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Assessing species richness patterns and conservation threats (due to overharvesting and climate change) in South African cycads, with emphasis on a population of *Encephalartos transvenosus* Stapf & Burtt Davy from the Soutpansberg Mountain, Limpopo Province

By

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Thesis submitted in fulfilment of the requirements of the degree

DOCTOR OF PHILOSOPHY

In Botany

In the

Faculty of Mathematical and Natural Sciences

University of Venda

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DECLARATION

I declare that this thesis submitted to University of Venda for the degree of Doctor of Philosophy (Botany) is my own work and have not been previously submitted to any other institution for any degree. The thesis does not contain other persons' writing unless specifically acknowledged and referenced accordingly.

……………………………………………

Bamigboye Samuel Oloruntoba

DEDICATION

This project is dedicated to my dad Late Elder Joseph Funsho Bamigboye who worked tirelessly to see me successful but death did not allow him to witness this period of this outstanding success.

ACKNOWLEDGEMENTS

I must first of all give thanks to my lord Jesus Christ for his grace and mercies upon my life to complete my doctorate degree. His name be praise forever and ever, Amen.

My appreciation goes to my academic supervisors, Prof Peter Tshisikhawe and Prof Peter Taylor for their tiredless effort to ensure that this degree becomes a success and also get completed within the stipulated time given by the university. Also I thank them for moral, financial and intellectual supports throughout this program.

I am grateful to my colleagues who assisted me in this project. First my appreciation goes to Mbambala Sipho, his expertise in ethnobotanical survey was a great leverage during this program. I thank Thumbe, for such a very relentless effort during my field work. Also to Tiawoun Andrea for his moral support I show appreciation. Their contributions were very encouraging.

Thanks to all the staff members of the department of botany at university of Venda for providing enabling environment for me to conduct my research. Also thanks to all the members of the South African Research Chair Initiative for Biodiversity Value and Change at university of Venda under the chair of Prof. Peter Taylor for suggestions on how to improve on my project.

My regards goes to my family starting from my mum (Deaconess Mary Omolola Bamigboye) for her prayers and support throughout my degree program. I also appreciate my siblings for supporting me all through the time of this program.

ABSTRACT

Cycads are regarded as the oldest living seed plants on earth and they have existed for about 300 million years. Ever since the awareness of the existence of this plant group, they have been facing high extinction risk. Currently they are referred to as the most threatened plant group in the world. Many ecological and anthropological forces are promoting extinction crisis of this taxonomic group.

Africa is one of the centres of diversity of this plant group with 70% of the total number of the taxa in this group in Africa found in South Africa. Also South Africa is one of the global hotspots for cycads and it contains the third largest number of cycads after Australia and Mexico. Studies have revealed that there have been high threats and extinction risks among the cycad taxa in South Africa.

The Soutpansberg Mountain is a major biodiversity hotspot in Limpopo Province in South Africa with high level of flora and fauna taxa. About 3000 vascular plants species are represented on this mountain. Biodiversity on this mountain has been under threat in recent times and there is need to investigate how cycads are facing risk on this mountain.

The main focus of this study is to look at the extinction pattern in South African cycads and cycads endemic to Soupandberg Mountain in Limpopo Province in South Africa.

The first objective evaluated all African cycads over a decade using IUCN red list. Data from IUCN 2014 version was used to calculate the percentages of African cycads in each IUCN categories. The results were compared with those presented by Donaldson 2003. They showed that there have been significant decline and increase in extinction of African cycads over this period. It was also discovered that majority of this extinction crisis were trending in South Africa.

The second objective used the IUCN red list to evaluate extinction pattern in South African cycads. The percentages of IUCN threat categories of South African cycads was calculated using IUCN red list. ArcGIS was used to construct distribution map for threatened and extinct South African cycads. The study revealed that the proportion of historically Extinct and Critically Endangered cycads is higher in Limpopo, KwaZulu-Natal and Mpumalanga than the rest of the provinces in South Africa.

The third objective of this research investigated extinction pattern of *Encephalartos transvenosus* Stapf & Burtt Davy (Modjadji cycad) on Soutpansberg Mountain. Indigenous knowledge and population ecology approaches were used to determine current threats Modjadji cycads are facing on Soutpansberg Mountain. The results showed that anthropogenic activities have caused a substantial decline of one important unprotected population of this species on Soutpansberg Mountain.

