenced reserves, elephants show feeding preferences to foraging over grazing, which only enhances the need for termite mounds (Jouquet et al., 2011).There have been studies on the relationship between termite mounds and herbivore feeding patterns (Muvengwi et al., 2013; Okullo et al., 2012; Van der Plas et al., 2013). A recent study focussed on the influence of mound size on vegetation diversity, finding that elephant damage to mound associated vegetation reduced the microclimate effects provided by vegetation (Joseph et al., 2013). However, termite mounds have been shown to provide both refugia and high-quality forage for a range of herbivore species (Fleming and Loveridge, 2003; Grant and Scholes, 2006; Mobæk et al., 2005). Therefore, we acknowledge that termite mounds are essential for biodiversity and providing ecosystem services and further research on the relationship between elephant impact and Macrotermes (mound-forming termites) is needed.

Further studies are therefore needed to determine the level of mitigation required to supress elephant induced impacts and the subsequent impacts of insects on susceptible trees. This way, we will be able to determine the best approach to maintain sufficient vegetation for elephant feeding. Some tree species are not impacted highly by feeding and can persist through time, however further impacts by insects can cause an increased severity of impacts and limit the ability of a tree to recover. Conservation efforts should focus on trees that are unable to recover and are susceptible to elephant and insect impact.

We attempted to address some of the explanatory factors of elephant impact and the impact of insects, however there are limitations to this study. We only considered termite and wood borer presence in our analysis. Our study is constrained both temporally and spatially, as we only collected data over 3 months in one area. If tree impact was recent, then there may havenot been enough time to show levels of recovery or subsequent insect activity. We recommend that studies using our approach consider a larger temporal range as well as considering other insect species. It may also be informative to further studies to identify the density and size of termite mounds and their spatial distribution, associated with impacted trees in a fenced reserve, as termite mounds themselves play a part in the spatial heterogeneity of the landscape.

Our study has provided fresh insight regarding insect presence on trees impacted by a high density of elephants within a fenced reserve, and their subsequent recovery. There remains a need to determine how insects directly impact further impacts to trees, and their subsequent recovery, in the longer-term. Therefore, we suggest carefully considering management approaches for elephant-induced insect impact on trees. We acknowledge the importance of insects for many ecological processes and other species that live within fenced reserves. We have shown that even impacted trees that exhibit recovery have wood borer presence, which is a concern when considering the level of damage in a fenced reserve. As reserves vary in elephant density and the spatial distribution of termite mounds and therefore termite induced impacts, it is essential that we determine how to manage the secondary effects of elephant impact so that vegetation can be maintained.

Chapter 4

4. The potential of photogrammetric point clouds derived from conventional aerial survey for estimating tree heights

This chapter has been redacted. The document and/or data contains information about research in progress where there is an intention to publish later.

See https://eprints.bournemouth.ac.uk/37449/

5. African and English school children's perception of elephants and elephant conservation

This chapter has been redacted. The document and/or data contains information about research in progress where there is an intention to publish later.

See https://eprints.bournemouth.ac.uk/37451/

6 General discussion and conclusions

6.1 Overview of thesis

Understanding the changes in vegetation structure within landscapes that elephants utilise is important for informing conservation and management practices, to support elephant conservation (Greyling, 2004). For conservationists, advances in field-based methods and remote sensing techniques have been applied to elephant impact studies in savanna ecosystems to increase understanding of such changes (Guldemond et al., 2017; Nkosi et al., 2019).

The focus of this research was:

- To determine elephant impact on tree species of > 5 m in height within a high elephant density fenced environment, through quantifying the level of impact and recovery on various tree species (Chapter 2)
- To then determine the secondary impacts on trees > 2 m in height, through quantifying the level of elephant impact, secondary impact and recovery on various tree species (Chapter 3)
- To understand the value of remote sensing techniques to complement field data collection by testing an alternative method estimating vegetation height at a reserve extent (Chapter 4).
- To explore school children's perceptions of elephant conservation in areas where elephants were both present and absent, to identify factors that would improve and foster perceptions of elephants and ultimately their conservation. (Chapter 5).

The African savanna elephant provided a strong model species for analysing impact to vegetation, given their capacity as ecosystem engineers (Western, 1989). In addition, the Karongwe Private Game Reserve (KPGR), South Africa, provided an appropriate fenced savanna ecosystem in which to examine elephant impact, given its highly monitored elephant population and high elephant density. The sites that were selected to determine school children's perceptions of elephants and elephant conservation, provided key comparisons of areas where elephants were native and non-native, in areas that were accessible.

6.2 Field data collection on elephant impact and recovery: limitations and implications

The level of elephant impact to trees > 5 m was assessed using field transects for data collection and twice daily sightings of elephants to delineate habitat use within a fixed, fenced environment (Chapter 2). Even though detecting elephant impact with this method is temporally limited, metrics determined here gave insights into the level of impact on the following five of the most common tree species within the reserve: (knobthorn [*Sengalia nigrescens*]; marula [*Sclerocarya birrea*]; velvet corkwood [*Commiphora mollis*]; red bushwillow [*Combretum apiculatum*]; leadwood [*Combretum imberbe*]). Determining the impact to various tree species was key, which complemented the growing body of literature quantifying the amount of elephant impacts across different environments (Boundja and Midgley, 2010; Holdo, 2003; Levick and Asner, 2013; Morrison, Holdo and Anderson, 2016) including studies that were specific in focus on single tree species (Gadd, 1997; Weaver, 1995; Jacobs and Biggs, 2002).

Additionally, determining the level of tree recovery, quantifying high-use and low-use of elephant areas and the effect of the fence line were also considered. Few studies have addressed the levels of recovery across multiple tree species with elephant impacts, and those that have identified this have not considered habitat use and fence line as important factors (Croze, 1974; Leuthold, 1977; Pellew, 1983; Lock, 1993; Dublin, 1995; Western and Maitumo, 2004). Understanding the influence of these factors is integral, as determining areas that elephants utilise within closed ecosystems will determine suitable methods of management for vegetation sustainment. Our study highlights the lack of recovery of some species in high-use areas, but no significant effect on fence line.

Within savanna ecosystems, where seasonality affects growth rates of vegetation, and many other biotic and abiotic factors affect recovery rates of trees after elephant impact, the limited temporal capacity of this study may be insufficient to determine the severity of elephant impact. Repeating the methods explored in Chapter 2 could resolve this, over consecutive years where vegetation impact and recovery could be determined on a larger temporal scale. However, the efficacy of this method would diminish in situations considering for tree impact and recovery alone. This could be improved by including other environmental factors, such as rainfall and temperature, within the statistical models in addition to those that were determined in Chapters 2 and 3. Including additional fixed effects within these models will increase the complexities of these and the subsequent inference which will require model selection methods to be employed (AIC; see 6.6.2). This would ultimately give a more comprehensive approach.

Given that a large proportion of literature focusses on large trees due to their economic importance, cultural significance, and environmental benefits to biodiversity, we considered large tree height (> 5 m) as an essential factor of elephant impact. Large trees are vital for ecosystem functioning and are important for the cycling of nutrients (Ludwig, De Kroon and Prins, 2008), provide a forage source for fauna (Kerley and Landman, 2006) as well as nesting sites for birds of prey (vultures and raptors; Vogel et al., 2014). However, it may be important to determine the effects on a range of tree heights, as Asner et al. (2015) stated that elephant density plays the greatest role in determining losses of trees > 2 m in height. This may be especially important within enclosed reserves, where forage capacity and mobility are limited due to the nature of these areas, and impacts may be seen with lower height classes of vegetation if there is sufficient foliage available. Therefore, determining impacts and recovery levels of different tree heights could complement the study in Chapter 2.

The level at which a tree can recover after elephant impact is dependent on many factors, including the regeneration time of a species, the level and therefore severity at which the impact occurs as well as other biotic constraints (Lewis, 1991; Ben-Shahar, 1996; Styles and Skinner, 2000). Most studies that have considered elephant impact on trees and any levels of recovery, fail to also address any other factors that may influence the survivability of trees. This includes insect colonisation once elephant impact occurs, which may be responsible for tree deaths that are commonly associated with elephant impact independently. The results from Chapter 3 gave new insights into insect colonisation on impacted trees, both with and without signs of recovery, withina high elephant density reserve. Findings here support existing literature that termites are likely tocolonise impacted trees (Hatcher, 1995; Gould et al., 1993; N'Dri et al., 2011), however results clearly demonstrated that woodborers are likely to colonise impacted trees that showed signs of recovery. The strong relationship between impacted trees showing signs of recovery and wood borer colonisation is concerning and yet to be fully understood. Moreover, in Chapter 3, trees of varying heights (> 2 m) did not show a significant relationship with colonisations of insects, suggesting that insects do not colonise tall trees. As this study was temporally limiting, longer term impacts to vegetation because of insect colonisation still need to be quantified. Additionally, this study could be enhanced by spatially locating termite mounds to determine the direct association between termite mounds and insect colonisation to elephant impacted trees. Given that two species (termites and wood borer) were observed, the results of this project could be complemented with the analysis of other insect species, to assess the extent of secondary impacts.

Within South Africa, the impact of elephants on large trees is viewed as unsustainable within fenced reserves (Asner et al., 2016), where efforts are focussed on protecting large trees and maintain an 'ideal' state, which remains a contentious issue among conservationists. At present, the management strategy of South African National Parks focuses resource use by elephants with regards to their distribution, rather than relying entirely on elephant densities within an area (Ferreira et al., 2017; SANParks, 2012). Historically, mitigation strategies directly reduced elephant number in response to their populations. This method, however, of maintaining elephant populations did not significantly influence the loss of large trees (> 5 m), which is inherently complicated due to their survival rates changing through different life stages. Managing the effects that elephants have on large trees has been targeted at a large-scale landscape manipulation, as well as small-scale individual tree protection methods which we identified in Chapter 2. It was suggested that in the reserve considered in Chapter 2, 3 and 4 (KPGR), methods should be utilised to protect large trees directly from elephant impact, such as creating enclosure areas (Kerley and Landman, 2006). Direct protection of trees could also include wire-net protection (Derham et al. 2016), beehives (Cook et al., 2018), and rocks (SANParks, 2012) to enable selected tree species and size classes to recover. Even with these direct protective methods to deter elephants, secondary impacts could still influence the level of recovery (Chapter 3), which needs to be further quantified.

6.3 Remote sensing methods: implications and limitations

Throughout the literature, elephant impact to vegetation has focussed on field data collection methods, often using transects as a method of sampling areas within a larger area of interest. These methods are important in quantifying levels of impact and tree recovery at fine scales, determining specific elephant associated impacts as well as recovery levels that can be applied to statistical models, which we have identified in Chapter 2 and 3.

The importance of field data collection to determine elephant impact still holds intrinsic value in research today (Ben Shahar, 1996; Shannon et al., 2011). Methods adapted from Cotezee et al. (1979) and Staub et al. (2013) highlight the importance of identifying tree characteristics including number of branches broken, whether the main stem has been broken etc. as determinants of elephant impact. The level of impact can in turn influence the recovery levels of tree species if impact is extensive and tree species don't have sufficient time to recover due to frequent utilisation in high elephant density areas (see Chapter 2). Determining tree characteristics is integral for ecological studies and wildlife habitat management, however field studies determining levels of impact through transect methods can be time consuming and not cost effective, especially within large spatial extents. This also holds true for small reserves that may have limited resources hindering effective, reliable, and repeatable field data collection. Consequently, the advancement of remote sensing methods applicable for detecting tree structure can enhance methods of understanding elephant impact, which have been identified in Chapter 4.

Concurrently, elephant densities need within an area need to be determined which have to date mainly been achieved through to aerial surveys. More recently, research has applied convolutional neural networks (CNNs) to high-resolution satellite imagery (derived from WorldView-3 and 4) (Duporge et al., 2020) and high-resolution aerial images (derived from UAVs) (Delplanque et al., 2021) to detect African elephants. Remote sensing techniques can be limited due to the skills and knowledge required for efficient analysis is high-level (Nkosi et al., 2019). Such data intensive methods necessitate suitable equipment for data acquisition and inference.

As with many field data collection methods, remote sensing studies to determine elephant impact within South Africa have also been concentrated within the Kruger National Park (KNP). Munyati and Sinthumule, (2016) used panchromatic aerial photographs and SPOT imagery, while Asner et al. (2009) and Levick (2009) used ALS to determine the large-scale impact of herbivory on the structure of vegetation. Determining the rate of treefall has been the focus for these analyses, where a subsequent algorithm intensive approach (Random Forest) was required to determine treefall rates over a large landscape scale (Asner et al., 2016). Asner et al. (2016) used ALS data captured over six years, biannually, to determine treefall at a landscape scale. Although ALS provides fine spatial resolution on tree metrics (Lim et al., 2003), this approach is one of the most expensive forms of remotely sensing, and therefore only small spatial extents are acquired. Therefore, the application of using ALS consistently across spatial and temporal extents is presently not a cost-effective approach.

Chapter 4 explored the different remote sensing approaches that had been used to determine elephant impact. ALS dominates the literature regarding tree structure detection in savanna ecosystems (Asner et al., 2009; Johansen et al., 2010; Levick et al., 2010; Levick and Rogers, 2008; Levick and Asner, 2013; Davies, Gaylard and Asner, 2018). An alternative approach was investigated here, using a point cloud derived from photogrammetry using conventional aerial survey as a novel method for estimating tree height at a reserve extent in savanna ecosystems. Results demonstrated that this method was effective. Tree metrics derived from this method can support monitoring of trees in response to elephant impact. The remote sensing approach applied here considered trees > 2 m high over a reserve extent, which gave key insights into the quantification of individual trees.

6.4 Children's perception of elephant conservation

This study has shown the importance of determining direct and indirect elephant impact, recovery and tree height to aid elephant conservation by maintaining areas with suitable elephant numbers and adequate vegetation. However, this study also considered how perceptions towards elephants and elephant conservation can be improved to enhance understanding of conservation approaches. This was deemed appropriate for this study as environmental education is a key strategy that can aid scientific research and encourage people to take informed action (Monroe and Karnsy, 2015). School children were chosen as the study demographic because there has been little focus on determining how they perceive elephants and elephant conservation, both in situ and ex situ (Makecha and Ghosal, 2017). School children are also not likely to have fully formed opinions or attitudes about the environment (Pelletier et al., 2004) and it is key to influence positive environmental attitudes at an early age as they are likely to remain once formed (Asunta, 2003).

Surveys were used across different schools that were accessible at the time of study. This was limiting (see Chapter 5) as only three schools were sampled to determine different levels of exposure based on their geographic location. Even with this limitation, this study provided key insights into how children perceived elephants at different levels of exposure. School children feared elephants where elephants were native, and students who feared elephants where elephants were not native were more likely to want to see them in the wild. This study also showed that there was a distinct misunderstanding of how elephants benefit other species as well as their feeding behaviours. The perception that elephants were in decline due to too many species in one place, was prevalent throughout school children in South Africa. It was also determined that a wildlife guide as a career choice was not valued as highly compared to other career choices.

With these new insights in relation to location, more research is required to improve school children's perceptions of elephant conservation. The next step would be to implement workshops at different levels of exposure to improve understanding around concepts that were identified here. This would require a pre- and post-workshop evaluation to determine if perceptions changed, which would be enhanced if this could be carried out repeatedly over time. With the recent changes in online learning due to the COVID-19 pandemic, both surveys and workshops could beconducted online at a large spatial area. However, using online methods will hinder data collectionin countries where there is limited access to computers, which was experienced first-hand in this study. Nevertheless, improving perceptions of elephants and elephant conservation is key within this demographic as children can act as message multipliers, transferring their knowledge to their communities (Domroese and Sterling, 1999). Our study considered secondary school children as our demographic, but a range of age groups could be tested to understand when perceptions are determined.

6.5 Conclusions

In summary, this thesis has provided insights into how savanna elephants impact occurs within a fenced reserve, and how this influences the level of tree species recovery in high-use and low use habitats. Furthermore, this study considered how secondary impacts to vegetation as a result of elephant impact could be reducing the trees' ability to recover, which has rarely been comprehensively studied when considering for elephant impact. This highlights the importance of considering both recovery and secondary impacts in maintaining suitable habitat to support elephants and elephant conservation in enclosed ecosystems. Results also revealed that a complementary remote sensing method can be applied to effectively determine tree height estimates, imperative for quantitative research on elephant impact. Additionally, the perception that school children have at different levels of exposure needs to be improved to support effective elephant and other wildlife conservation. Future avenues of research, detailed above, could be used to improve best practice monitoring of elephants, and expand current knowledge and understanding of the impacts that elephants have on vegetation, and the implications of these.

6.6 Future research

6.6.1 Ecological considerations

This thesis has given key insights into direct and indirect effects of elephants on vegetation (both impact and recovery), which is especially important to identify when considering for constrained areas. These also need to be quantified across different spatial extents, not only considering for impact and recovery, but also in response to additional abiotic and biotic factors. These factors should be considered in areas across different regions of Africa to achieve a broader understanding on the influences of multiple factors on vegetation.

A major threat to wildlife conservation is climate change, which is increasingly being driven by human activities. Rising temperatures are being seen throughout sub-Saharan Africa, which poses problems for both the vegetation and animals alike, that are found in areas of high temperatures. Extreme temperatures effect animals in different ways, but some megafauna species cannot dissipate heat easily which makes them more vulnerable to such changes. Moreover, increasing temperatures means longer drought periods, which will affect many megafauna species that are reliant on large volumes of water and sufficient vegetation for survival.

Therefore, understanding how vegetation and megafauna species react and are reacting to climate changes is important for future conservation research. Artificial water points (AWPs) have been used in many areas to support wildlife, but more research is needed on how these can effectively be safeguarded in areas with adequate vegetation to support megafauna. This can only be achieved in areas with sufficient vegetation, which is becoming increasingly fragmentated. Therefore, more research is required on suitable areas for megafauna species to ensure there are sufficient resources for survival.

Future wildlife species conservation can only be achieved if we know where wildlife is located and their associated densities. This is especially challenging to determine across large spatial extents with free roaming wildlife. However, recent technological advances in artificial intelligence have shown potential in identifying megafauna from high resolution and satellite and aerial images. Future research should be targeted at applying these approaches to not only identify megafauna species, but also accurately mapping vegetation in areas where species are present. This will also give key insights into determining suitable areas for wildlife.

Another threat that has increased in recent years is Human Wildlife Conflict, which is exacerbated with land fragmentation. Future ecological research on megafauna needs to consider how people respond to wildlife and improve measures to protect wildlife species. Local communities are especially important, and increased awareness is needed on the ecological problems species face and how this can be mitigated.

6.6.2 Data analyses

Some prospective methods were discussed to improve our research earlier in this chapter. Throughout this project, different types of analyses were considered and tested. Future studies that consider other data types could be applied for different levels of impact and recovery (e.g., a percentage score of debarking, the number of broken trees, the number of coppiced branched etc.). Further detail on future studies has been explained in the following section.

6.6.2.2 Impact and recovery classifications

Chapter 3 aimed to establish the impact and recovery levels of trees species after elephant impact occurs. Impact and recovery levels were recorded in the field as direct observations, and a subsequent classification was applied as a 'ImpactScore' (0-5, depending on the number of types of impacts identified) and 'RecoveryScore' (0-3, depending on the number of types of recovery identified) for each observed tree. Initially, adding together all impact and recovery variables was considered, but the variables were correlated and therefore not truly independent (a type of impact may be more beneficial to termite than another). The significance may also change depending on whether termites or wood borers were considered. Before the classification approach was decided, a principal component analysis (PCA) followed by a discriminant function analysis (DFA) was considered, to see whether the variability could be reduced. PCA is used to obtain a smaller number of summary variables from a larger number of candidate independent variables. PCA was tested but was unsuitable for this study. However, these methods were explored as they could be applied to other data studies on elephant impacts.

Principal component analysis (PCA) was considered as a dimensionality reduction method. PCA is an effective method to reduce the dimensionality of higher order systems and capture most of the covariance on preferable a 2 dimensional or 1 dimensional field. The strategy is similar to the development of generalised linear models, to perform regression analysis for data belonging to the exponential family. It has been argued that PCA assumptions are not appropriate for binary, or count data and generalisations exist. Multiple Correspondence Analysis (MCA) (also known as a homogeneity analysis) could be applied to binary data (Josse and Husson, 2012; Abdi and Valentin, 2007).

6.6.2.3 Modelling approaches

Both data Chapters 2 and 3 used statistical modelling to predict outcomes based on various variables that were collected in the field and adapted accordingly for hypothesis testing. Generalised Linear Mixed Models (GLMM) were selected as the most appropriate for the data collected (categorical: binomial), however initial model investigations determined that Generalised Linear Models (GLM), could also be suitable. GLMs can be used when the residuals from a General Linear Model are not normal (based on normal/gaussian distribution) between dependent and independent variables. GLMs was performed on the datasets collected in chapter 2 and 3, using a binomial error family and logit link function. However, when GLMs were run, model validations indicated that there was high spatial autocorrelation. To correct for this, GLMMs were used where fixed and random effects were identified and included. Transect location was a suitable random factor within the models and removed identified spatial autocorrelation. GLMs that do not have spatial autocorrelation present, can be used for ecological studies. These could also be considered for studies that do not have pseudo-replication present, which will need to be determined before appropriate models are tested.