Comprehensive records of all South African cycads were obtained from South African National Biodiversity Institute (SANBI). These records were used for the last objective which was to determine predicted range changes due to future climate change in South African cycads from geographic point. Climate change modelling revealed that South African cycads might possibly not be affected by climate, but anthropogenic activities might still be a major factor that might be responsible for extinction of these taxa in the future.

This study explored patterns of extinction risk in South African cycads and Soutpansberg cycads. Patterns of extinction risk is defined as certain taxa experiencing change of status to higher threat status according to IUCN categories and the factors responsible for such changes. We made some conservation recommendations in this study that might decrease cycads extinction crisis in South Africa and Soutpansberg if properly channelled and implemented.

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CHAPTER ONE

INTRODUCTION

1.1 Research Problem Statements

There has been a rapid change in conservation status of all the cycads globally in the last decade, with majority of cycads taxa experiencing increase in extinction risk. Increase in extinction risk is when species experience change of status to higher threat categories, for instance changes from Critically Endangered to Extinct in the wild on IUCN red list is called increase in extinction risk (Rodrigues et al. 2006; Mace et al. 2008).

Cycads taxa endemic to cycads hotspot nations, including South Africa, have also experienced a significant increase in extinction risk in recent times. A high proportion of cycad taxa have experienced population decreases in recent times, and there is a higher probability of cycad extinction risk increase in the future, based on their population trend in the IUCN red list (IUCN 2014, 2016).

African cycads have witnessed a significant increase in extinction risk in recent times, with the majority of these extinction occurrences found in South Africa. Modjaji cycads in the Soutpansberg biodiversity hotspot might be at risk of extinction due to anthropogenic activities. Limpopo Province is the region of highest extinction risk in South Africa. Climate change might not be a major factor responsible of extinction risk in South African cycads but anthropogenic activities might be the driving force.

1.2 Overall Aim and Objectives of the Study

The overall aim of this research was to evaluate the patterns of extinction risk in South African cycads. To also determine anthropogenic factors that might be accelerating extinction of cycads in the Soutpansberg biodiversity hotspot in Limpopo Province, South Africa. To also determine if climate change might be a factor that can promote extinction risk in South African cycads. Objectives of this research were as follows:

i. To evaluate extinction risk in African cycads by making use of the IUCN data.
ii. To evaluate and assess extinction risk patterns in South African cycads using IUCN red list.
iii. To use the indigenous knowledge approach to determine threats to *Encephalartos transvenosus* Stapf & Burtt Davy on Soutpansberg Mountain.
iv. To use population sampling to assess harvesting impact, and also quantify threats to an important population of *Encephalartos transvenosus* on Soutpansberg Mountain, Limpopo Province, South Africa.
v. To determine the region of higher extinction crisis in South Africa cycads using herbarium records of all South African cycads.

vi. To determine South African cycads' possible response to future climatic predictions.

1.3 Hypothesis

Cycads are the most threatened of all plant species in the world http://www.cycads.org.za/status.html. Because of the high degree of extinction risk in this plant order, a continuous evaluation of the extinction risk is necessary to keep track of progress in terms of conservation, and also make recommendations on how total extinction of this plant group can be avoided.

In the light of recent trends in unsustainable harvesting (Williams et al. 2014), I predict that anthropogenic activities will have an adverse effect on a population of cycads species endemic to Soutpansberg Mountain in Limpopo Province in South Africa. Hence, this decrease in population of these cycads species will therefore increase the extinction risk of cycads, promoting biodiversity loss, and loss of genetic diversity.

Threats in South African cycads have increased significantly in the past decade and Limpopo Province stood out as the province with the largest extinction occurrences in South Africa. Since climate change has emerged a force to be reckon with in species extinction, testing South African cycads response to climatic predictions in the future becomes a very important aspect of South African cycads conservation studies. Climate change has not been reported in the past as a factor that promotes South African cycads extinction, and future prediction of climate might also not influence cycads decline in South Africa. This means that anthropogenic activities might still be the major factor that will be responsible for cycad decline in the future.