Model selection methods were also investigated for Chapter 3, where impacts and recovery were added together for the first data exploration. This was identified as unsuitable (as the variables were correlated), but methods of model selection and model averaging were still investigated within the early stages of data exploration. Designing an appropriate model for a dataset requires decisions based on terms that you want to include. Model selection can be time consuming, and a subjective approach (Crawley, 2007) when choosing the "best" model.

There are several model selection approaches that can be applied, where many scientists and researchers are now moving towards comparisons of models using an information-theory approach such as Akaike Information Criterion (AIC) (Grueber et al., 2011; Richards et al., 2011). There are numerous model selection criteria based on mathematical information theory (IT) that can be used to select models from among a set of candidate models. The most used information criteria in ecology and evolution are Akaike's Information Criterion (AIC), the corrected AIC_c (corrected for small sample sizes), and the Bayesian Information Criterion (BIC, also known as the Schwarz

Criterion) (Johnson and Omland, 2004). Advantages include not relying on a single model; models can be ranked and weighted according to their fit to the observed data and the best supported models can be averaged to get parameter estimates.

AIC is a measure of the goodness of fit of a model, where an "efficient" model explains a relatively large amount of the variance in y, using few independent variables to do so. This approach examines the model fitness. The lower the AIC value the better the model, which can then be used for further inference (Zuur et al., 2009). AIC is calculated following this equation:

$$AIC = -2LogL + 2p$$

AIC_c can be used when there are small sample sizes and can correct for that limitation. It is recommended to use this when n/k is less than 40, with n being the sample size (i.e. total number of observations) and k being the total number of parameters in the most saturated model, including both fixed and random effects, as well as intercepts (Symonds and Moussalli, 2011). AIC_c is calculated as follows:

$$AICc = AIC + 2k(k+1)n - k - 1$$

Within data Chapter 3, the sample acquired applied to n/k would produce > 40, therefore AIC would be applicable. However, this approach would not have been suitable for our analyses in Chapter 3 as impacted trees and all trees (both impacted and not impacted by elephants) were used for testing, and it isn't possible to compare AIC values between models based on different subsets of data. AIC should therefore be a consideration where no caveats are present. Consideration was also given to using the AIC approach within Chapter 3, when preliminary investigations discerned that impact and recovery were independent variables. However, as these were added together, this was later deemed an unsuitable approach. Future studies could employ the AIC method if a suitable research question and hypothesis testing approach is present within the study.

Model averaging is an approach that can follow model selection testing, such as AIC. AIC is a measure of how good a model is among candidate sets; therefore, it is prone to poor choices, in that the chosen variables must be meaningful for the chosen study. Therefore, it's important to assess the goodness of fit (x^2 or R^2) that includes all variables of the study, and inference from that can determine whether the approximating model (model averaging) will be a good fit. Model averaging can either be used directly within a model selection object in statistical programmes. This method is useful when model selection uncertainty is evident. This method produces parameter and error estimates that derive weighted averages across multiple models (Symonds and Moussalli, 2011). There is still uncertainty whether model averaging improves inference (Richards, 2005; Richards et al., 2011), but this approach has proved to be an effective method within ecological studies.

There are different types of model averaging approaches that can be used for: Full averaging and conditional averaging. Conditional averaging is derived from Burnham and Anderson (2002). This method keeps the averaged parameter in the original scale and is applied when there is strong support for the best AIC model. Alternatively, unconditional variance can be used, which is an estimate of variance and is not conditional on a single model and is typically more significant than inference based on one model (Symonds and Moussalli, 2011).

Secondly, full model averaging can be applied when there is high model selection uncertainty, where for example the best AIC model is not strongly weighted (Richards et al., 2011). This is the case when inference is based on all models in the candidate set. Full model averaging produces a predictive formula for the global model, assuming that a variable is included in every model, but in some models, the corresponding coefficient (and its respective variance) is zero. This method can be used in studies where the aim is to formulate how a particular predictor relates to the response variable, which is applicable for ecological studies.

6.6.3 Elephant-induced vegetation change on a temporal extent

To determine elephant impact and recovery, we considered the application of remote sensing approaches, as they provide an array of imagery with various spectral, spatial, radioactive and temporal characteristics that can be used in broad vegetation studies (Xie et al., 2008). Nkosi et al. (2019) reviewed the methods used by different studies to determine the impact of elephants on woody vegetation in sub-Saharan Africa over a 47-year period (1970 – 2017). Though there were various studies that utilised remote sensing methods, none had considered the use of 3-D photogrammetric point clouds as a means to determine elephant impact. The potential of using this remote sensing method was explored in Chapter 4.

This method proved to be effective in determining vegetation height from aerial photographs. Raw data were obtained from the National Geo-Spatial Information (NGI) and GeoSpace International. The data that was analysed in Chapter 4, was from 2018 which was acquired from a digital camera (Table 6.1) and could be tested against vegetation height data that was acquired in Chapter 2 (Appendix 3; field data). As identified in Chapter 4, there is scope to conduct a temporal study within KPGR, with data acquired for previous years.

Vertical, stereo aerial photographs have now been received from aerial surveys conducted of KPGR between 1954 and 2018. This holds great potential for future research projects based around the following research questions:

- Can aerial photographs be used to determine the change in vegetation heights pre- and post-elephant introduction within a reserve? (*Using home- and core-range of elephants since 1999 (see Appendix 3)*).
- How can we use historical aerial photographs to determine long term vegetation change over time (1954-2018)?
- Can aerial photographs be used to determine tree metrics over a large extent: within a protected area and outside of a protected area?

Even though this offers great opportunity for a study on a temporal extent, the spatial extent varies for each year that the air surveys were conducted. Due to the historical methods that have been used to acquire imagery, both digital and analogue photographs have been acquired at different scales. According to the NGI, aerial photographs of the entire reserve are available for research purposes, however the years 2008-2012 have yet to be received in the correct format (orthophotos only) (Table 6.1).

Table 6.1 KPGR archive airphoto details derived from the NGI and GeoSpace International

Year	Date	Approximate local time	Analogue/Digital	Approximate nominal scale or GSD	Format
1954	29th June	1:15pm	Analogue	1:36,000	Greyscale, individual frames
1970	10th July	11:00am	Analogue	1:33,000	Greyscale, individual frames
1986	31st May	12 Noon	Analogue	1:50,000	Greyscale, individual frames
1995	29th July	2:30pm	Analogue	1:20,000	Greyscale, individual frames
1997	10th August	1:00pm	Analogue	1:60,000	Greyscale, individual frames

2003	2nd & 5th October	2:15pm	Analogue	1:32,000	Greyscale, individual frames
2008	-	-	Digital	50cm	Orthophoto only
2012	-	-	Digital	50cm	Orthophoto only
2015	-	-	Digital	50cm	RGB orthophoto
2018	9th June	10:30	Digital	25cm	RGBN individual frames

Therefore, conducting a study on a temporal scale will require careful application depending on the scale of aerial photographs and additional information throughout the analysis process that was shown in Chapter 4.

6.6.4 Elephant management

6.6.4.1 Immunocontraception

Various methods have been used to control elephant numbers in areas where elephants are present in high densities (see Chapter 1). One of the aims of this research project was to identify elephant impact on vegetation and the levels of recovery, which considered habitat use as a key determinant of impact (Chapter 2). The data that was collected on the effects of elephants on vegetation was within a high-density elephant reserve: KPGR. The population of elephants within this reserve is managed by immunocontraception to limit numbers. Bull elephants on the reserve were administered with GnrH contraception in 2012 and this was stopped in 2016 (administered by Professor Bertschinger). The movement patterns of these elephants are shown to be uncharacteristic to the natural behaviours of elephants where the breeding herd and bull elephants only associate with each other during mating (Buss, 1961). However, using twice daily sightings and home range and core range analysis of these data, the bull elephants were shown to move concurrently with the breeding herd (see Appendix 3). One reason for this behaviour is that the bulls were young at the time of introduction to the reserve, so they have "grown up" with the herd, which has also been shown in a group of rewilded elephants where a single bull mirrors the herd's movement (from a conversation with Dr Audery Delsink).

This behaviour could be explained by the age of immunocontraception administration, but this could also be attributed to there not being an unrelated mature bull within the reserve. Contrary to assumptions that older male elephants are redundant within the population, recent research has suggested that older male elephants act as repositories for ecological knowledge (Allen et al., 2020). As mentioned in Chapter 1, the long-term implications of contraceptive methods with regards to elephant's societal change has not been evaluated (Nyakaana et al., 2001; Wittemyer et al., 2009). Within large areas without contraception, bull elephants have been shown to exert a greater impact on vegetation in comparison to cows and calves (Greyling, 2004). However, the influence that immunocontraception has on elephant herd dynamics and the subsequent impact to vegetation is not known. This observed behaviour change should be considered in future studies of elephant impacts to vegetation, as bull elephants on contraception could show less aggressive behaviours and therefore less impact to vegetation. This would need to be investigated in other reserves, where long-term ranges of elephants are known within enclosed areas, which could give new insights into elephant impact on vegetation.

6.6.4.2 Beehive deterrent project

Strategies aimed at directly protecting resource such as large trees are a key method of management to mitigate elephant impact within fenced environments (Derham et al., 2016; Cook et al., 2018). One such method is the use of African honeybees (*Apis mellifea* subsp. *scutellata*) which is effective at protecting individual trees from elephant impact as elephants are afraid of bees and have been shown to actively trees with beehives on/near. Simultaneously, beehives used as a mitigation strategy provide pollination to flora and honey as a biproduct which can be harvested for income (Cook et al., 2018). Though beehives can provide benefits to the local communities, they can be expensive to set up, sensitive to drought and overload the environment with honeybees which may in turn exclude other pollinators.

An alternative novel approach that was a consideration during this PhD research was using Artificial Intelligence (AI) to generate AI beehives. The AI beehive would be trained (using CNN and NVIDIA) to respond when elephants are within a certain distance, which cause responses that simulate hive activity i.e., noise, pheromone production etc. Our AI solution will enable protection of trees and farmland all year round, as it will not be affected by seasonality, when resources are low for the honeybees. In addition, this solution will not need regular monitoring, as the aim is to create a self-sustaining unit. This was beyond the scope of this project, but project planning was initiated for future research opportunities. After networking with data scientists, this project presented an opportunity to be developed with Project 15, Microsoft (https://microsoft.github.io/project15/). Project 15 from Microsoft is an open platform for conservation and ecologically sustainable solutions. Working with data science experts and the latest Microsoft cloud and Internet of Things (IoT) technologies, this project will aim to develop a suitable platform to develop AI beehives that can be tested for efficiency in reducing elephant impact to vegetation and can also be used as a method of deterring elephants from breaking down fences. This project will work with the following collaborators: Ajit Jaokar (University of Oxford); Ayse Mutl (Data Scientist, Feynlabs); Associate Professor Lee Scott (University College London (UCL) and Microsoft); Sarah Maston (Senior Solutions Architect, Mircosoft); and Kate Gilman Williams (CEO & Founder of Kids Can Save Animals). Collaborators from the University of Oxford, UCL and Microsoft will support the project with their expertise in data science, and Kate Gilman Williams will benefit the project with her skills in advocacy and public speaking to younger demographics. The project funding is still to be determined.

6.6.5 Public engagement

Alongside this research project, public engagement and outreach activities were conducted and aimed to provide impact in various ways. This involved numerous talks to the public, activities with local communities and events at science festivals (both face to face and virtually). With the aim of increasing public awareness of elephants and elephant conservation, these engagement activities were mostly targeted at the younger demographic. The need for improved methods of engagement with this age group has been identified in Chapter 5, where focussing concepts of environmental education can foster positive attitudes towards younger generations. A future project that has been developed alongside this thesis is a children's picture book educating children on the importance of elephants within the ecosystem. Information surrounding elephant conservation that has been identified throughout this thesis has been incorporated in the text of this book. This way, research can be communicated to school children effectively.

The manuscript was submitted to Inspire Bytes Publishers in 2021 and accepted for publication. This book will form part of a series in their 'Conservation4Kids' initiative (www.conservation4kids.com), and a supplementary workbook will be developed.

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Appendices

Appendix 1.

Table A.1 The number of species (n) found within the area (Karongwe Private Game Reserve) with common name, family and genus

Species	**Common name**	**Family**	**Genus**	**Count (n)**
Acacia nigrescens	Knob Thorn	*Fabaceae*	*Senegalia*	240
Sclerocarya birrea	Marula	*Anacardiaceae*	*Sclerocarya*	153
Commiphora mollis	Velvet-Leaved Corkwood	*Burseraceae*	*Commiphora*	107
Combretum apiculatum	Red bush willow	*Combretaceae*	*Combretum*	93
Combretum imberbe	Leadwood	*Combretaceae*	*Combretum*	43
Combretum hereroense	Russet bush willow	*Combretaceae*	*Combretum*	21
Diospyros mespiliformis	Jackalberry	*Ebenaceae*	*Diospyros*	17
Acacia tortilis	Umbrella thorn	*Fabaceae*	*Vachellia*	16
Acacia nilotica	Gum arabic	*Fabaceae*	*Vachellia*	13
Bolusanthus speciosus	Wisteria	*Fabaceae*	*Bolusanthus*	11
Lannea schweinfurthii	False marula	*Anacardiaceae*	*Lannea*	11
Philenoptera violacea	Apple leaf	*Fabaceae*	*Philenoptera*	11
Peltophorum africanum	Weeping wattle	*Fabaceae*	*Peltophorum*	10
Searsia pyroides	Common currant-rhus	*Anacardiaceae*	*Searsia*	6
Spirostachys africana	Tamboti	*Euphorbiaceae*	*Spirostachys*	6

Combretum collinum	Weeping bush willow	*Combretaceae*	*Combretum*	4
Olea europaea	European olive	*Oleaceae*	*Olea*	4
Commiphora glandulosa	Tall firethorn corkwood	*Burseraceae*	*Commiphora*	3
Schotia brachypetala	Weeping boer-bean	*Fabaceae*	*Schotia*	3
Ziziphus mucronata	Buffalo thorn	*Rhamnaceae*	*Ziziphus*	3
Acacia gerrardii	Red Thorn	*Fabaceae*	*Acacia*	2
Balanites maughamii	Torchwood	*Zygophyllaceae*	*Balanites*	2
Combretum molle	Velvet bushwillow	*Combretaceae*	*Combretum*	2
Ozoroa paniculosa	Common resin tree	*Anacardiaceae*	*Ozoroa*	2
Strychnos spinosa	Green monkey orange	*Loganiaceae*	*Strychnos*	2
Acacia erubescens	Blue thorn	*Fabaceae*	*Vachellia*	1
Acacia robusta	Splendid thorn	*Fabaceae*	*Vachellia*	1
Albizia harveyi	Common false thorn	*Fabaceae*	*Albizia*	1
Dovyalis caffra	Kei-apple	*Salicaceae*	*Dovyalis*	1
Gymnosporia buxifolia	Common spike-thorn	*Celastraceae*	*Gymnosporia*	1
Strychnos madagascariensis	Black monkey orange	*Loganiaceae*	*Strychnos*	1
Terminalia prunioides	Purple-pod Clusterleaf	*Combretaceae*	*Terminalia*	1

Appendix 2.

Table A.2.1 Contingency table showing aggregated career choice data for male and female students within each country

			Career type							
Country	***Gender***	**Ranking**	**Teacher**	**Doctor**	**Veterinarian**	**Artist**	**Musician**	**Athlete**	**Wildlife Guide**	**Business manager**
England	*Male*	Most favourite 1	7	14	1	6	2	18	3	14
		2	10	14	6	6	5	9	5	10
		3	12	10	11	6	5	8	6	7
		4	9	11	6	11	8	7	9	5
		5	6	5	19	10	7	5	9	5
		6	4	6	6	8	17	5	10	8
		7	5	2	10	8	9	5	18	7
		Least favourite 8	12	3	6	10	12	8	5	9
England	*Female*	Most favourite 1	10	34	8	13	9	8	10	6

		2	21	13	13	10	10	2	15	14
		3	21	17	17	12	10	5	9	7
		4	11	10	20	14	9	12	12	10
		5	8	11	15	18	11	9	16	10
		6	13	5	8	14	12	17	10	19
		7	5	4	9	8	16	25	19	12
		Least favourite 8	9	4	8	9	21	20	7	20
Kenya	*Male*	Most favourite 1	1	4	3	2	10	2	6	6
		2	2	6	2	8	3	2	7	5
		3	3	4	3	4	7	2	3	11
		4	5	7	2	9	1	4	5	2
		5	3	4	10	1	5	4	4	2
		6	1	6	6	8	3	4	5	3
		7	8	3	5	2	1	9	2	5

		Least favourite 8	12	1	4	1	5	8	3	1
Kenya	*Female*	Most favourite 1	4	29	3	4	11	4	3	4
		2	9	13	4	7	5	3	11	7
		3	15	5	1	7	5	8	7	16
		4	9	6	8	8	8	5	7	10
		5	3	3	9	6	7	13	11	9
		6	6	2	9	16	7	7	12	1
		7	8	2	11	10	11	9	2	6
		Least favourite 8	7	1	16	3	7	12	8	8
South Africa	*Male*	Most favourite 1	7	10	6	3	2	2	5	7
		2	11	6	5	7	4	5	3	2
		3	7	12	4	4	2	7	1	5
		4	7	5	8	6	6	3	2	4
		5	2	1	6	9	6	5	8	5

		6	2	4	1	5	9	6	10	5
		7	4	3	7	4	4	9	5	6
		Least favourite 8	2	1	5	4	9	5	8	8
South Africa	*Female*	Most favourite 1	5	30	4	3	3	2	4	3
		2	12	7	7	3	6	1	8	9
		3	9	6	9	10	6	3	8	4
		4	10	2	6	11	7	7	9	4
		5	6	3	6	8	11	9	8	6
		6	6	3	8	10	7	7	5	9
		7	5	2	7	5	11	13	7	6
		Least favourite 8	2	2	8	5	4	13	6	14

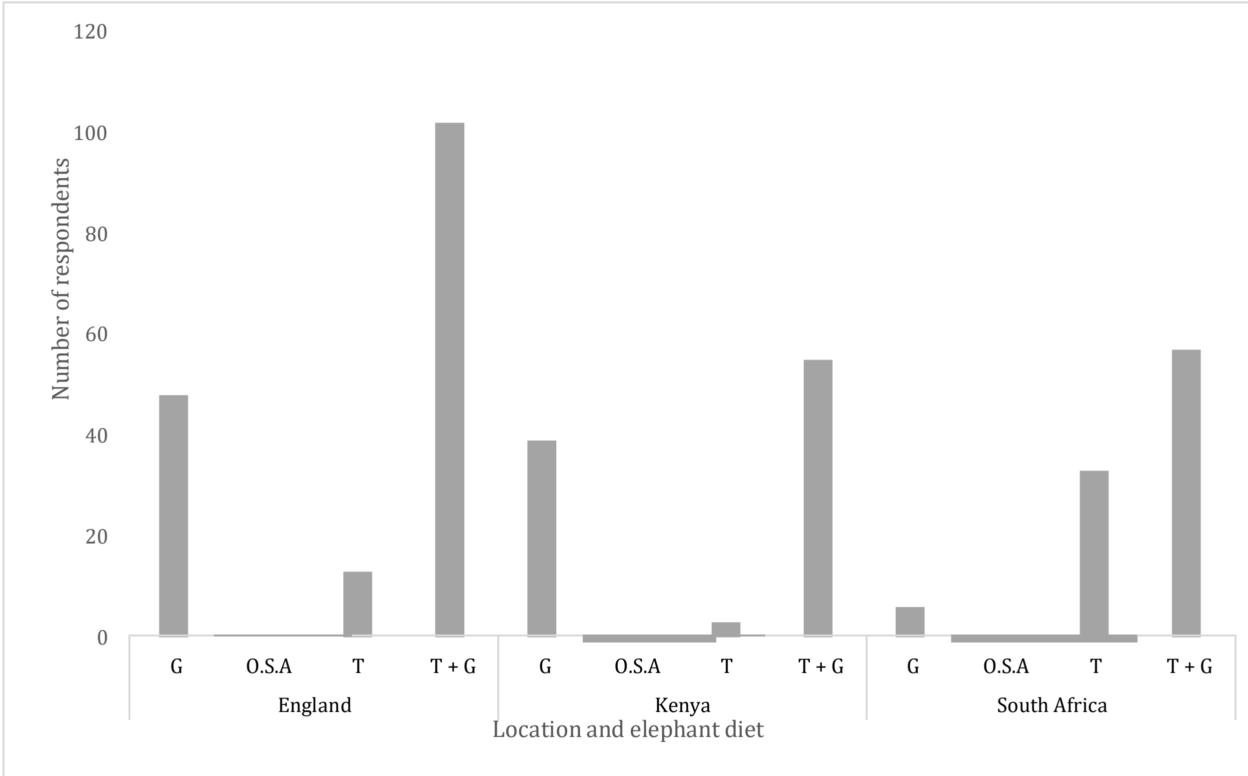
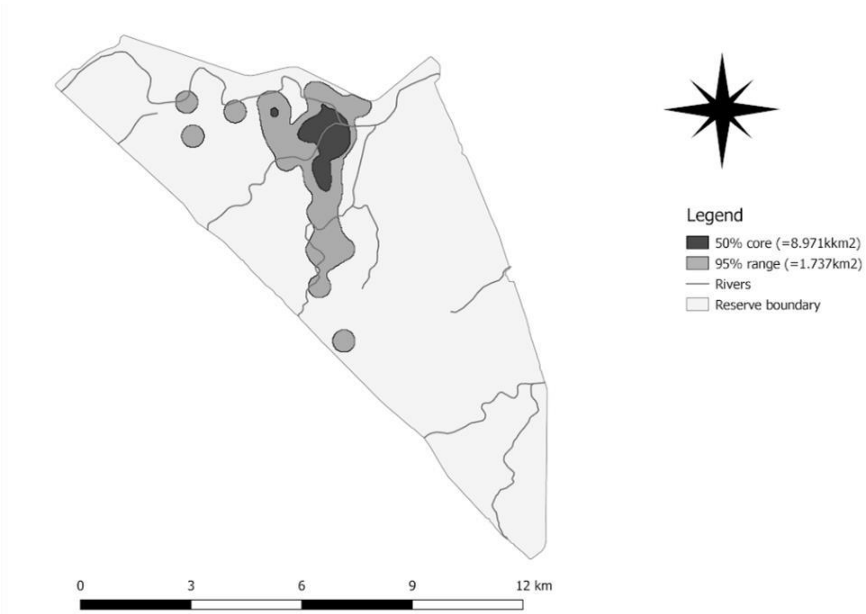


Figure A.2.2. Total participant response of what elephants eat: G = Grasses; O.S.A = Other small animals; T = Trees, and T + G = Trees and Grasses.

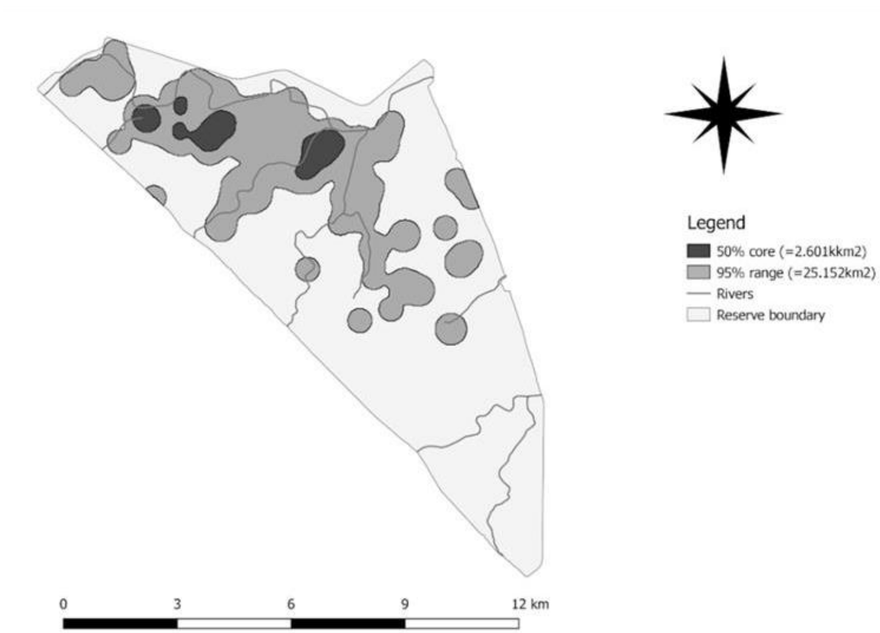
Appendix 3.

Figure A.3: Elephant home- (95%) and core-range (50%) analysis from introduction (1999) until 2018 for breeding herd and bulls. Data were complied for each month, and maps were generated from combined yearly data.