1.4 Structure of thesis

This thesis is structured in publication format in which each objective of the research was reported in a form suitable for journal submission. This research is expected to produce a minimum of three publications, with each publication format section addressing key issues relating to this research. By putting this structure into consideration, it is necessary to state that certain repetitions are unavoidable in this thesis, as there might be certain components of the research that are useful for the publication of different sections of this research. The chapters' layout, which address the objectives of this whole research, are as follows:

Chapter One gives an Introduction that introduces the title together with the aim and objectives of the research while Chapter Two gives a General Literature Review (Broad overview on Biodiversity loss, with cycads as a case study). Chapter Three gives a Review of Extinction Risk in African cycads. Work from this chapter was published in *Phyton International Journal of Experimental Botany*. Chapter Four evaluated extinction risk in South African cycads using IUCN red list while Chapter Five looked at Detecting threat to *Encephalartos transvenosus* (Limpopo cycads) through indigenous knowledge in Limpopo Province, South Africa. This chapter has been published in *Indian Journal of Traditional Knowledge*. Chapter Six unravelled threat to an *Encephalartos transvenosus* (Limpopo cycads) population in Mutale Mutale Municipality, Limpopo Province, South Africa. Chapter Seven on the other hand investigated correlation between extinction crisis and species richness in South African cycads while Chapter Eight looked at how Climatic predictions may not accelerate decline in South African cycads. In conclusion Chapter Nine gave a General Summary of the whole research.

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CHAPTER TWO

GENERAL LITERATURE REVIEW (BROAD OVERVIEW ON BIODIVERSITY LOSS WITH CYCADS AS A CASE STUDY)

2.1 Biodiversity loss (species extinction) a global concern

Biodiversity loss is a global problem (Dana et al. 2012) occurring at an unprecedented rate (May et al. 1995; Millennium Ecosystem Assessment 2005; Vamosi & Vamosi 2008; Butchart et al. 2010). An estimate revealed that 10 to 30% of amphibians, reptiles and mammals are threatened with extinction (Millennium Ecosystem Assessment 2005). Futhermore, 10% of the total number of plant taxa became extinct in the past three decades (Tali et al. 2015). The current extinction rate is 1,000 to 10,000 times greater than the past extinction rate (Butchart et al. 2004). This, therefore, generates concern in the area of conservation due to human reliance on nature and its ecosystem services.

2.2 Biodiversity and ecosystem services

Ecosystem services can be defined as a wide range of services delivered to man by his natural environment (Costanza et al. 1997; Daily 1997). The quality of human life is therefore dependent on this ecosystem services both now and in the future (Millennium Ecosystem Assessment 2005). Ecosystem services includes services such as seafood, wild animals, forage/browse food, timber, biomass fuels, natural fibres, and many pharmaceuticals, industrial products, and their precursors (Omar 2014). There is a strong correlation between species richness and ecosystem services, as higher species richness translate into improved, stable and higher ecosystem services (Hector & Bagchi 2007; Khan et al. 2013). This implies that enriched biodiversity improves ecosystem services, because different species plays different roles in the system, and biodiversity loss reduces quality of ecosystem services (Wessels et al. 2003).

2.3 Invasive species as agent of biodiversity loss

Invasive species are species that are introduced to new environments outside their natural distribution, and these species become naturalized to these new environments in which they find themselves (Lockwood et al. 2007). These species compete with native ones in area of dispersal mechanisms, and possess the ability to colonize empty niches within the ecosystem (Elton 1958; Baker 1974). Human influence is a major driver of invasive success in any environment because humans are important agents of dispersal (Groves & Di Castri 1996). With effective means of movement, such as improved transportation, non-native plant and animal species are introduced to new environments where these species spread to other suitable niches (Mack et al. 2000).

The economic and ecological impact of invasive makes them an important area of research in conservation biology and ecology (Bergmans & Blom 2001). From an ecological perspective, invasive species alter ecosystem functioning, composition and structure of native ecosystems (Mack et al. 2000; Rice & Emery 2003). Ecosystem alterations by invasive leads to biodiversity loss (Dalmazzone & Giaccaria 2014).