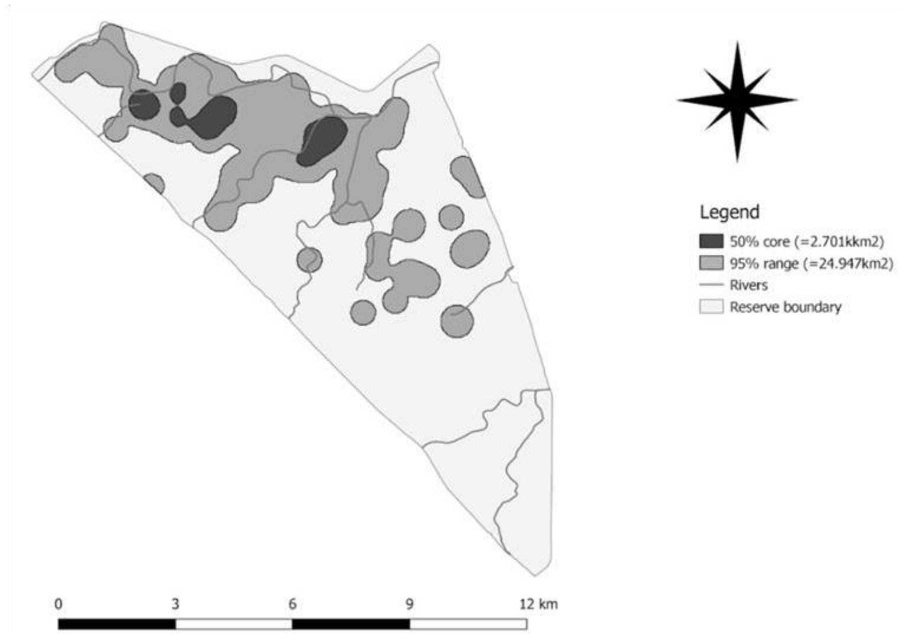
All elephants 1999



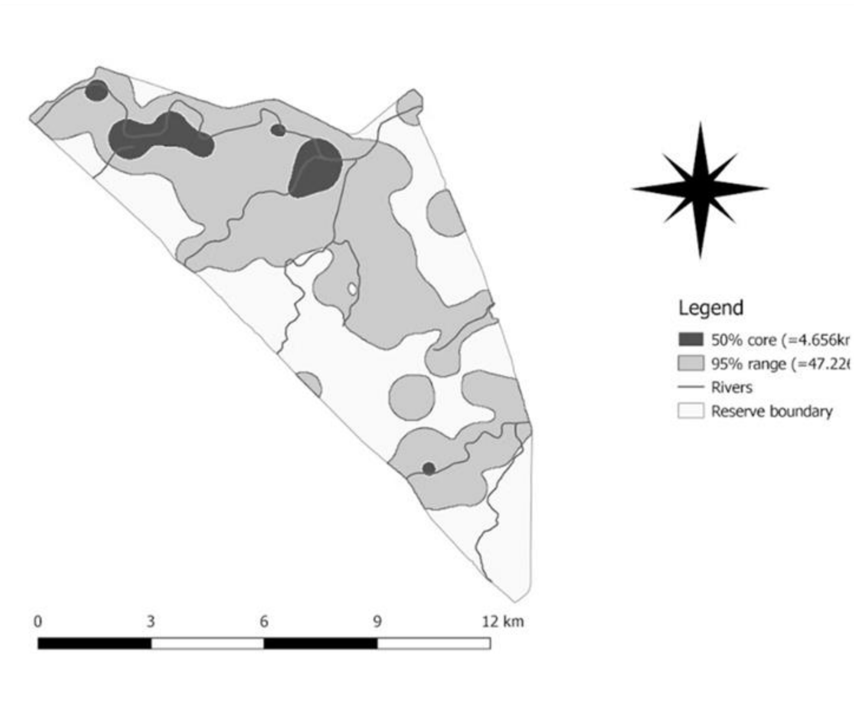
Breeding Herd 2000



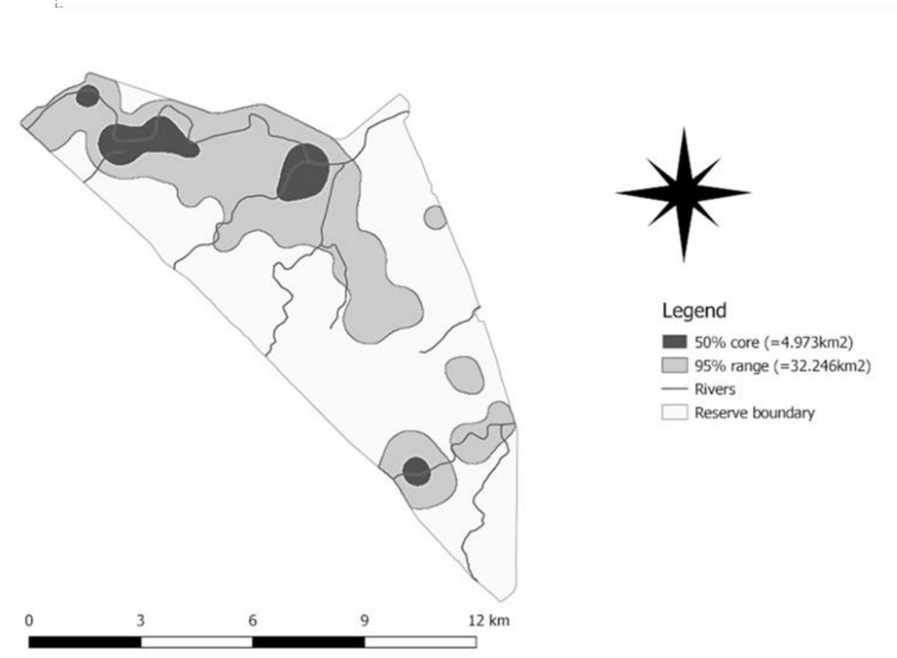
Bull 2000



Breeding Herd 2001

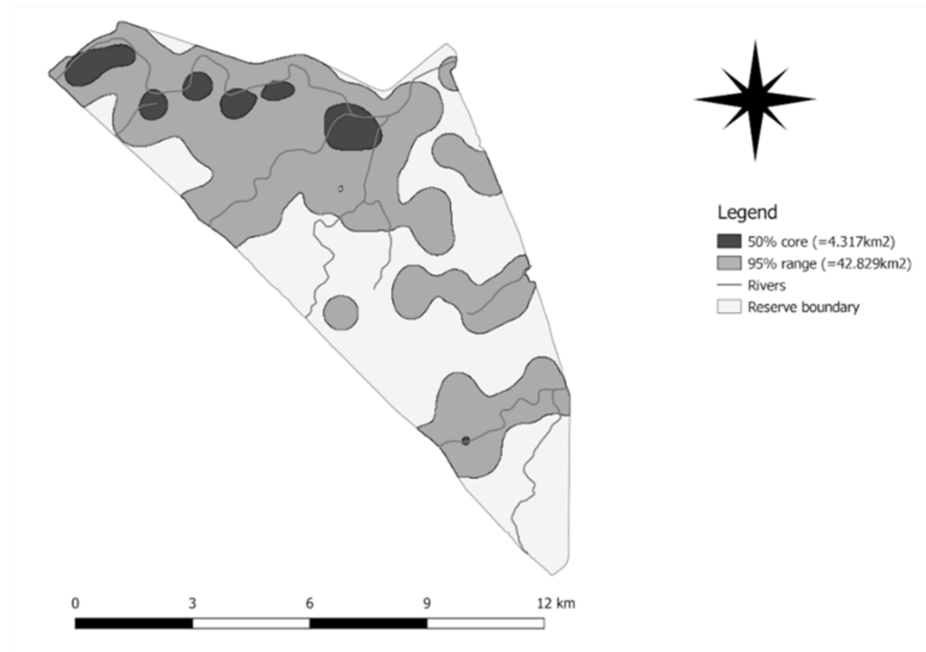


Bull 2001

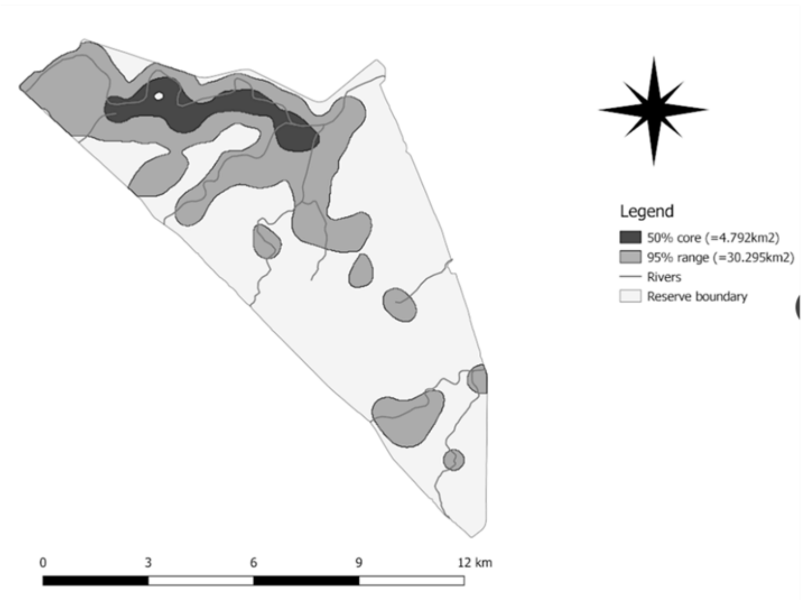


Breeding Herd 2002

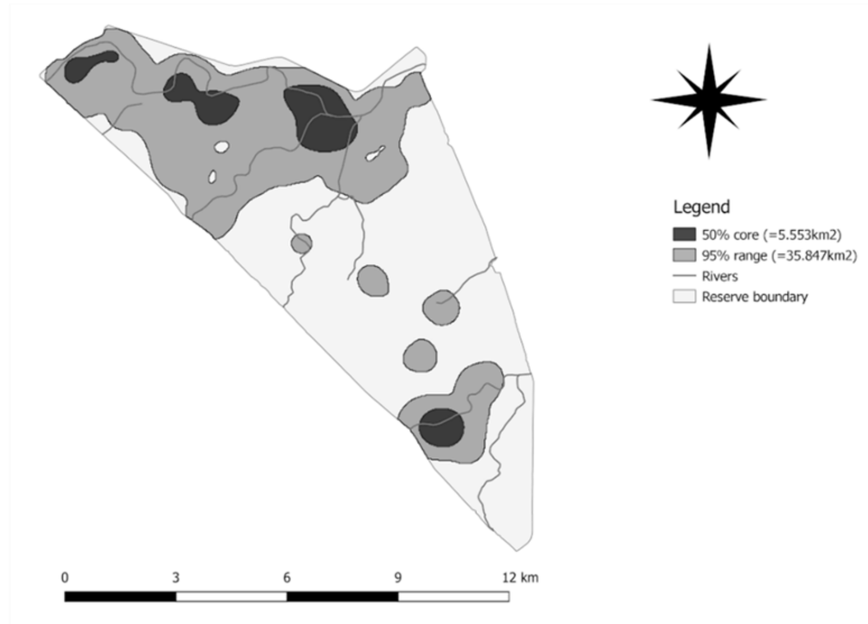
Bulls 2002



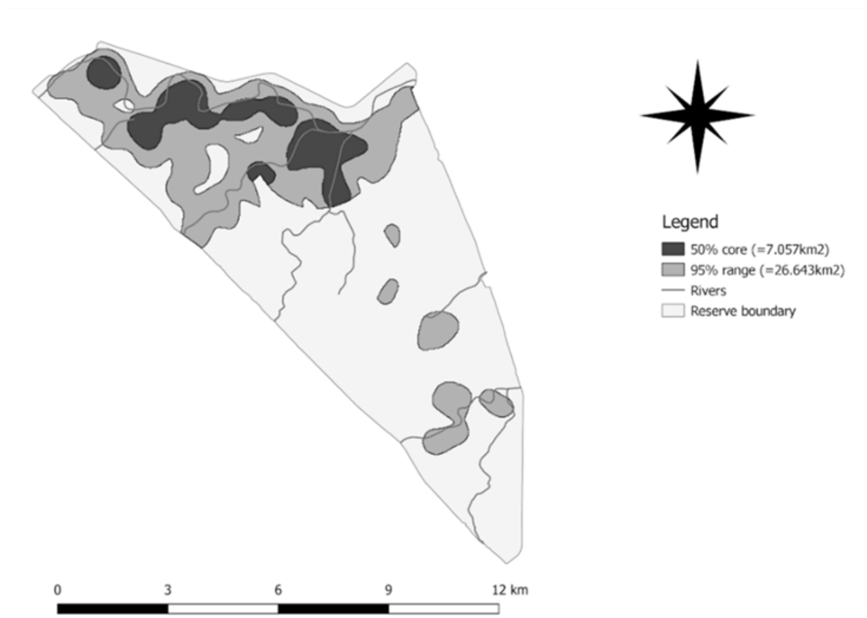
Breeding Herd 2003



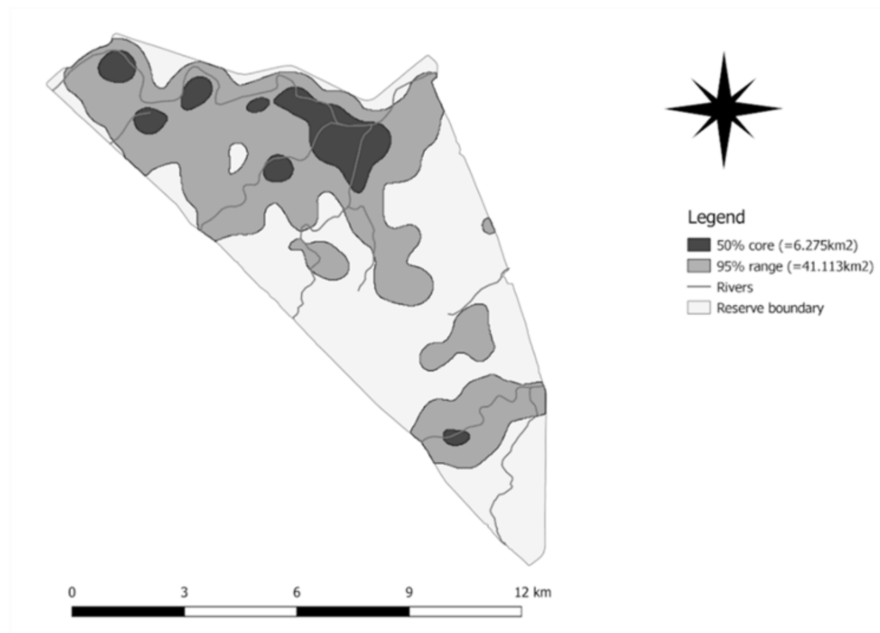
Bulls 2003



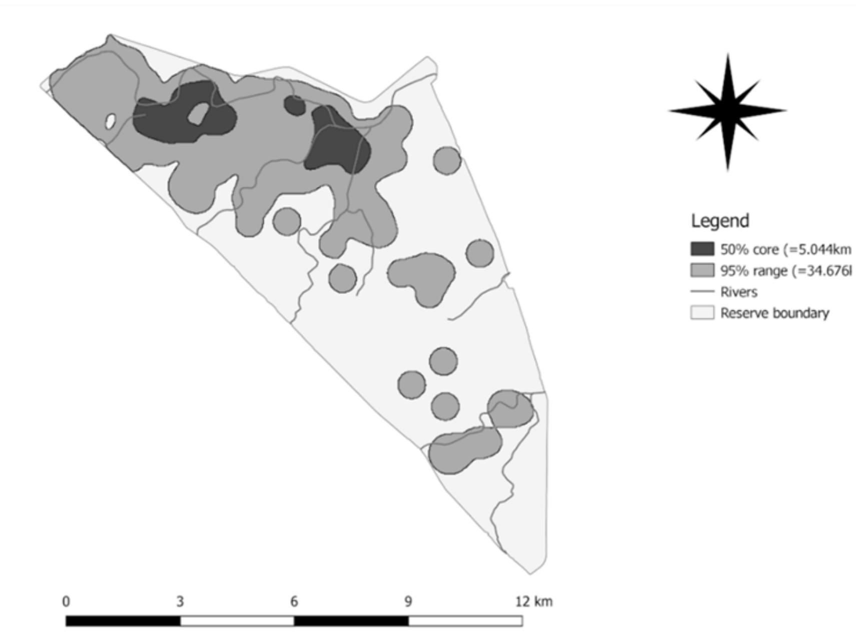
Breeding Herd 2004



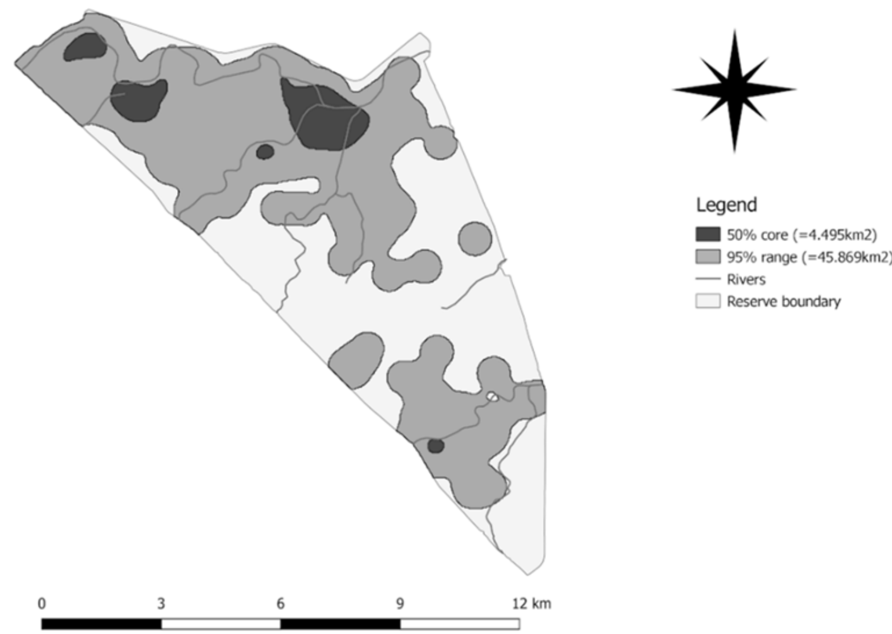
Bulls 2004



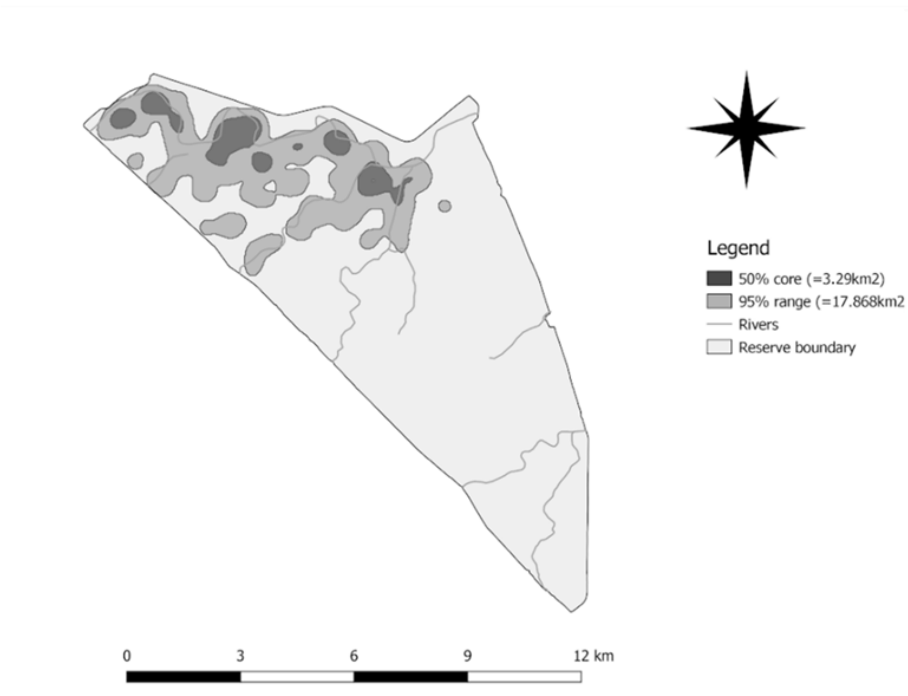
Breeding Herd 2005



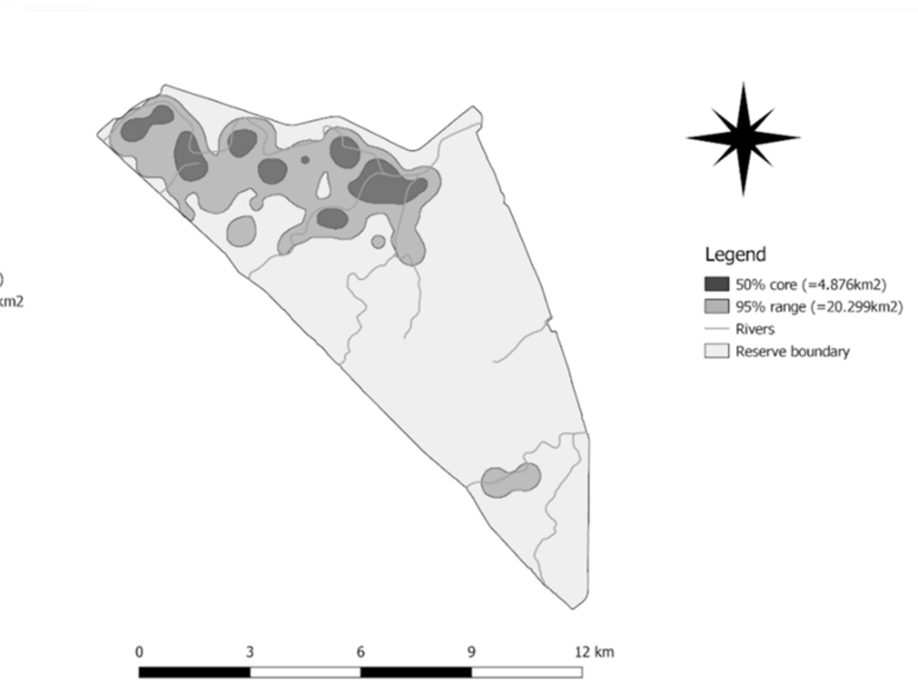
Bulls 2005



Breeding Herd 2006

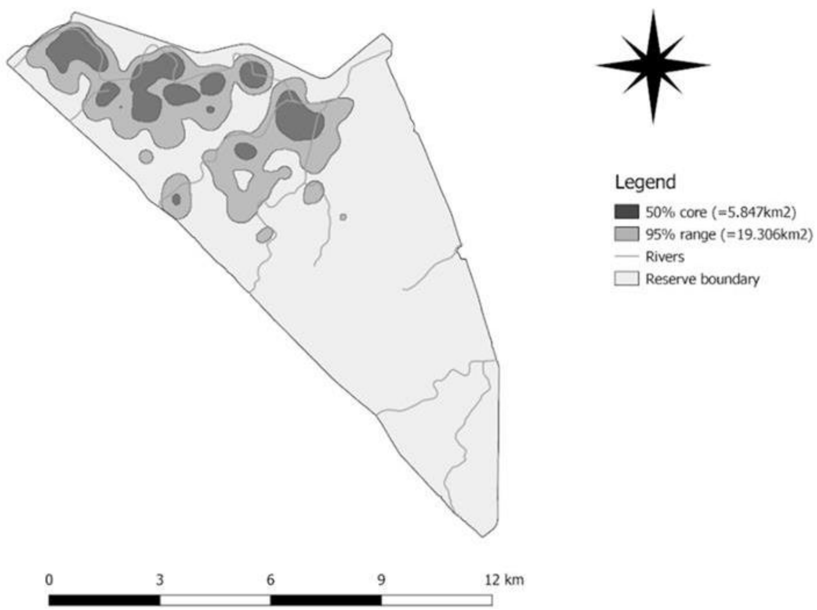


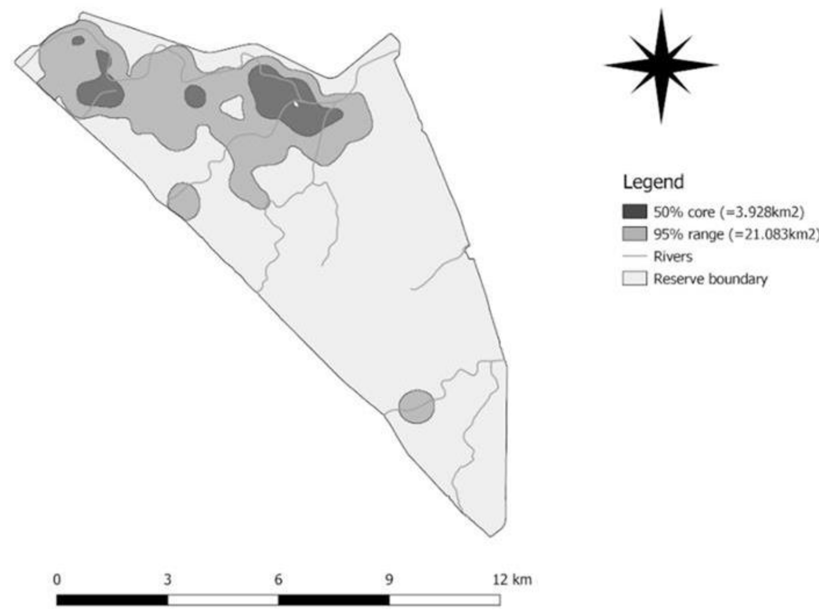
Bulls 2006



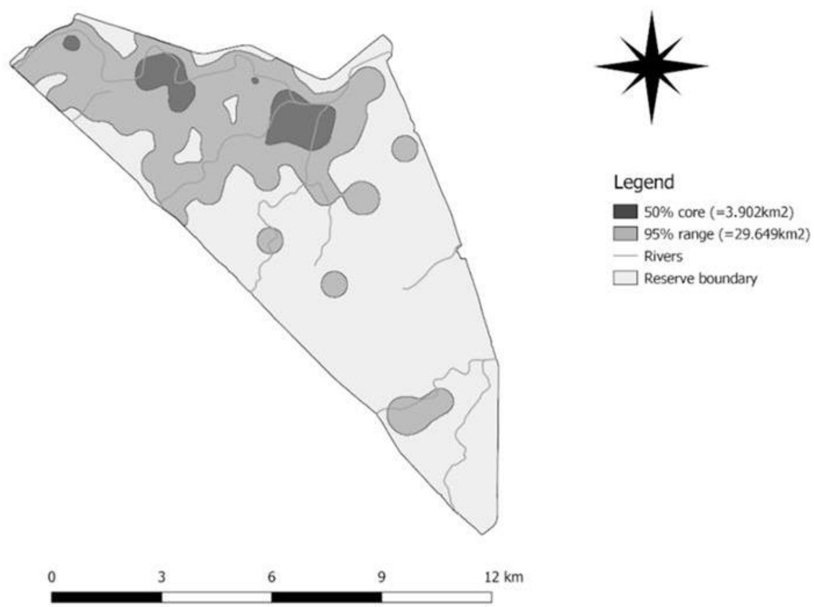
Breeding Herd 2007

Bulls 2007

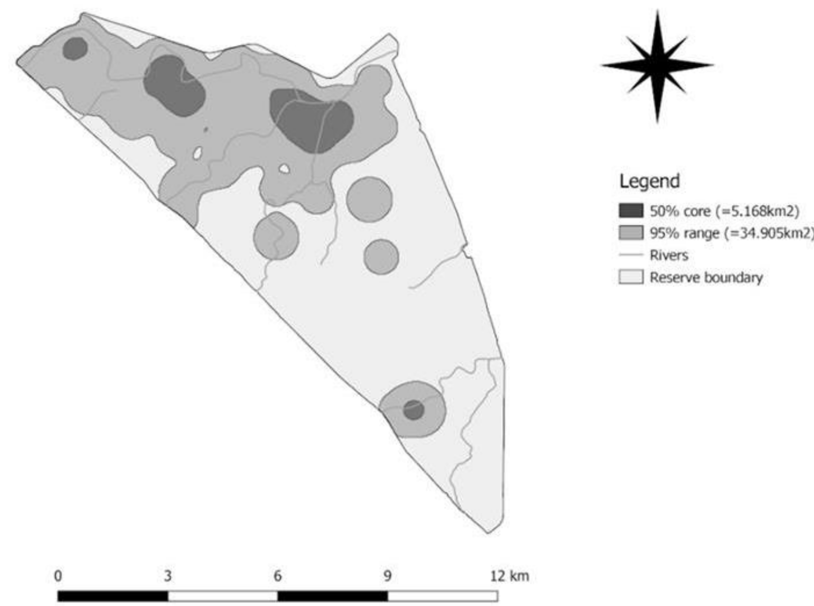




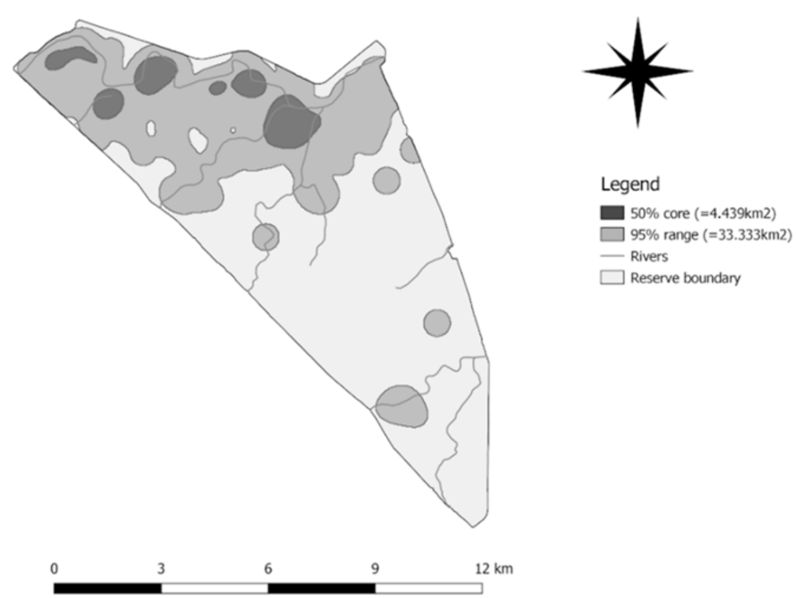
Breeding Herd 2008



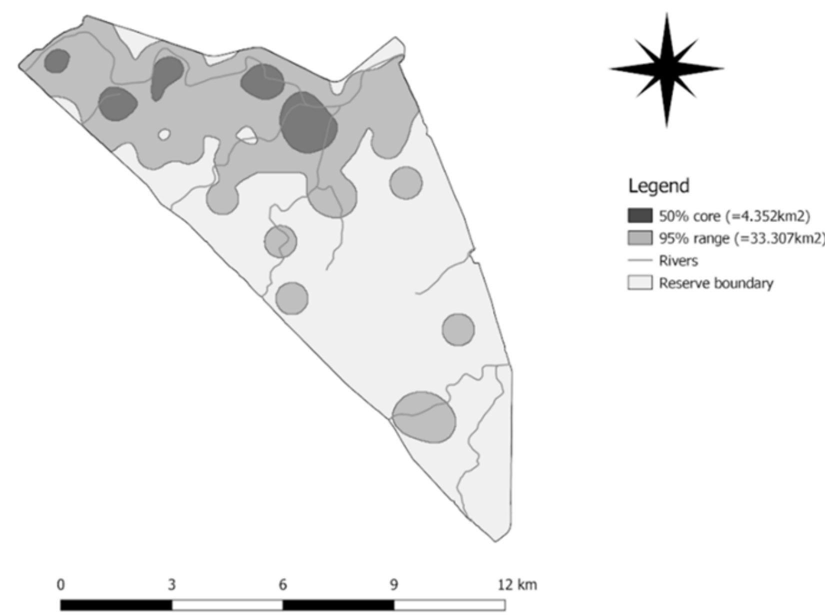
Bulls 2008



Breeding Herd 2009



Bulls 2009



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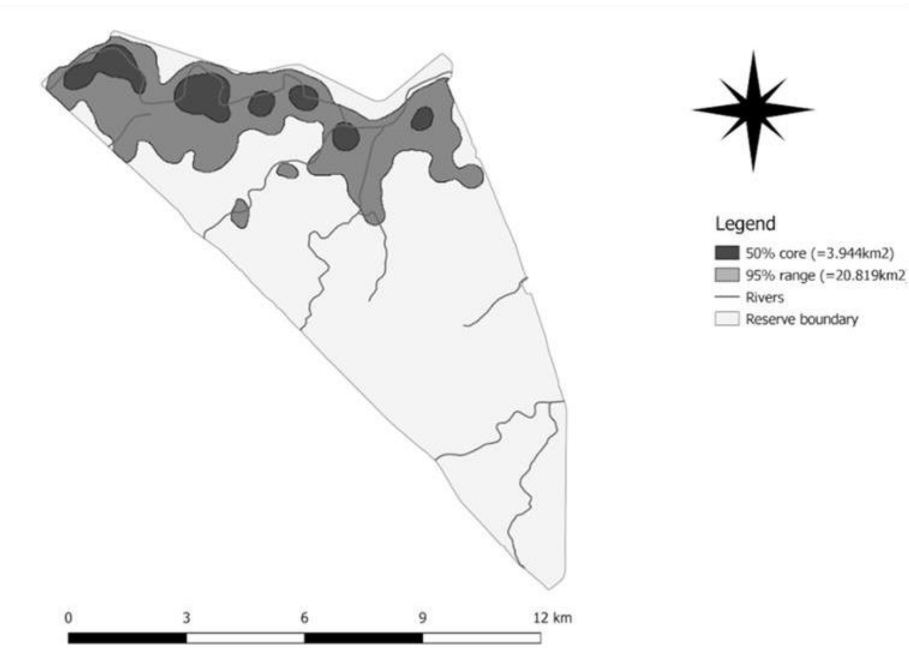
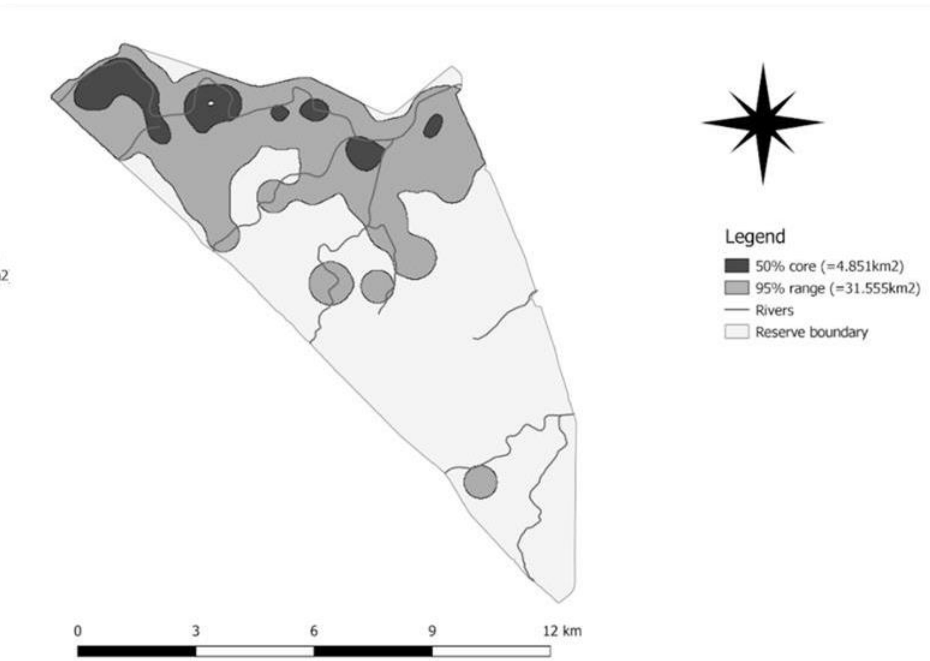
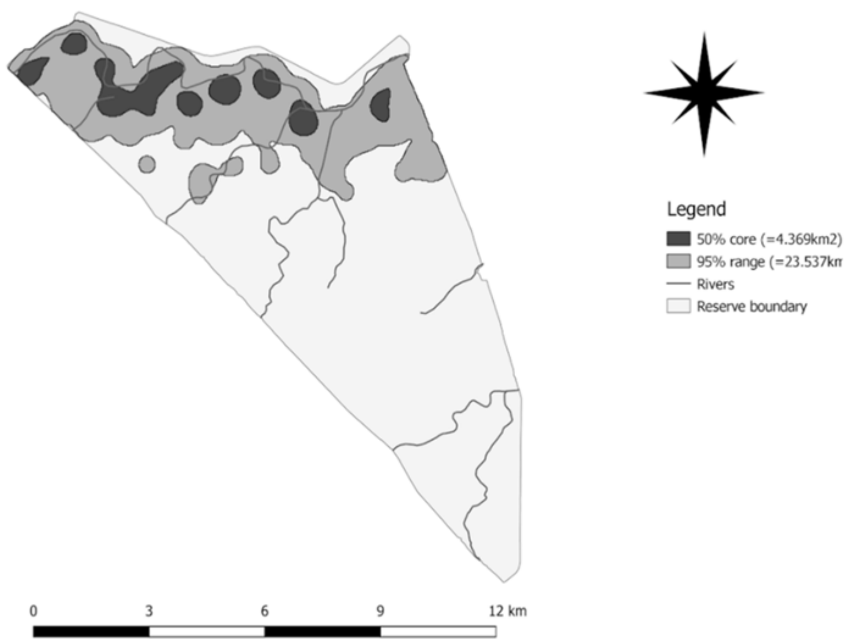


Bulls 2010



Breeding Herd 2011



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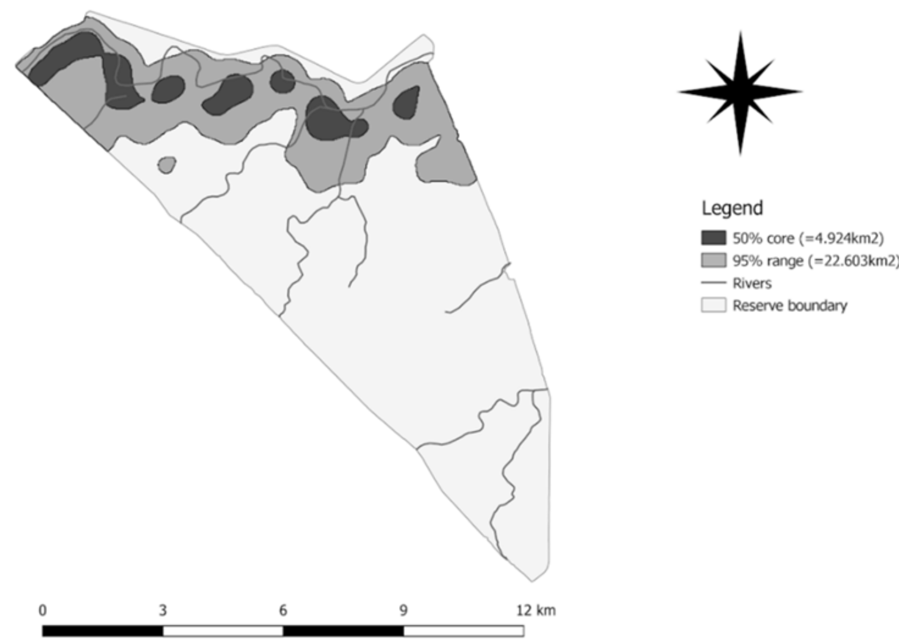
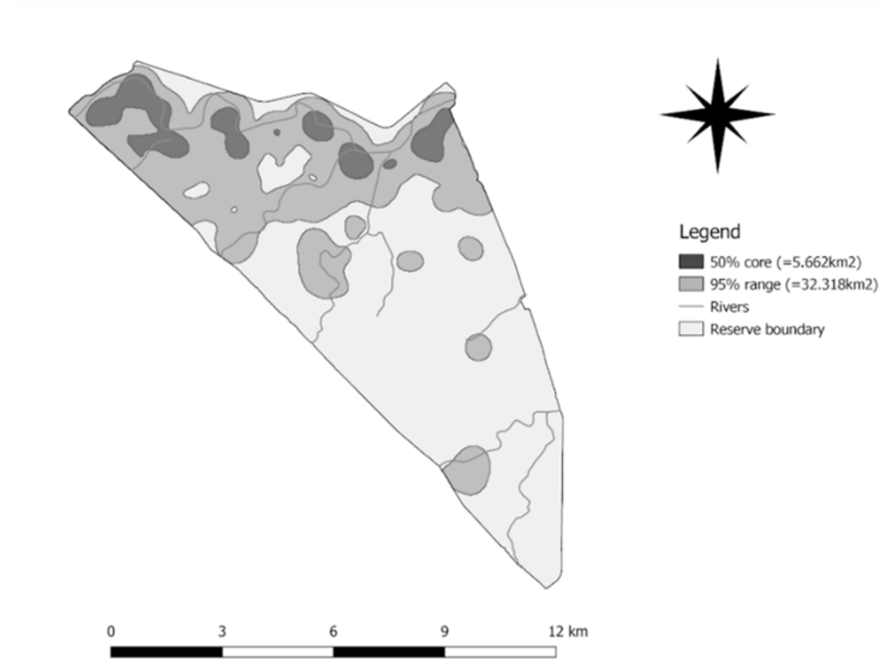


Breeding Herd 2012

Bulls 2012



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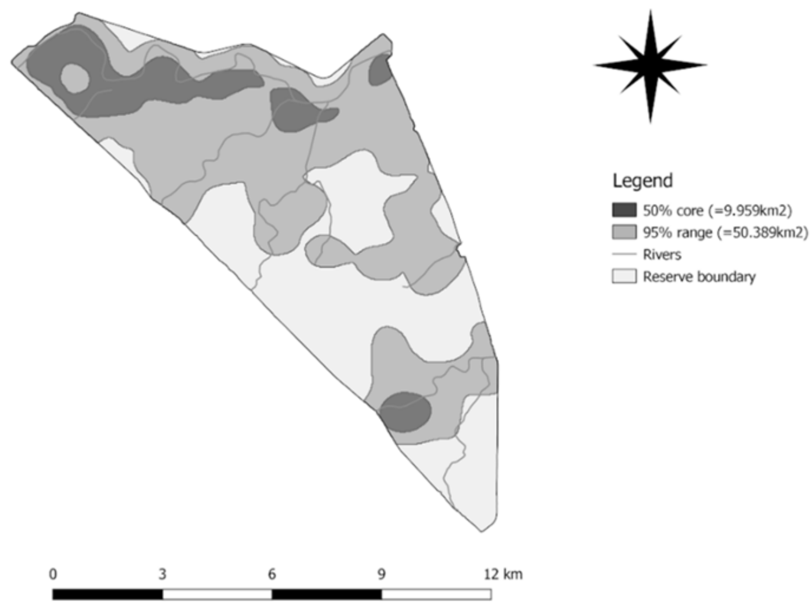

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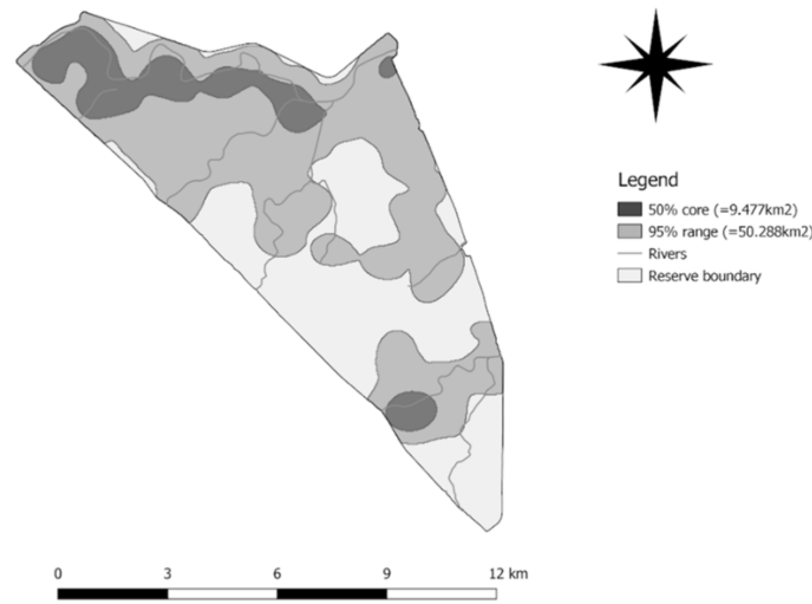

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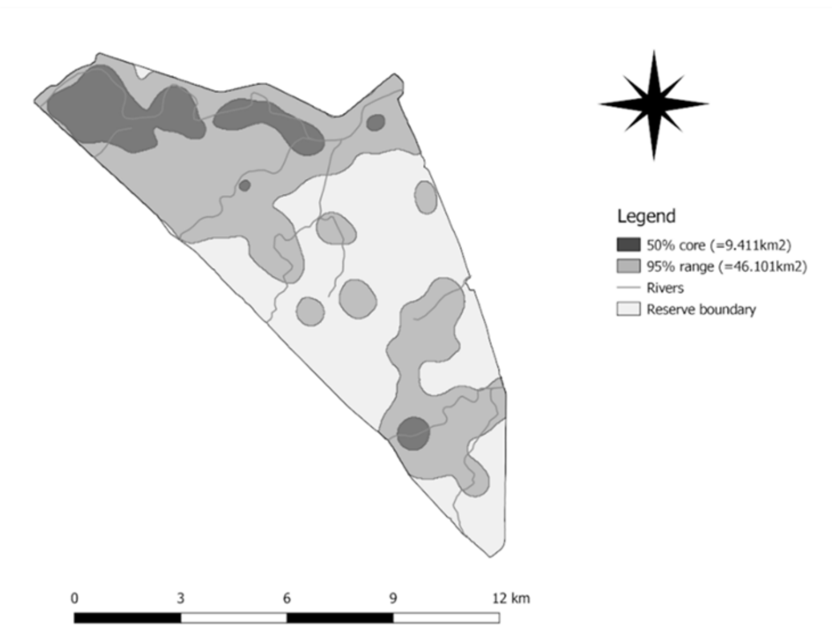

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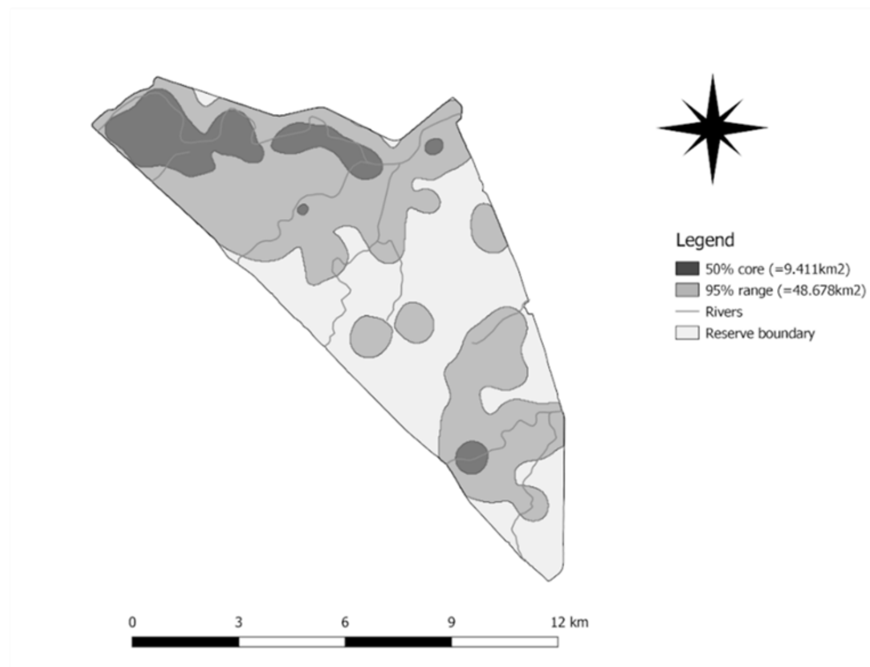

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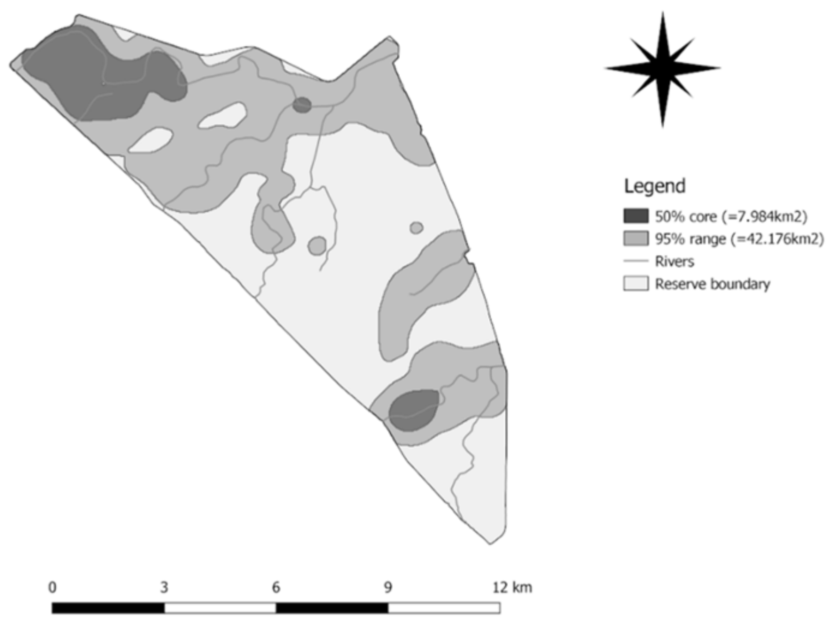

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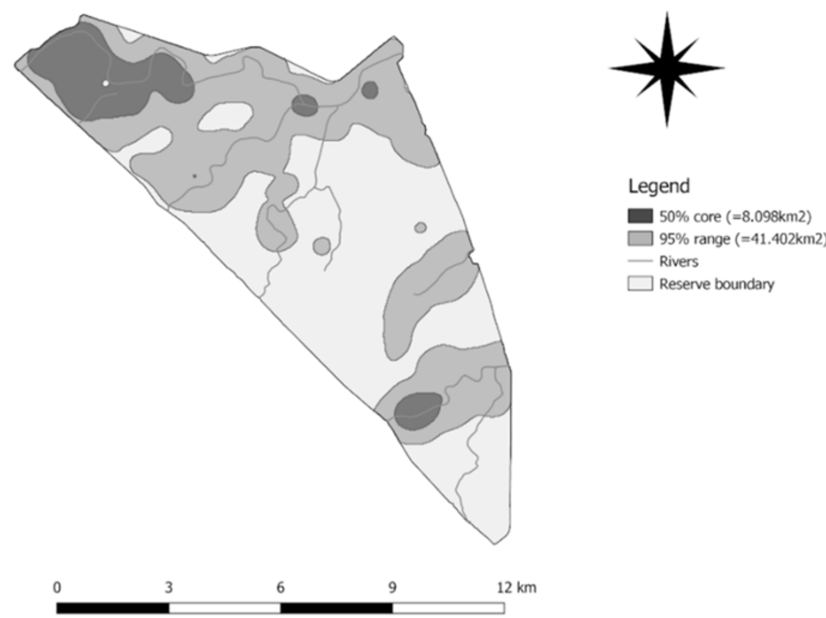
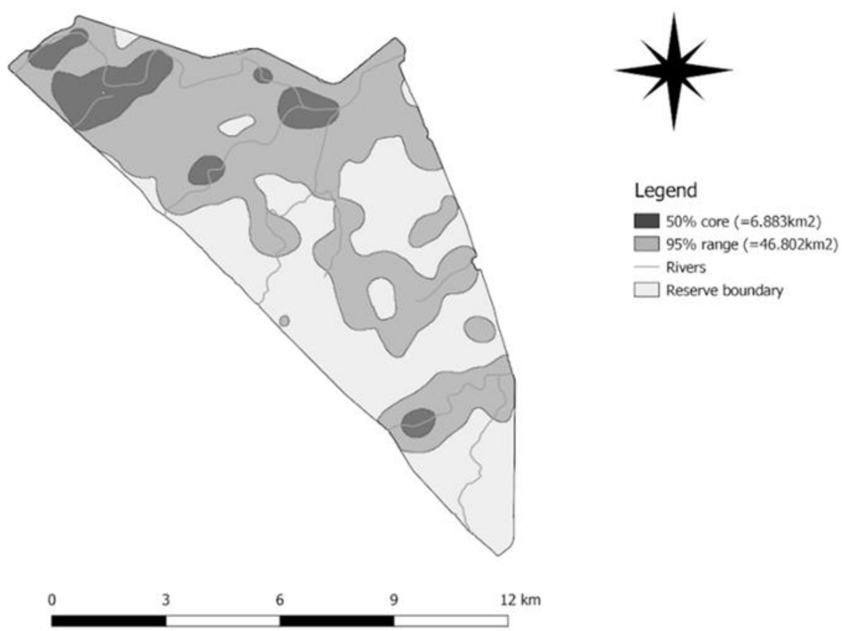


Breeding Herd 2016



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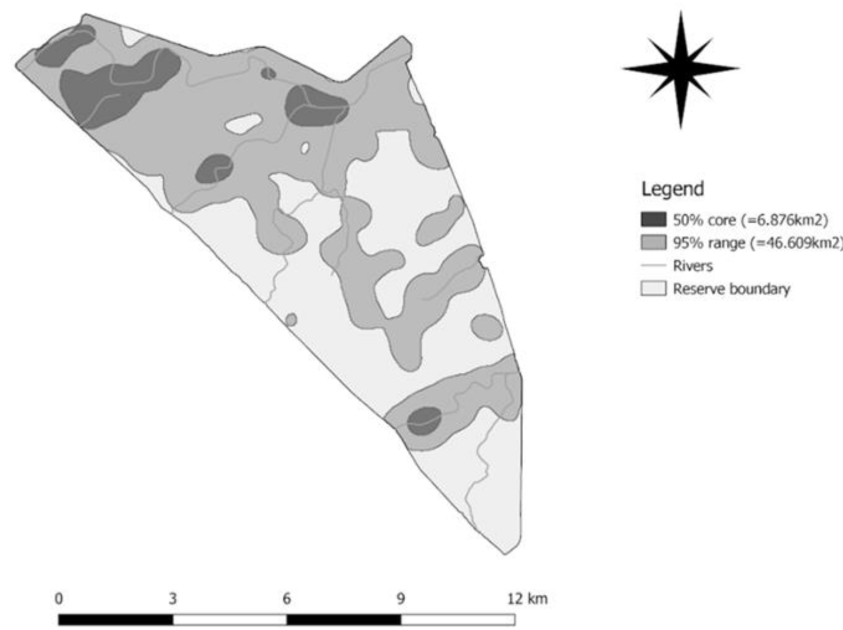

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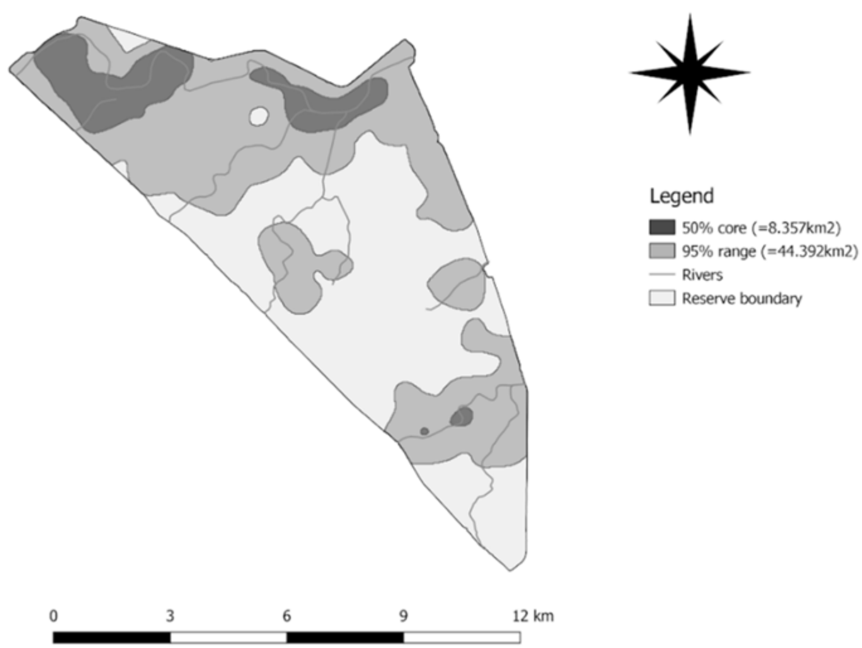