2.4 Climate Change and Biodiversity loss

Climate change promote biodiversity loss (Leadley et al. 2010) through decrease in genetic diversity that leads to poor ecosystems functioning (Botkin et al. 2007). Indirect effects of climate change leading to biodiversity loss also include habitat destruction (Mantyka-Pringle et al. 2015), absence of pollinators and parasites due to change in climatic condition, hence affecting the survival of certain species (Koh et al. 2004). The role of climate change in species extinction have made research on effect of climate change on biodiversity an important aspect of biodiversity and conservation biology, with studies trying to predict how species diversity will respond to climate change in the future (Dillon et al. 2010; Gilman et al. 2010; Pereira et al. 2010; Salamin et al. 2010; Beaumont et al. 2008; Dawson et al. 2011; McMahon et al. 2011).

2.5 Human population growth and anthropogenic impact on biodiversity

Human population in the world has been estimated to about 7.2 billion people, with expected increase to about 9.6 billion by 2050 (United Nation Population Division 2012). In Africa, the population is about a billion, with projections of close to 2 billion in 2045 (United Nations Population Division 2010; Linard et al. 2013). This dramatic increase in human population is posing threat to biodiversity and ecosystem functioning due to factors such as high anthropogenic activities, land clearing for agricultural purpose, industrialization and urbanization (Kerr & Currie 1995; Forester & Machlis 1996; Kirkland & Ostfeld 1999; Thompson & Jones 1999; Abbitt et al. 2000; Cincotta et al. 2000; Cincotta & Engelman 2000; Balmford et al. 2001; Harcourt et al. 2001; McKinney 2001; Ceballos & Ehrlich 2002; Harcourt & Parks 2003). The ecosystem is greatly influenced by humans, and there is no aspect of ecosystem on earth that is devoid of human intervention directly or indirectly (Vitousek et al. 1997). Biodiversity loss has been linked to human activities, and the current mass extinction crisis is largely caused by human activities (Burgess et al. 2007; Luck 2007; Pautasso 2007). Also, human reliance on nature for survival poses threat to biodiversity as resource utilization for meeting human needs keeps removing species at an unprecedented rate (Mukwevho 2014).

2.6.0 Taxonomy of cycads

Cycads consists of long-lived woody gymnosperms that possess a perennial caudex or trunk, and leaves that are shed and renewed over many years (Laidlaw & Forster 2012). They are generally restricted in distribution with this plant group confided to specific areas in different parts of the world (Donaldson 2003).

Currently, this plant group exist between two plant families, which are Zamiaceae and Cycadaceae. The Cycadaceae family contains 99 species, with their geographical distribution found mostly along the eastern coast of Africa, Madagascar and Australasia (Figure 2.1). Zamiaceae contains more species, and are also more diverse geographically compared to the Cycadaceae. The genera represented in Zamiaceae are; *Bowenia*, *Ceratozamia* Brongn., *Dioon* Lindl., *Encephalartos* Lehm., *Lepidozamia* Lehm., *Macrozamia* Miq., *Microcycas* (Miquel) A.DC., *Stangeria* T.Moore, and *Zamia* L. (Christenhusz et al. 2011).

2.6.1. Evolutionary history of cycads

Cycads are regarded as ancient plants (Klavin et al. 2003; Makhegu 2007), although recent studies have shown that extant cycads are not as ancient as earlier thought (Nagalignum et al. 2011). Extant cycads are not older than 12 million years (Crisps &

Cook 2009, Crisps & Cook 2011; Nagalignum et al. 2011). A study has revealed that some extant cycads are actually younger than their angiosperm counterparts (Crips & Cook 2011).

Rull (2012), in a review of cycads origin and evolution, showed that the majority of species found in genus *Encephalartos*, *Cycas* and *Macrozamia* originated during the Pliocene era, while the majority of *Zamia* species originated during the Pleistocene age. This study revealed that 80% of extant cycads originated between 2.6 to 12 million years ago.