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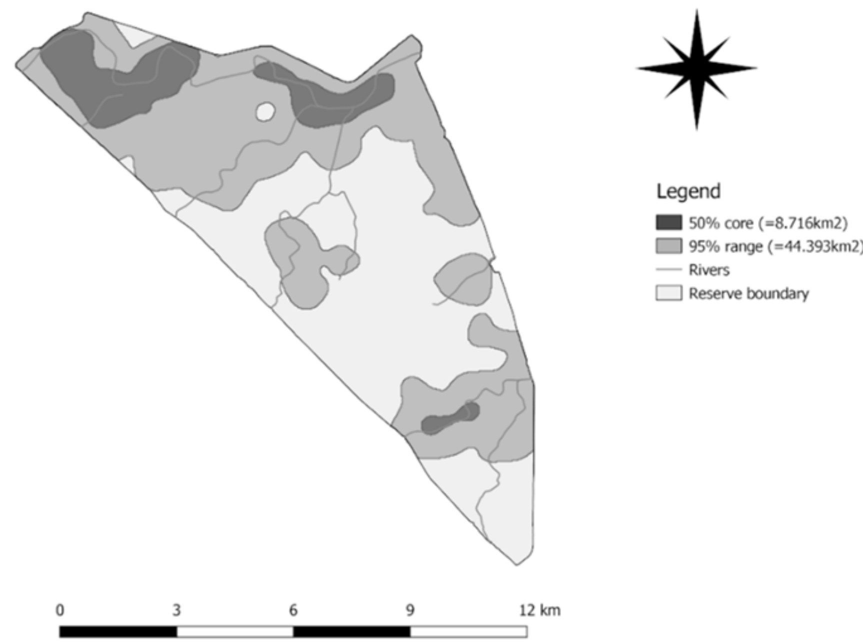
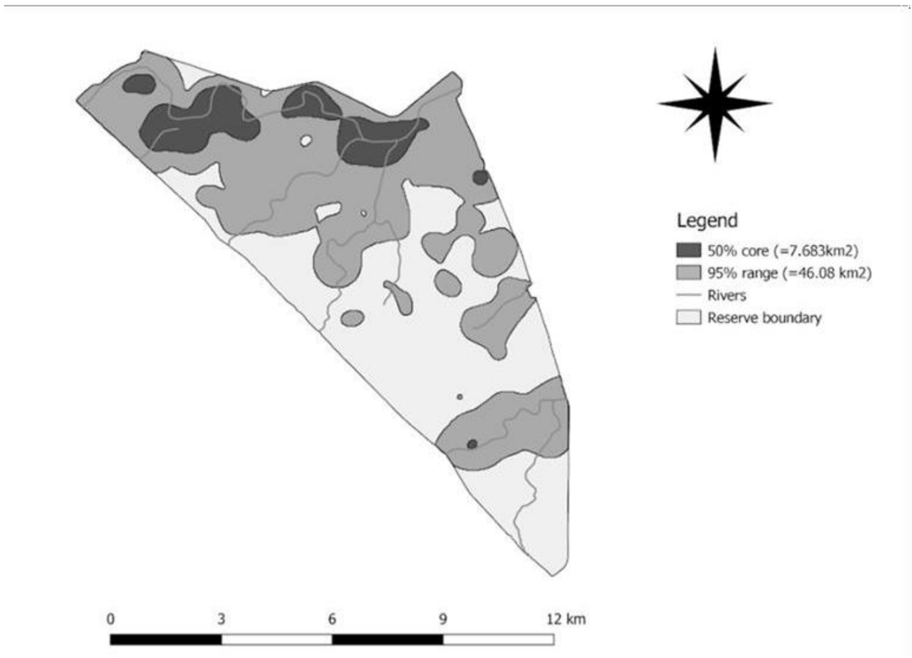
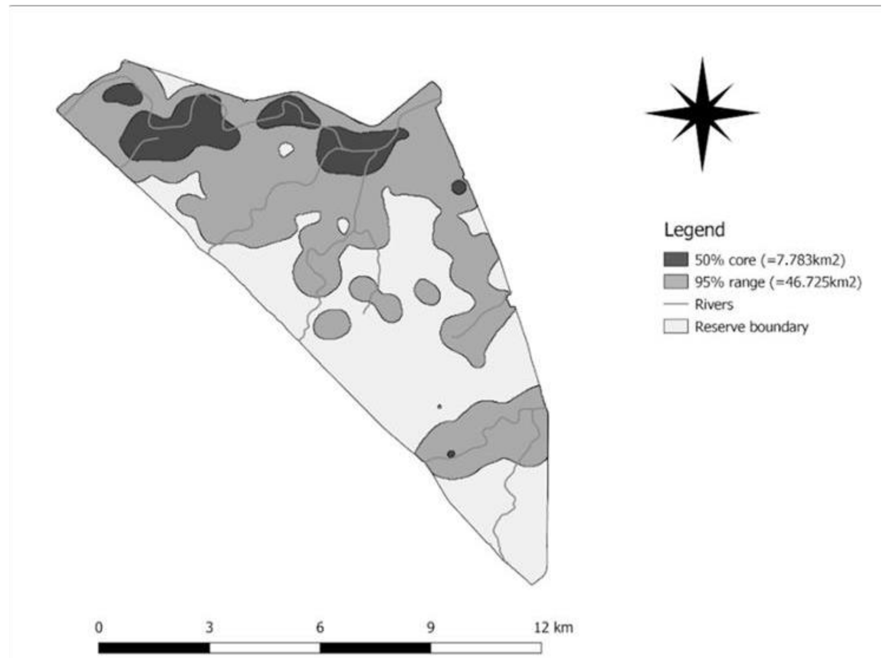


Breeding Herd 2018



Bulls 2018



Appendix 4.

Table A.4.1: Raw data collected in 2018 for Chapter 2. PO = Pushed Over; BB = Branches Broken; MSB = Main Stem Broken; D =Debarking; C = Coppicing; S = Sprouting; R = Regrowth; FL = Fence Line

Species	Height (m)	Alive	PO	BB	MSB	D	C	S	R	FL
Combretumapiculatum	5	1	1	1	0	0	1	1	0	1
Combretumapiculatum	6.5	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	0	1	0	0	0	0	0	1
Combretumapiculatum	8	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6.5	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	1	1	0	0	0	0	0	1
Combretumapiculatum	7	1	1	1	0	0	0	0	0	1
Combretumapiculatum	5.5	1	1	1	0	0	0	0	0	1
Combretumapiculatum	7	1	0	1	0	0	0	0	0	1
Commiphoramollis	7	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	6.3	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	1	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Commiphoramollis	8	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7.5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	12	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.7	1	0	0	0	1	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7.8	1	0	1	0	0	0	0	0	0

Commiphoramollis	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	10	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	1	0	0	0	0
Sclerocaryabirrea	12	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	8.5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	13	1	0	0	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	0
Sengalianigrescens	6	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	1	0	0	0	0	0
Sengalianigrescens	5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	0	0	0	0	0	0	0
Sengalianigrescens	6	1	1	1	0	0	0	0	0	0
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Commiphoramollis	6.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0

Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	11	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	0	1	0	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Combretumapiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	7	0	1	1	0	0	1	0	0	1
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	0	1	0	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	8	1	0	0	0	0	0	0	0	0
Combretumapiculatum	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	8	1	0	0	0	0	0	0	0	0
Combretumapiculatum	6	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	0	0	0	0	0	0	1
Combretumapiculatum	9	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Commiphoramollis	6	0	1	0	0	0	0	0	0	1
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0

Combretumapiculatum	5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	0	0	1	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	6.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	0
Combretumapiculatum	8	1	0	0	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Combretumapiculatum	7.5	0	1	0	0	0	0	0	0	1
Combretumapiculatum	5	0	1	0	0	0	0	0	0	1
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.5	1	0	0	0	0	0	0	0	0
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	1	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	0	0	0	0	0	0	0

Combretumapiculatum	7	0	1	0	0	0	0	0	0	0
Sclerocaryabirrea	9.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6.5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Combretumapiculatum	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	1	0	0	1
Sengalianigrescens	5.5	1	0	1	0	0	0	0	0	1
Combretumapiculatum	7	1	0	1	0	1	0	0	0	0
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.5	1	0	0	0	0	0	0	0	0
Combretumapiculatum	6.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	0	0	0	0	0	0	0
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	0	0	0	0	0	0	0
Combretumapiculatum	5.5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	0	1	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	7	1	0	0	0	0	0	0	0	0
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	0

Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	6	1	1	1	0	0	0	0	0	0
Sengalianigrescens	6	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	6	0	1	0	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	0	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Combretumimberbe	7	1	0	0	0	0	0	0	0	0
Sengalianigrescens	7	0	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0

Sengalianigrescens	12	1	0	1	0	0	0	0	0	0
Sengalianigrescens	12	1	0	1	0	0	0	0	0	0
Combretumimberbe	5	1	0	1	0	0	1	0	0	0
Sengalianigrescens	8	0	0	1	0	0	0	0	0	0
Combretumimberbe	12	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	1	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	5	1	1	1	0	0	1	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	1	0	0	0	0	0	0	1
Sengalianigrescens	8	1	1	1	0	0	1	0	0	1
Sclerocaryabirrea	9	1	0	0	0	1	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	0	0	1	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	12	1	0	1	0	1	0	0	0	1
Combretumapiculatum	6	0	1	0	0	0	0	0	0	1

Combretumimberbe	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	5	0	1	0	0	1	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	0	0	0	0	0	0	0	0	1
Combretumimberbe	8	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Combretumimberbe	10	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	0	1	0	0	0	0	1	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Combretumapiculatum	5.5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6.5	1	0	1	0	0	0	0	0	1
Commiphoramollis	6	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Combretumapiculatum	8	0	1	0	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	0	1	1	0	0	0	0	0	0
Sengalianigrescens	14	1	0	1	0	1	0	0	0	1

Sengalianigrescens	16	1	0	1	0	0	0	0	0	1
Sengalianigrescens	15	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	0	0	0	1
Sengalianigrescens	12	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	1	0	0	0	1
Sengalianigrescens	11	0	1	0	0	1	1	0	0	1
Sengalianigrescens	12	1	0	1	0	1	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	14	1	0	1	0	1	0	0	0	1
Sengalianigrescens	16	1	0	1	0	0	0	0	0	1
Sengalianigrescens	15	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	0	0	0	1
Sengalianigrescens	12	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	1	0	0	0	1
Sengalianigrescens	11	0	1	0	0	1	1	0	0	1
Sengalianigrescens	12	1	0	1	0	1	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1

Sclerocaryabirrea	5.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	5.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	1	1	0	0	0	1	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5.5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Combretumapiculatum	5	0	1	1	0	0	0	0	0	0
Combretumapiculatum	5.5	1	1	1	0	0	1	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	6	0	1	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	7	1	1	1	0	0	1	0	0	0

Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0
Combretumimberbe	7.5	1	0	0	0	0	0	0	0	0
Combretumimberbe	6.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	12	1	0	1	0	1	1	0	1	1
Sclerocaryabirrea	12	1	0	1	0	1	1	0	1	1
Combretumapiculatum	6.5	1	1	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.5	1	0	0	1	0	1	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	0
Combretumapiculatum	6	0	1	1	0	0	0	0	0	0
Combretumapiculatum	7	1	1	0	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Combretumapiculatum	5.5	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	0	1	1	1	0	0	0
Sclerocaryabirrea	6	0	1	0	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	5.5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	5	1	0	1	0	0	0	0	0	0
Sengalianigrescens	8	0	1	1	0	0	0	0	0	0

Commiphoramollis	5.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	12	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	18	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Combretumapiculatum	8	1	0	1	0	0	0	0	0	1
Combretumapiculatum	7	1	1	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	11	0	1	1	0	0	0	0	0	1
Sengalianigrescens	9	0	0	1	0	1	0	0	0	1
Sengalianigrescens	10	1	0	1	0	1	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	12	1	0	1	0	0	0	0	0	1
Sengalianigrescens	9	0	1	1	0	1	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	1	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	1	0	0	1
Sclerocaryabirrea	9	1	0	1	0	1	1	0	0	1
Combretumapiculatum	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	1	0	0	0	1

Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	1	0	0	1
Sclerocaryabirrea	9	1	0	1	0	1	1	0	0	1
Combretumapiculatum	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	1	0	0	1
Sclerocaryabirrea	5	1	0	1	1	0	1	0	0	1
Sclerocaryabirrea	11	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Combretumapiculatum	8	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	7	0	0	1	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	1	1	0	0	0	0	1
Sclerocaryabirrea	6	1	1	1	1	0	0	0	0	1
Sclerocaryabirrea	10	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	11	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	9.5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8.5	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	10	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1
Combretumimberbe	10	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8.5	1	0	1	0	1	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1
Combretumimberbe	10	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8.5	1	0	1	0	1	0	0	0	1
Sengalianigrescens	7	0	1	0	0	0	0	0	0	1

Combretumimberbe	14	1	0	0	0	0	0	0	0	1
Combretumimberbe	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	6	1	0	1	1	0	1	0	0	1
Combretumimberbe	15	1	0	1	0	0	0	0	0	1
Combretumimberbe	16	1	0	1	0	0	0	0	0	1
Combretumimberbe	14	1	0	0	0	0	0	0	0	1
Combretumimberbe	12	1	0	0	0	0	0	0	0	1
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Commiphoramollis	8	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	1	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Combretumapiculatum	7	1	0	1	0	0	0	0	0	0
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Commiphoramollis	7	1	0	0	0	0	0	0	0	0
Commiphoramollis	7	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	5	1	0	1	0	0	0	0	0	0

Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	0
Combretumimberbe	9	1	1	1	0	1	0	0	0	0
Commiphoramollis	7	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	1	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	12	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	0
Commiphoramollis	5	1	0	1	0	0	0	0	0	0
Combretumapiculatum	6	1	0	1	0	0	0	0	0	0
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	10	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6	0	1	0	0	0	0	0	0	1
Combretumimberbe	7	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	11	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	1	1	0	0	0	0	0	1
Combretumimberbe	7	1	0	1	1	0	0	1	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	1	0	1	0	0	0	1
Sclerocaryabirrea	9	1	0	1	0	0	0	0	0	1

Sengalianigrescens	6	0	1	0	0	0	0	0	0	1
Sengalianigrescens	8	0	1	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	1	0	0	0	1
Combretumimberbe	8	0	1	0	0	0	0	1	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	1	0	0	0	1
Sengalianigrescens	6	0	0	1	0	1	0	0	0	1
Sengalianigrescens	6	1	0	1	0	0	1	0	0	1
Sengalianigrescens	8	0	0	1	0	1	0	0	0	1
Combretumapiculatum	7	1	1	1	0	0	0	0	0	1
Sengalianigrescens	8	0	1	0	0	0	0	0	0	1
Sengalianigrescens	10	0	1	1	0	1	0	0	0	1
Combretumapiculatum	6	1	0	0	0	0	0	0	0	1
Combretumapiculatum	5	1	1	0	0	0	0	1	0	1
Sengalianigrescens	6	1	0	1	0	0	1	0	0	1
Sengalianigrescens	8	0	0	1	0	1	0	0	0	1
Combretumapiculatum	7	1	1	1	0	0	0	0	0	1
Sengalianigrescens	6	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	1	0	0	0	1
Combretumimberbe	6	1	0	1	0	0	1	0	0	1
Sengalianigrescens	6	1	0	0	0	1	0	0	0	1
Sengalianigrescens	8	1	1	1	0	1	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	12	1	0	1	0	1	0	0	0	1
Combretumimberbe	14	1	0	1	0	0	0	0	0	1
Sengalianigrescens	13	1	0	1	0	1	0	0	0	1
Sengalianigrescens	9	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	1	0	0	0	0	0	0

Sengalianigrescens	10	1	0	1	0	0	0	0	0	0
Sengalianigrescens	10	1	0	0	0	1	0	0	0	0
Combretumimberbe	7	0	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	1	0	0	0	0	0	0
Combretumimberbe	7	0	1	1	0	0	0	0	0	0
Sengalianigrescens	10	0	0	1	0	1	0	0	0	0
Sengalianigrescens	8	1	0	1	0	1	0	0	0	0
Sengalianigrescens	8	1	0	1	0	0	0	0	0	0
Sengalianigrescens	7	1	0	0	0	0	0	0	0	0
Combretumapiculatum	5	0	1	0	0	0	0	0	0	0
Combretumimberbe	6	0	0	1	1	0	0	0	0	1
Combretumapiculatum	6	1	0	1	0	0	0	0	0	1
Combretumimberbe	7	1	0	1	0	0	1	0	0	1
Combretumimberbe	8	1	0	1	0	0	0	0	0	1
Combretumimberbe	8.5	1	0	1	0	0	1	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	0	1	0	0	1
Sengalianigrescens	9	0	1	0	0	0	0	0	0	1
Combretumapiculatum	6	1	1	0	0	0	1	1	0	1
Combretumapiculatum	7	1	1	0	0	0	0	0	0	1
Combretumapiculatum	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	0	1	0	0	0	0	0	0	1
Combretumapiculatum	5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	0	0	1	0	0	1	1
Sengalianigrescens	9	1	0	0	0	1	0	0	0	1
Sengalianigrescens	9	1	0	0	0	1	0	0	1	1
Sengalianigrescens	8	0	1	0	0	0	0	0	0	1
Combretumapiculatum	9	1	0	0	0	0	1	0	0	1

Combretumapiculatum	6	1	0	0	0	0	0	0	0	1
Combretumapiculatum	8	1	0	0	0	0	0	1	0	1
Combretumapiculatum	7	1	1	0	0	0	1	1	0	1
Sengalianigrescens	10	1	0	0	0	1	0	0	1	1
Sengalianigrescens	8	0	1	0	0	1	0	0	0	1
Sengalianigrescens	7	1	0	0	0	1	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	1	0	0	1	1
Sengalianigrescens	13	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	11	1	0	1	0	0	0	0	0	1
Combretumimberbe	16	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	9	1	0	0	0	1	0	0	1	1
Sengalianigrescens	9	1	0	0	0	1	0	0	0	1
Sengalianigrescens	9	1	0	0	0	1	0	0	1	1
Sengalianigrescens	8	0	1	0	0	0	0	0	0	1
Combretumapiculatum	9	1	0	0	0	0	1	0	0	1
Combretumapiculatum	6	1	0	0	0	0	0	0	0	1
Combretumapiculatum	8	1	0	0	0	0	0	1	0	1
Combretumapiculatum	7	1	1	0	0	0	1	1	0	1
Sengalianigrescens	10	1	0	0	0	1	0	0	1	1
Sengalianigrescens	8	0	1	0	0	1	0	0	0	1
Sengalianigrescens	7	1	0	0	0	1	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	1	0	0	1	1
Sengalianigrescens	13	1	0	0	0	0	0	0	0	1

Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	11	1	0	1	0	0	0	0	0	1
Combretumimberbe	16	1	0	0	0	0	0	0	0	1
Combretumimberbe	10	1	1	0	0	0	1	0	1	1
Combretumimberbe	10	1	0	0	0	0	0	0	0	1
Combretumimberbe	12	1	1	0	0	0	1	0	0	1
Combretumimberbe	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	12	1	0	0	0	0	0	0	0	1
Combretumimberbe	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	5	1	0	1	0	0	0	0	0	1
Sengalianigrescens	5.5	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Combretumimberbe	9	1	0	1	0	0	0	0	0	1
Sengalianigrescens	6.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	6	0	1	0	0	0	1	0	0	1
Combretumapiculatum	6	1	1	1	0	0	1	0	0	1
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9.5	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Combretumimberbe	6.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1

Sclerocaryabirrea	9	1	0	0	0	1	0	0	1	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Combretumapiculatum	10	1	1	0	0	0	1	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	1	0	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9.5	1	0	0	0	1	0	0	1	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	1	0	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	9.5	1	0	0	0	1	0	0	1	1
Sengalianigrescens	6	1	1	0	0	0	1	1	0	0
Combretumapiculatum	8	0	1	1	0	0	1	0	0	0
Sengalianigrescens	12	1	0	1	0	0	0	0	0	0
Combretumimberbe	11	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7.5	1	0	0	0	0	0	0	0	0

Sengalianigrescens	6.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	7.5	1	0	0	0	0	0	0	0	0
Sengalianigrescens	8	0	1	0	0	0	0	0	0	0
Commiphoramollis	5	0	1	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	5	1	0	0	0	0	0	0	0	0
Commiphoramollis	6	1	0	0	0	0	0	0	0	0
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	0
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	1	0	0	0	1
Combretumapiculatum	5.5	1	1	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	0	0	0	0	1
Combretumapiculatum	6	1	1	1	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Commiphoramollis	5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8.5	1	0	0	0	0	0	0	0	1
Combretumapiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	6	1	0	0	0	0	0	0	0	1
Commiphoramollis	5.5	1	0	0	0	0	0	0	0	1
Combretumapiculatum	6	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	5.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	6.5	1	0	0	0	0	0	0	0	1
Combretumimberbe	9	1	0	0	0	0	0	0	0	1

Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Combretumimberbe	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7.5	1	0	0	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	1	0	1	0	0	1	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	1	0	0	0	0	0	0	0	1
Sengalianigrescens	10	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	10	1	0	1	0	1	0	0	1	1
Sclerocaryabirrea	10	1	0	0	0	0	0	0	0	1
Combretumapiculatum	7	1	0	0	0	0	0	0	0	1
Sengalianigrescens	11	0	1	1	0	1	0	0	1	1
Sclerocaryabirrea	13	1	0	1	0	0	0	0	0	1
Sclerocaryabirrea	12	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	12	1	0	0	0	0	0	0	0	1
Combretumapiculatum	9	1	1	0	0	0	1	0	0	1
Sclerocaryabirrea	10	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	13	0	1	1	0	0	0	0	0	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sclerocaryabirrea	14	1	0	0	0	1	0	0	1	1
Sengalianigrescens	11	1	0	0	0	1	0	0	1	1
Sengalianigrescens	9	1	0	0	0	0	0	0	0	1
Sengalianigrescens	7	1	0	1	0	0	0	0	0	1
Sengalianigrescens	8	1	0	0	0	0	0	0	0	1

Sengalianigrescens	8	1	0	0	0	0	0	0	0	1

Table A.4.2: Raw data collected in 2019 for Chapter 3. PO = Pushed Over; BB = Branches Broken; MSB = Main Stem Broken; D =Debarking; C = Coppicing; S = Sprouting; R = Regrowth; IP = Insect Presence

Species	Height (m)	A	PO	BB	MSB	D	C	S	R	IP
Acacia nigrescens	9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.6	1	0	1	0	0	0	0	0	0
Combretum imberbe	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	12	1	0	0	0	0	0	0	0	1
Acacia nigrescens	12	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8	1	0	0	0	0	0	0	0	1
Combretum imberbe	5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8.8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.1	1	0	0	0	0	0	0	0	0

Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	8	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7	1	0	1	0	0	1	0	0	0
Commiphora mollis	**6**	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.8	1	0	3	0	0	1	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	5	0	0	1	1
Commiphora mollis	7	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	7	1	0	0	0	0	0	0	0	0
Commiphora mollis	**7**	1	0	0	0	0	0	0	0	0
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	2	0	0	1	0	0	0
Sclerocarya birrea	8	1	0	0	0	0	0	0	0	1

Combretum apiculatum	6.8	1	0	2	0	5	1	0	1	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	10	1	0	1	0	0	1	0	0	0
Combretum apiculatum	9.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	10	1	0	3	0	0	1	0	0	0
Commiphora mollis	7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	0
Acacia nigrescens	10	1	0	3	0	5	1	0	0	0
Commiphora mollis	7.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	1	0	0	1	0	0	1
Acacia nigrescens	10	1	0	2	0	0	1	0	0	1
Acacia nigrescens	12	1	0	3	0	0	1	0	0	1
Acacia nigrescens	11.3	1	0	2	0	0	1	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.8	1	0	1	0	0	1	0	0	1
Acacia nigrescens	6.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.4	1	0	2	0	0	1	0	0	1
Acacia nigrescens	7.9	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.2	1	0	0	0	25	0	0	1	0
Combretum apiculatum	5.4	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.1	1	0	1	0	0	0	0	0	0
Acacia nigrescens	9	1	0	5	0	0	1	0	0	1
Acacia nigrescens	10.9	1	0	3	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	1	0	0	1	0	0	1
Combretum apiculatum	9.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1

Sclerocarya birrea	4.5	1	0	4	0	0	1	0	0	1
Sclerocarya birrea	5.5	1	1	0	1	0	1	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.1	1	0	1	0	0	1	0	0	1
Sclerocarya birrea	7.7	1	0	4	1	0	1	0	0	1
Combretum apiculatum	4	1	0	2	1	0	1	0	0	1
Sclerocarya birrea	11.2	1	0	1	0	0	1	0	0	1
Sclerocarya birrea	9	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	9	1	0	6	0	0	1	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	1	2	0	0	1	1	0	1
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.72	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.72	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.16	1	0	1	0	0	1	0	0	1
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	1
Commiphora mollis	7.04	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.72	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.36	1	0	1	0	0	0	0	0	1
Commiphora mollis	7.92	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.04	1	0	1	0	0	0	0	0	0
Commiphora mollis	7.92	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.92	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	3.96	1	0	6	0	0	1	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	1

Commiphora mollis	6.16	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6.16	1	0	0	0	0	0	0	0	0
Commiphora mollis	7.04	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.28	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	8.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.4	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.2	1	0	0	0	0	0	0	0	0
Commiphora mollis	6.3	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	8	1	0	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.8	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.1	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.8	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	1	0	0	0	0	0	0	1
Sclerocarya birrea	4	1	0	3	0	0	1	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	0

Commiphora mollis	4	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	1	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.3	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.1	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.4	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.2	1	1	0	0	0	0	0	0	1
Sclerocarya birrea	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.4	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.4	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.4	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	1

Combretum apiculatum	6	1	0	1	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4	1	1	0	0	0	0	0	0	1
Combretum apiculatum	4.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	1	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.8	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	9	1	0	1	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.5	1	0	0	0	0	0	0	1	0
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	4.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	4.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1

Acacia nigrescens	10	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.5	1	0	0	0	0	0	0	0	0
Combretum imberbe	5.6	1	0	0	0	0	0	0	0	1
Combretum imberbe	7.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Combretum imberbe	7	1	0	0	0	0	0	0	0	1
Combretum imberbe	7	1	0	0	0	0	0	0	0	1
Combretum imberbe	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8	1	0	0	0	0	0	0	0	1
Combretum imberbe	6.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	9.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.6	1	0	1	0	0	0	0	0	1
Combretum apiculatum	4.9	1	0	0	0	0	0	0	0	1
Commiphora mollis	**4.5**	1	0	0	0	0	0	0	0	0

Commiphora mollis	**5.5**	1	0	0	0	0	0	0	0	0
Commiphora mollis	**4.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4	1	0	0	0	0	0	0	0	0
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	0
Commiphora mollis	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5	1	0	1	0	0	1	0	0	1
Combretum apiculatum	5.5	1	0	1	0	0	0	0	0	1
Combretum apiculatum	7.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	**4.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.5	1	0	2	0	5	0	0	0	1
Combretum apiculatum	2.9	0	0	1	0	60	0	0	0	1
Combretum apiculatum	5.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6	1	1	0	0	30	0	1	0	1

Combretum apiculatum	4.9	1	0	0	0	5	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.8	1	0	1	0	5	0	0	0	1
Combretum apiculatum	5	1	1	0	0	20	0	0	0	1
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	1	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	0	1	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	1	0	1
Commiphora mollis	4.7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.4	0	1	0	0	0	0	1	0	0
Sclerocarya birrea	5.4	1	0	3	0	0	0	0	0	0
Combretum apiculatum	8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.1	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	0
Commiphora mollis	4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.5	1	1	0	0	0	1	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.7	1	0	1	0	0	0	0	0	1
Commiphora mollis	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	2	0	0	0	0	0	0
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.7	1	0	3	0	0	0	0	0	1

Combretum apiculatum	4.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.6	1	1	2	0	0	0	0	0	0
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.4	1	0	1	0	0	0	0	0	1
Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6.3	1	0	4	0	0	1	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8.3	1	1	1	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	0
Combretum apiculatum	3.9	1	0	1	0	0	1	0	0	1
Acacia nigrescens	9.6	1	0	0	0	0	0	0	0	1
Commiphora mollis	8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	1
Combretum imberbe	7.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.8	1	0	0	0	0	0	0	0	0
Acacia nigrescens	9.2	1	0	1	0	0	0	0	0	0
Combretum imberbe	7.2	1	0	0	0	0	0	0	0	0
Acacia nigrescens	11.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6	1	0	1	0	0	0	0	0	1
Acacia nigrescens	5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6	1	0	3	0	0	1	0	0	0

Commiphora mollis	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.1	1	0	2	0	0	0	0	0	1
Combretum apiculatum	4.8	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.3	1	0	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	4	0	0	1	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.3	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	3	0	0	1	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	1	0	0	0	0	0	1
Acacia nigrescens	8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	1	0	0	1
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	0
commiphora mollis	5.5	1	0	1	0	0	0	0	0	1
Acacia nigrescens	10	1	0	3	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	10.6	1	0	1	0	0	0	0	0	1
Combretum apiculatum	8	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.5	1	0	2	0	0	0	0	0	1
Commiphora mollis	4.3	1	0	1	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	2	0	0	0	0	0	0
Acacia nigrescens	9	1	0	2	0	0	0	0	0	1

Combretum apiculatum	6.1	1	0	1	0	0	0	0	0	0
Commiphora mollis	6.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8	1	0	2	0	0	0	0	0	1
Commiphora mollis	4.8	1	1	1	0	0	0	0	0	0
Combretum apiculatum	5.1	1	1	2	0	0	1	1	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	11	1	0	2	0	0	0	0	0	0
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	1	0	0	1	0	0	0
Combretum apiculatum	7.5	1	1	3	0	0	1	1	0	1
Combretum apiculatum	4.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.5	1	0	1	0	0	1	0	0	0
Sclerocarya birrea	9.4	1	0	3	0	0	1	0	0	1
Sclerocarya birrea	5.4	1	0	1	0	0	1	0	0	0
Sclerocarya birrea	6	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	1	0	0	1	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	2	0	0	1	0	0	0
Combretum apiculatum	5.9	1	0	1	0	0	1	0	0	1
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	8	1	0	0	0	0	0	0	0	0

Combretum apiculatum	6	1	1	2	0	0	1	1	0	1
Sclerocarya birrea	9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.5	1	1	2	0	0	1	1	0	1
Combretum apiculatum	6.2	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	8	1	0	5	0	0	1	0	0	0
Commiphora mollis	4.7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.9	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.8	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.3	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	12	1	0	0	0	0	0	0	0	0
Combretum apiculatum	8	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.8	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5.4	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5.3	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5.4	1	0	0	0	0	0	0	0	0
Acacia nigrescens	9	1	0	0	0	5	0	0	0	1
Sclerocarya birrea	12	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	10	1	1	1	0	0	0	1	0	1

Commiphora mollis	8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	10	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.6	1	0	0	0	0	0	1	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.4	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	10	1	0	0	0	0	0	0	0	1
Acacia nigrescens	10	1	0	0	0	20	0	0	0	1
Sclerocarya birrea	9	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	13	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	10	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.9	1	0	1	0	0	0	0	0	0
Combretum apiculatum	9	1	0	0	0	0	0	0	0	0
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	1	0	0	0	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0

Commiphora mollis	5.5	1	0	3	0	0	0	0	0	1
Commiphora mollis	5.8	1	0	1	0	0	0	0	0	0
Combretum apiculatum	5.2	1	0	5	0	0	1	0	0	1
Sclerocarya birrea	5	1	1	3	0	0	0	0	0	1
Sclerocarya birrea	6	1	0	2	0	0	0	0	0	0
Commiphora mollis	5.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	10	0	0	4	0	0	0	0	0	1
Sclerocarya birrea	5	1	0	1	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.1	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	1	0	0	0	0	0	0
Commiphora mollis	4.5	1	1	0	0	0	0	0	0	0
Acacia nigrescens	9	1	0	2	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	6	0	0	1	0	0	1
Acacia nigrescens	7	1	0	2	0	0	0	0	0	0
Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	1
Combretum imberbe	7.6	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	3	0	0	1	0	0	0
Sclerocarya birrea	6.5	1	0	2	0	0	0	0	0	0
Combretum imberbe	7.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	0	0	0	0	0	0	0
Combretum imberbe	8.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	1	0	0	0	0	0	0
Combretum imberbe	6.5	1	0	1	0	0	0	0	0	0
Commiphora mollis	4.5	1	1	1	0	0	0	1	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1

Acacia nigrescens	6.7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	2	0	0	0	0	0	1
Commiphora mollis	5.1	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	4.5	1	0	1	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	6.2	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5	1	0	1	0	0	0	0	0	0
Sclerocarya birrea	5.1	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	4.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	4.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.3	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.8	0	1	1	0	0	0	1	0	1
Sclerocarya birrea	7.5	1	0	2	0	0	0	0	0	0
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	7	1	0	0	0	0.2	0	0	1	1
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	12	1	0	0	0	0	0	0	0	1
Commiphora mollis	5.6	1	0	0	0	0	0	0	0	0

Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	0
Acacia nigrescens	10.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8	1	0	1	0	0	1	0	0	0
Combretum apiculatum	7.2	1	0	1	0	0	0	0	0	1
Commiphora mollis	6.9	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	7	1	0	3	0	0	1	0	0	0
Sclerocarya birrea	4	1	0	5	0	0	1	0	0	0
Combretum apiculatum	5.2	1	1	0	0	0	0	0	0	1
Combretum apiculatum	5	1	0	1	0	0	1	0	0	1
Combretum apiculatum	7.5	1	0	2	0	0	1	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	4	0	0	1	0	0	0
Commiphora mollis	4	1	1	1	0	0	1	1	0	1
Commiphora mollis	5.1	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.1	1	0	1	0	0	0	0	0	1
Commiphora mollis	4.9	1	0	0	0	10	0	0	0	1
Commiphora mollis	4.8	1	1	0	0	0	0	0	0	0
Sclerocarya birrea	8	1	0	1	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	15	0	0	1	0
Commiphora mollis	6.2	1	0	0	0	30	0	0	1	0
Commiphora mollis	5.8	1	0	1	0	0	1	0	0	0
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1

Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	10	1	0	1	0	0	0	0	0	1
Acacia nigrescens	7	1	0	1	0	0	0	0	0	0
Acacia nigrescens	4.2	1	0	0	0	0	0	0	0	1
Combretum imberbe	8.8	1	0	4	0	0	1	0	0	1
Acacia nigrescens	8.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	4	0	0	0	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	1	0	0	1	0	0	0
Acacia nigrescens	4.6	1	0	4	0	0	1	0	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.8	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	7.3	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.5	1	0	0	0	0	0	0	0	0
Commiphora mollis	8.4	1	0	0	0	0	0	0	0	0
Commiphora mollis	4	1	0	0	0	0	0	0	0	1
Commiphora mollis	4	1	1	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	6	0	0	0	0	0	1
Combretum imberbe	8	1	0	1	0	0	0	0	0	1
Commiphora mollis	4	1	1	2	0	0	1	1	0	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.5	1	1	0	0	0	0	0	0	0
Commiphora mollis	4.8	1	1	0	0	0	0	0	0	0
Acacia nigrescens	8	1	0	1	0	0	0	0	0	0
Commiphora mollis	4.5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	0	0	0	0	0	0	0
Commiphora mollis	5.3	1	1	0	0	0	0	0	0	0

Acacia nigrescens	8	1	0	1	0	0	0	0	0	1
Acacia nigrescens	5	1	0	2	0	0	0	0	0	1
Commiphora mollis	4.4	1	1	0	0	0	0	0	0	0
Acacia nigrescens	7	1	0	3	0	0	0	0	0	0
Commiphora mollis	5.7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6.5	1	0	0	0	0	0	0	0	0
Acacia nigrescens	4.6	0	1	0	0	0	0	0	0	1
Combretum imberbe	8	1	0	1	0	0	1	0	0	0
Acacia nigrescens	5.4	1	0	1	0	0	0	0	0	1
Commiphora mollis	4.4	1	0	0	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.16	1	0	2	0	0	0	0	0	1
Commiphora mollis	4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.5	1	1	1	0	0	0	0	0	1
Sclerocarya birrea	5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	7	1	0	2	0	0	1	0	0	0
Combretum apiculatum	6.5	1	1	0	0	0	0	0	0	1
Commiphora mollis	5	1	0	1	0	0	0	0	0	0
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	5	0	0	1	0	0	1
Combretum apiculatum	5.28	1	1	2	0	0	0	0	0	0
Commiphora mollis	6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.28	1	0	0	0	0	0	0	0	0
Commiphora mollis	5	1	1	0	0	0	0	0	0	0
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	5	1	0	4	0	0	1	0	0	0
Sclerocarya birrea	4.84	1	0	2	0	0	0	0	0	1
Combretum apiculatum	7.04	1	0	3	0	0	0	0	0	1
Sclerocarya birrea	3.96	1	0	3	0	0	1	0	0	0

Combretum apiculatum	6.16	1	0	2	0	0	0	0	0	0
Combretum apiculatum	5.28	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.84	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	4.84	1	0	6	0	0	1	0	0	1
Sclerocarya birrea	6	1	0	3	0	0	0	0	0	1
Sclerocarya birrea	7.04	1	0	3	0	0.05	0	0	1	1
Commiphora mollis	5	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	2	0	0	0	0	0	0
Sclerocarya birrea	7.48	1	0	1	0	0	0	0	0	1
Commiphora mollis	5.28	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.84	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	4	0	0	1	0	0	0
Combretum apiculatum	8	1	0	0	0	0	0	0	0	0
Commiphora mollis	6.16	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.28	1	1	0	0	0	0	0	0	0
Combretum apiculatum	5.28	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	0
Commiphora mollis	4.3	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.9	1	0	2	0	0	0	0	0	1
Commiphora mollis	5.1	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6	1	0	5	0	0	1	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	1
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Commiphora mollis	**6**	1	0	0	0	0	0	0	0	0

Sclerocarya birrea	**9**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	6.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	4.7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**5.5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.9	1	0	2	0	0	0	0	0	1
Combretum apiculatum	**7.5**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.8	1	0	2	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	1	0	0	0	0	0	0
Combretum imberbe	6.8	1	0	2	0	0	1	0	0	1
Combretum apiculatum	4.8	1	1	1	0	0	1	1	0	1
Combretum apiculatum	6.5	1	1	3	0	0	1	0	0	1
Commiphora mollis	**5**	1	1	1	0	0	0	0	0	1
Combretum apiculatum	**5**	1	1	0	0	0	1	0	0	1
Combretum apiculatum	6.3	1	1	2	0	0	1	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.3	1	0	2	0	0	0	0	0	0
Combretum apiculatum	7.3	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	**6**	1	0	3	0	0	1	0	0	0
Combretum apiculatum	6.4	1	0	2	0	0	1	0	0	1
Combretum apiculatum	8.1	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	4	0	0	0	0	0	1

Combretum apiculatum	6	1	0	1	0	0	1	0	0	0
Sclerocarya birrea	**7**	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.8	1	0	2	0	0	0	0	0	1
Combretum apiculatum	4.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	**6**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	1
Commiphora mollis	**4**	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**7**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.4	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**5.5**	1	1	3	0	0	0	0	0	1
Sclerocarya birrea	**5**	1	0	2	0	0	1	0	0	1
Combretum apiculatum	**6**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	1	0	0	0	0	0	1
Combretum apiculatum	**6.5**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	7.7	1	0	2	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.3	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.1	1	1	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	2	0	0	1	0	0	1
Commiphora mollis	**5**	1	1	1	1	0	1	0	0	0
Acacia nigrescens	**7**	1	0	1	0	0	1	0	0	0
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	5.2	1	0	2	0	0	1	0	0	1
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**5.5**	1	0	1	0	0	1	0	0	1
Acacia nigrescens	6.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	4.2	1	0	0	0	0	0	0	0	0

Commiphora mollis	**5**	1	1	0	0	0	0	0	0	0
Combretum apiculatum	**4.5**	0	1	3	0	0	0	0	0	1
Sclerocarya birrea	**9.5**	1	0	4	0	0	1	0	0	1
Sclerocarya birrea	6.8	1	0	1	0	0	1	0	0	1
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**7**	1	1	2	0	0	1	1	0	1
Combretum apiculatum	**6**	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	**7.5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	**7**	1	0	2	0	0	0	0	0	1
Sclerocarya birrea	**4**	1	0	3	0	0	1	0	0	0
Combretum apiculatum	8.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**4.5**	1	0	7	0	0	1	0	0	1
Combretum apiculatum	6.6	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.5	1	1	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	1	1	0	0	1	1	0	0
Sclerocarya birrea	4.7	1	0	1	0	0	1	0	0	0
Commiphora mollis	5.1	1	1	0	0	0	0	0	0	1
Combretum apiculatum	6.9	1	1	3	0	0	1	1	0	1
Combretum imberbe	5.2	1	0	0	0	0	0	0	0	1
Commiphora mollis	6.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**4.5**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**5**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1

Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.5	1	1	0	0	0	0	0	0	1
Sclerocarya birrea	**5**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	9.9	1	0	0	0	0.2	0	0	0	1
Acacia nigrescens	6.1	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	4	0	0	0	0	0	0
Acacia nigrescens	10.1	1	0	2	0	0	1	0	0	0
Sclerocarya birrea	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**7.5**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	8.8	1	0	3	0	0	0	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	1	0	0	1	0	0	1
Acacia nigrescens	7.2	1	0	2	0	0	0	0	0	1

Acacia nigrescens	**8**	1	0	3	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	1	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	7.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.3	1	0	1	0	0	0	0	0	1
Acacia nigrescens	8.7	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	8.6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	4	0	0	1	0	0	1
Combretum apiculatum	4	1	1	0	0	0	1	1	0	0
Combretum apiculatum	5.2	1	0	1	0	0	1	0	0	0
Acacia nigrescens	**10**	1	0	2	0	0	1	0	0	0
Acacia nigrescens	8.8	1	0	2	0	0	1	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**6**	1	0	1	0	0	1	0	0	1
Acacia nigrescens	**9**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	7.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**11**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	**7**	1	0	2	0	0	0	0	0	0

Acacia nigrescens	**8**	1	0	0	0	0	1	0	0	1
Acacia nigrescens	**10**	1	0	2	0	0	1	0	0	0
Combretum apiculatum	5.5	1	0	1	0	0	0	0	0	1
Combretum apiculatum	7.5	1	0	2	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	1	0	0	0	0	0	0
Sclerocarya birrea	**5**	1	0	2	0	0	1	0	0	1
Combretum apiculatum	6.6	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.3	1	0	3	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	3	0	0	1	0	0	1
Combretum apiculatum	6.3	1	0	1	0	0	1	0	0	1
Acacia nigrescens	**8**	1	0	3	0	0	0	0	0	1
Combretum apiculatum	8.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**8**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.8	1	1	1	0	0	0	0	0	1
Combretum apiculatum	8.3	1	0	2	0	0	0	0	0	1
Combretum apiculatum	7.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6.8	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	1	0	0	1
Combretum apiculatum	8.4	1	0	2	0	0	0	0	0	0
Combretum apiculatum	5.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.5	1	1	1	0	0	0	0	0	1
Sclerocarya birrea	**7**	1	0	3	0	0	1	0	0	1
Combretum apiculatum	9.3	1	0	2	0	0	0	0	0	1

Combretum apiculatum	7.4	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	4.8	1	1	3	0	0	0	0	0	1
Combretum imberbe	**9**	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Combretum imberbe	**7**	1	0	0	0	0	0	0	0	0
Combretum imberbe	**4.5**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.1	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.2	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**4.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.1	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.3	1	0	2	0	0	1	0	0	1

Combretum imberbe	**7**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**11**	1	0	0	0	0.7	0	0	1	1
Acacia nigrescens	7.9	1	1	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	2	0	0	1	0	0	0
Acacia nigrescens	**10**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	0
Combretum imberbe	6.8	1	0	2	0	0	1	0	0	1
Sclerocarya birrea	**10**	1	0	3	0	0.2	1	0	1	1
Combretum apiculatum	**7**	1	0	2	1	0	1	0	0	1
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	12	1	0	1	0	0.5	1	0	1	1
Acacia nigrescens	**11**	1	0	2	0	0	0	0	0	1
Acacia nigrescens	7.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.1	1	0	2	0	0	0	0	0	1
Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	10.5	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**13**	1	0	5	0	0.05	1	0	1	1
Combretum apiculatum	6.6	1	1	0	0	0	1	0	0	1
Combretum apiculatum	**9**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**10**	1	0	3	0	0	1	0	0	1
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	8	0	0	1	0	0	1
Combretum apiculatum	6.16	1	0	0	0	0	0	0	0	1
Combretum imberbe	**10**	1	0	1	0	0	0	0	0	1
Combretum imberbe	**10**	1	0	1	0	0	0	0	0	0
Combretum imberbe	10.8	1	0	0	0	0	0	0	0	1

Combretum imberbe	**11**	1	0	1	0	0	0	0	0	0
Combretum apiculatum	**5**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**4**	1	0	7	0	0	1	0	0	1
Sclerocarya birrea	**5**	1	0	2	0	0	1	0	0	0
Sclerocarya birrea	**6**	1	0	2	0	0	0	0	0	0
Combretum apiculatum	**6.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.2	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**8**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**6**	1	0	2	0	0	1	0	0	0
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**7**	1	0	2	0	0	1	0	0	0
Combretum apiculatum	**4**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	5	0	0.4	0	0	0	1
Combretum apiculatum	**5.5**	1	1	1	0	0	1	0	0	1
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	4.4	1	0	3	0	0	1	0	0	1
Commiphora mollis	4.3	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.1	1	0	2	0	0	1	0	0	1
Acacia nigrescens	**11**	1	0	2	0	0	1	0	0	0
Combretum apiculatum	5.3	1	0	1	0	0	0	0	0	1
Combretum apiculatum	**6**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	1	0	0	1	0	0	1
Commiphora mollis	**5**	1	1	0	0	0	0	0	0	0
Commiphora mollis	**4**	1	1	0	0	0	0	0	0	0
Sclerocarya birrea	**6**	1	0	6	0	0	1	0	0	1
Sclerocarya birrea	5.8	1	0	4	0	0	1	0	0	1

Sclerocarya birrea	4.9	1	0	9	0	0	1	0	0	1
Combretum apiculatum	4.5	1	0	0	0	0	0	0	0	1
Commiphora mollis	**4.5**	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	6.5	1	0	5	0	0	1	0	0	1
Sclerocarya birrea	**7**	1	0	3	0	0	1	0	0	1
Commiphora mollis	5.6	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.8	1	0	1	0	0	1	0	0	0
Combretum apiculatum	6.3	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.2	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	**6**	1	0	7	0	0	1	0	0	1
Commiphora mollis	5.8	1	0	2	0	0	1	0	0	0
Combretum apiculatum	6.4	1	0	1	0	0	1	0	0	1
Combretum apiculatum	**6**	1	0	2	0	0	1	0	0	1
Commiphora mollis	**5.5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.4	1	0	2	0	0	0	0	0	1
Acacia nigrescens	**5.5**	1	0	1	0	0	0	0	0	0
Combretum apiculatum	6.6	1	0	1	0	0	1	0	0	0
Acacia nigrescens	7.3	1	1	3	0	0	1	1	0	1
Combretum apiculatum	5	1	0	3	0	0	0	0	0	1
Acacia nigrescens	7.5	1	0	1	0	0	0	0	0	1
Combretum apiculatum	7	1	0	1	0	0	1	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.4	1	0	1	0	0	1	0	0	1
Commiphora mollis	5.72	1	0	0	0	0.25	0	0	0	1
Sclerocarya birrea	**5.5**	1	0	0	0	0	0	0	0	0

Acacia nigrescens	6.16	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**6.5**	1	0	1	0	0	1	0	0	0
Acacia nigrescens	7.04	1	0	1	0	0	0	0	0	0
Acacia nigrescens	6.16	1	0	0	0	0	1	0	0	0
Acacia nigrescens	7.04	1	0	1	0	0	0	0	0	0
Acacia nigrescens	7.92	1	1	5	0	0	0	0	0	0
Acacia nigrescens	7.04	1	0	1	0	0	0	0	0	0
Acacia nigrescens	7.04	1	0	0	0	0	0	0	0	0
Combretum imberbe	6.16	1	0	2	0	0	1	0	0	0
Acacia nigrescens	7.48	1	0	1	0	0	1	0	0	0
Sclerocarya birrea	7.92	1	0	2	1	0	0	0	0	1
Acacia nigrescens	8.8	1	1	3	0	0	0	0	0	1
Combretum apiculatum	8.8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.04	1	0	1	0	0	0	0	0	1
Combretum apiculatum	7.04	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.92	0	1	5	1	0	0	0	0	1
Combretum apiculatum	**5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	5	0	0	0	1
Commiphora mollis	6.5	1	0	0	0	0	0	0	0	0
Commiphora mollis	**4**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	7.4	1	0	1	0	0	1	0	0	0
Sclerocarya birrea	**7**	1	0	1	0	0	0	0	0	0
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	0
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.6	1	1	1	0	0	1	1	0	1
Commiphora mollis	**5**	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	**7**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	7.3	1	0	11	0	0	1	0	0	1
Commiphora mollis	5.1	1	0	0	0	0	0	0	0	0

Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	9.2	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	8.9	1	0	3	0	0	1	0	0	1
Sclerocarya birrea	9.6	1	0	4	0	0	1	0	0	1
Combretum apiculatum	6.9	1	0	2	0	0	1	0	0	1
Combretum apiculatum	6.1	1	0	2	0	0	1	0	0	0
Combretum apiculatum	6.7	1	1	2	0	0	1	0	0	1
Acacia nigrescens	8.2	1	0	0	0	0	0	1	0	1
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.5	1	1	0	0	0	1	0	0	1
Sclerocarya birrea	9.2	1	0	0	0	0	1	0	0	1
Acacia nigrescens	**7**	1	1	0	0	0	1	0	0	1
Acacia nigrescens	**7**	1	0	1	0	0.95	0	0	0	0
Combretum apiculatum	7.6	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**8**	1	1	0	0	0	0	1	0	0
Combretum apiculatum	5.1	1	0	2	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	2	0	0	0	0	0	0
Commiphora mollis	6.3	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**6**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	1	0	0	0	0	0	1
Combretum apiculatum	7	1	0	1	0	0	0	0	0	1
Commiphora mollis	4.8	1	0	1	0	0	0	0	0	1
Combretum apiculatum	4.4	1	0	0	0	0	0	0	0	0

Acacia nigrescens	7.7	1	0	3	0	0	0	0	0	0
Combretum imberbe	**7**	1	0	3	1	0	1	1	0	1
Combretum apiculatum	5.8	1	1	2	0	0	1	0	0	1
Combretum apiculatum	6.7	1	0	1	0	0	1	0	0	1
Acacia nigrescens	8.2	1	0	3	0	0	1	0	0	1
Sclerocarya birrea	**9**	1	0	3	0	50	1	0	1	1
Acacia nigrescens	8	1	0	0	0	25	1	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	9.2	1	0	6	0	0	1	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.2	1	0	1	0	0	1	0	0	1
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.8	1	0	1	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.2	1	0	1	0	0	1	0	0	1
Acacia nigrescens	7.3	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8.1	1	0	1	0	0	1	0	0	1
Combretum apiculatum	6.5	1	0	1	0	0	1	0	0	1
Combretum apiculatum	**6**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	1	0	0	0	0	0	1
Acacia nigrescens	6.9	1	0	1	0	0.1	0	0	0	1
Combretum apiculatum	6.7	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	1	0	0	1	0	0	1
Sclerocarya birrea	8.5	1	0	1	0	0	1	0	0	1
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**12**	1	0	2	0	0.4	1	0	1	1
Combretum apiculatum	5	1	0	1	0	0	1	0	0	1

Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**5**	1	0	1	0	0	1	0	0	1
Acacia nigrescens	**6.5**	1	0	5	0	0	1	0	0	0
Acacia nigrescens	6.9	1	0	5	0	0	1	0	0	1
Combretum apiculatum	6.2	1	0	1	0	0	1	0	0	0
Combretum imberbe	9.6	1	0	4	0	0	1	0	0	1
Acacia nigrescens	**5.5**	1	0	0	0	0	0	0	0	1
Combretum imberbe	6.6	1	0	2	0	0	1	0	0	1
Combretum apiculatum	**6**	1	1	1	0	0	1	1	0	1
Acacia nigrescens	8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.3	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6.9	1	0	1	0	0	0	0	0	1
Acacia nigrescens	7.7	1	0	2	0	0	1	0	0	1
Acacia nigrescens	6.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.4	1	0	1	0	0	0	0	0	0
Acacia nigrescens	7.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	1
Combretum imberbe	**9**	1	0	8	1	0	1	1	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1

Acacia nigrescens	**11**	1	0	0	0	0.4	0	0	1	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.3	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	0
Acacia nigrescens	5.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	4.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	9.1	1	0	1	0	0	0	0	0	0
Acacia nigrescens	6.2	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	4.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7.2	1	0	1	0	0.5	0	0	1	1
Combretum apiculatum	7.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.1	1	0	2	0	0	0	0	0	1
Acacia nigrescens	7.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6	1	1	1	0	0	1	1	0	1
Sclerocarya birrea	**6**	1	0	1	0	0	0	0	0	0
Combretum apiculatum	**10**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7.5**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9.5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	1	0	0	0	0	0	1
Acacia nigrescens	5.6	1	0	0	0	0	0	0	0	0

Acacia nigrescens	**10**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	5.1	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	6.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	6.9	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.3	1	1	1	0	0	1	0	0	1
Acacia nigrescens	**11**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	5.8	1	1	1	0	0	1	0	0	0
Acacia nigrescens	7.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**8**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**12**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	6.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	7.7	1	0	0	0	0	0	0	0	1
Combretum imberbe	4.4	1	0	0	1	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.5	1	0	2	0	0	0	0	0	1

Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.1	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	5.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	9.6	1	0	0	0	0	0	0	0	1
Combretum imberbe	8.2	1	0	0	0	0	0	0	0	1
Acacia nigrescens	8.7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**10**	1	0	0	0	0.1	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.8	0	1	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	0	1	0	0	0	0	1
Sclerocarya birrea	**12**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	2	0	0	0	0	0	1
Combretum apiculatum	7.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.7	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	8.8	1	0	0	0	0	0	0	0	1

Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	1	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**10**	1	0	0	0	0.05	0	0	0	1
Combretum apiculatum	7	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	1	0	0	0	0	0	1
Combretum apiculatum	**8**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**11**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	1	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	1	0	0	0	0	0	1
Sclerocarya birrea	**8**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	4.6	1	1	0	1	0	1	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	0	0	0	1	0	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.3	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8.5**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	8.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1

Acacia nigrescens	10.3	1	0	0	0	0	0	0	0	0
Sclerocarya birrea	4.1	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	5.1	0	1	1	0	0	0	0	0	1
Sclerocarya birrea	**6**	0	1	1	0	0	0	0	0	1
Combretum apiculatum	6.4	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.2	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	1	0	0	0	0	0	0	1
Combretum apiculatum	**7**	1	1	0	0	0	1	0	0	1
Combretum apiculatum	**8**	1	1	0	0	0	1	1	0	1
Combretum apiculatum	6.8	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	8.8	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	6.5	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**5**	1	1	0	0	0	0	0	0	0
Combretum apiculatum	6.7	1	1	0	0	0	0	0	0	1
Combretum apiculatum	**4.5**	0	1	0	0	0	0	0	0	1
Acacia nigrescens	**11**	1	0	0	0	0.4	0	0	1	1
Acacia nigrescens	**6**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**9**	1	0	0	0	0	0	0	0	1
Sclerocarya birrea	**9**	1	0	0	0	0.3	1	0	1	1
Acacia nigrescens	**8**	0	1	2	0	0	0	0	0	1
Acacia nigrescens	**10**	1	0	5	0	0	1	0	0	1
Acacia nigrescens	**10**	1	0	6	0	0.05	1	0	0	1
Acacia nigrescens	**10**	1	0	3	0	0.1	1	0	0	0
Acacia nigrescens	**8**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	7.9	1	0	2	0	0	0	0	0	1
Acacia nigrescens	8.2	1	0	3	0	0	1	0	0	1
Acacia nigrescens	8.8	1	0	2	0	0	0	0	0	1

Acacia nigrescens	6.5	1	1	2	1	0	0	0	0	1
Acacia nigrescens	7	1	0	3	0	0	1	0	0	1
Acacia nigrescens	8.4	1	0	1	0	0.5	0	0	1	1
Acacia nigrescens	**6**	1	0	2	1	0	1	0	0	1
Acacia nigrescens	**9**	1	0	2	0	0	0	0	0	1
Acacia nigrescens	**12**	1	0	4	0	0.4	1	0	0	1
Acacia nigrescens	**12**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	7	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	**7**	1	0	2	0	0	1	0	0	1
Acacia nigrescens	5.9	1	0	3	0	0	1	0	0	1
Acacia nigrescens	7.2	1	0	2	0	0	1	0	0	1
Acacia nigrescens	6.5	1	0	2	0	0	1	0	0	1
Acacia nigrescens	**8**	1	0	3	0	0	1	0	0	1
Acacia nigrescens	**11**	1	0	5	0	0	1	0	0	1
Acacia nigrescens	5.6	1	0	3	0	0	1	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	4	1	0	2	1	0	1	0	0	1
Combretum apiculatum	5.5	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5.6	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	5.4	1	0	1	0	0	0	0	0	1
Acacia nigrescens	6.1	1	0	3	0	0	1	0	0	1
Acacia nigrescens	5.7	1	0	5	0	0	1	0	0	1
Combretum apiculatum	6.3	1	0	0	0	0	0	0	0	1
Acacia nigrescens	7	1	0	0	0	0.05	0	0	1	1
Acacia nigrescens	5.9	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	2	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	2	0	0	0	0	0	1

Acacia nigrescens	**7.5**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	5	0	0	1	0	0	1
Acacia nigrescens	**8**	1	0	3	0	0	0	0	0	1
Acacia nigrescens	6	1	0	2	0	0	1	0	0	1
Combretum apiculatum	5.9	1	0	2	0	0	1	0	0	1
Acacia nigrescens	6.3	1	0	2	0	0	1	0	0	1
Acacia nigrescens	6.4	1	0	2	1	0	0	0	0	1
Combretum apiculatum	6.6	1	0	0	0	0	0	0	0	1
Combretum apiculatum	6.3	1	0	1	0	0	0	0	0	1
Combretum apiculatum	5	1	0	3	0	0	1	0	0	1
Combretum apiculatum	6	1	0	1	0	0	0	0	0	1
Combretum apiculatum	6.9	1	0	5	0	0	1	0	0	1
Acacia nigrescens	4.7	1	0	4	0	0	1	0	0	1
Sclerocarya birrea	**9**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**6**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	4.8	1	0	0	0	0	1	0	0	1
Combretum apiculatum	8.1	1	0	1	0	0	0	0	0	1
Combretum apiculatum	**8**	1	0	0	0	0	0	0	0	0
Combretum apiculatum	**9**	1	0	0	0	0	0	0	0	1
Combretum imberbe	9.9	1	0	2	0	0	0	0	0	1
Combretum imberbe	**14**	1	0	3	0	0	0	0	0	1
Combretum imberbe	11.3	1	0	3	0	0	0	0	0	1
Acacia nigrescens	12.3	1	0	3	0	30	0	0	0	0
Combretum imberbe	**12**	1	0	4	0	0	1	0	0	1
Acacia nigrescens	8.9	1	0	1	0	70	0	0	1	1
Combretum imberbe	15	1	0	4	0	0	1	0	0	0
Combretum imberbe	11.1	1	0	1	0	0	1	0	0	1
Acacia nigrescens	7.5	1	0	0	0	0	0	0	0	1

Acacia nigrescens	10.3	1	0	0	0	80	0	0	1	1
Combretum imberbe	8.8	1	0	5	0	0	1	0	0	1
Acacia nigrescens	8.9	1	0	1	0	5	1	0	0	1
Acacia nigrescens	8.3	1	0	1	0	0	0	0	0	1
Acacia nigrescens	**8**	1	1	2	0	0.1	0	0	1	1
Combretum apiculatum	**4.5**	1	0	3	0	0	1	0	0	1
Acacia nigrescens	4.3	0	1	2	0	0.3	0	0	0	1
Combretum apiculatum	5.9	1	0	2	0	0	1	0	0	1
Acacia nigrescens	**10**	1	1	3	0	0	1	0	0	0
Acacia nigrescens	6.7	1	0	3	0	0	1	0	0	0
Acacia nigrescens	**7**	1	0	2	0	0.05	0	0	1	1
Combretum apiculatum	5.6	1	1	3	0	0	1	0	0	1
Acacia nigrescens	6.2	0	1	2	0	0	0	0	0	1
Acacia nigrescens	6.4	1	0	2	0	0	1	0	0	0
Acacia nigrescens	7.2	1	1	1	0	0	0	0	0	1
Acacia nigrescens	6.3	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**7.5**	1	0	2	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	1	0	0	0	0	0	1
Acacia nigrescens	7.3	1	1	4	0	0	0	0	0	1
Combretum apiculatum	**7**	1	0	4	1	0	1	0	0	1
Acacia nigrescens	**10**	1	0	0	0	0	0	0	0	1
Combretum apiculatum	7.2	1	1	4	0	0	1	0	0	1
Combretum apiculatum	5.2	1	1	2	0	0	1	0	0	1
Acacia nigrescens	7.2	1	1	2	0	0	0	0	0	1
Acacia nigrescens	8.4	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**8**	1	0	0	0	0.6	1	0	1	1
Acacia nigrescens	6.5	1	0	4	0	0.25	1	0	0	1
Acacia nigrescens	**12**	1	0	0	0	0.1	0	0	1	1
Combretum imberbe	**10**	1	0	3	0	0	1	0	0	1

Sclerocarya birrea	5.4	1	0	3	0	0	1	0	0	0
Sclerocarya birrea	6.6	1	0	7	0	0	1	0	0	1
Sclerocarya birrea	**12**	1	0	2	0	0.35	1	0	1	0
Combretum imberbe	10	1	0	4	0	0	0	0	0	0
Acacia nigrescens	**8**	1	0	3	0	0.5	1	0	0	1
Acacia nigrescens	4.9	1	1	0	0	0	0	0	0	1
Combretum apiculatum	**6**	1	1	2	0	0	1	1	0	1
Acacia nigrescens	**6**	1	0	3	0	0	1	0	0	0
Acacia nigrescens	7	1	0	2	0	0.8	0	0	0	1
Combretum apiculatum	**7**	1	1	2	0	0	1	1	0	1
Acacia nigrescens	**8**	0	1	4	0	0.25	0	0	0	1
Combretum apiculatum	**4**	1	0	2	0	0	1	1	0	1
Combretum apiculatum	**5**	1	0	2	0	0	0	0	0	1
Combretum imberbe	**6**	1	0	4	0	0	1	0	0	1
Acacia nigrescens	9.2	0	0	6	0	0.9	1	0	0	1
Combretum imberbe	**15**	1	0	5	0	0	1	0	0	1
Combretum imberbe	5.3	1	0	3	0	0	1	0	0	1
Acacia nigrescens	**10**	1	0	3	0	0	1	0	0	0
Acacia nigrescens	**10**	1	0	2	0	0	0	0	0	0
Acacia nigrescens	**10**	1	0	1	0	0	0	0	0	0
Acacia nigrescens	12.1	1	0	2	0	0.5	1	0	1	1
Combretum imberbe	**7**	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1
Combretum imberbe	**7**	1	1	2	0	0	1	0	0	1
Acacia nigrescens	5.9	1	0	0	0	0	0	0	0	1
Acacia nigrescens	**10**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	**9**	1	0	0	0	0	0	0	0	0
Acacia nigrescens	8.3	1	1	1	0	0	0	0	0	0
Acacia nigrescens	**7**	1	0	0	0	0	0	0	0	1

Acacia nigrescens	4.7	1	1	1	0	0	1	0	0	1
Acacia nigrescens	**8**	1	1	0	0	0.25	0	0	0	0
Acacia nigrescens	4.5	1	0	0	1	0	1	0	0	1
Acacia nigrescens	4.9	1	0	0	0	0	0	0	0	1
Combretum apiculatum	**5**	1	1	2	0	0	1	1	0	1
Acacia nigrescens	**8**	1	0	2	0	0	1	0	0	1