Cycads are the oldest living representative of gymnosperms and their origin date back to about 300 million years ago (Makhegu 2007). They are mostly referred to as the Dinosaur of the world of plants with their ancestral lineages found to be contemporaries of that of Dinosaurs (Crisp & Cook 2011; Nagalingum et al. 2011). Resemblance of this species with some fossil data led them to be referred to as living fossils (Klavins et al. 2003). Most extant cycads have a recent origin, with their species radiation dating back to the Pleistocene era (1.75 million year to 10,000 years ago). A study by Stevenson (1990), have revealed this group of plants, to be monophyletic with uncertainty on the exact ancestor and its relationship with other plants.

2.6.2 Cycad biogeography

Cycads are represented in Africa, Asia, Australia and the new world with distribution that varies at family, generic and species level (Donaldson 2003). Cycadaceae, and Zamiaceae are found in Africa and Australia while only Cycadaceae is in Asia and only Zamiaceae found in the new world (see figure 2.1; Hill et al. 2003).

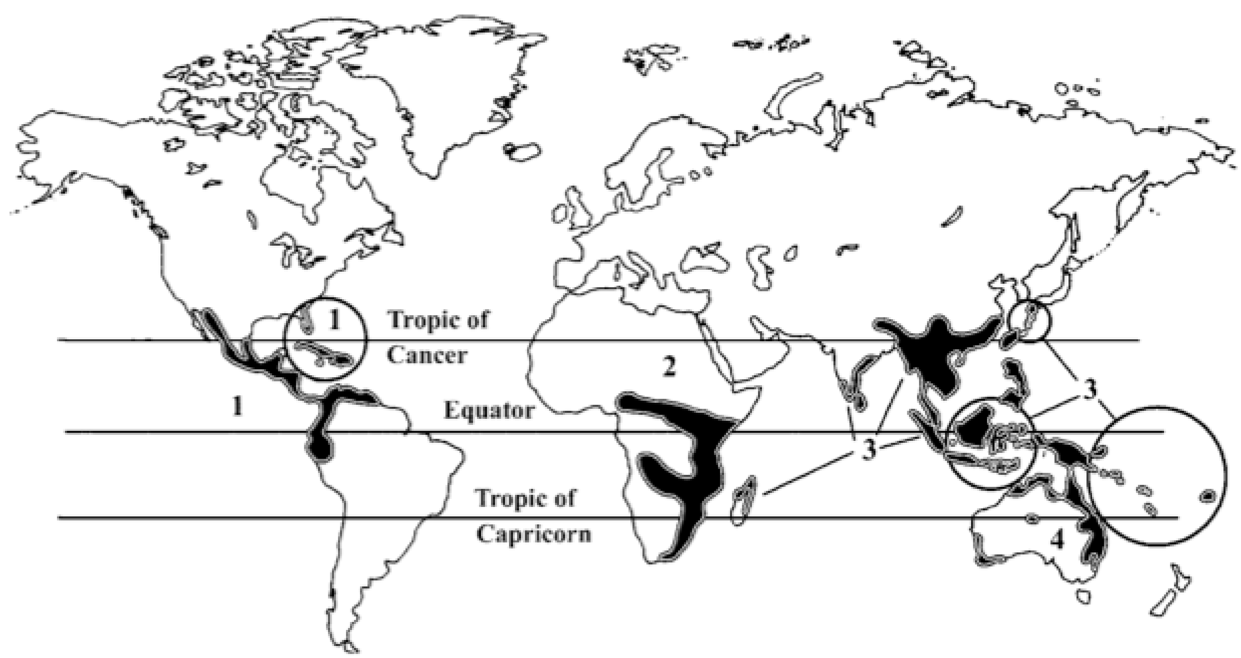

Figure 2.1: A map showing global geographical distribution of cycads (Hill et al. 2003).1 stands for *Ceratozamia, Zamia, Microcycas, Dion,* 2 represents *Encephalartos* and *Stangeria,* 3 represents *Cycas*, 4 represent *Macrozamia*, *Lepidozamia* and *Bowenia.*

2.6.3 Cycads in Australia

There are 76 species and subspecies, 4 genera and 2 families of cycads endemic to Australia (Hill et al. 2003). About 25% of the total population of cycads are endemic to Australia, which makes the country a centre of high cycads diversity (Donaldson 2003; Hill et al. 2003). Cycads in Australia are found in restricted areas with an uneven distribution in the country (Hill et al. 2003). The cycads diversity hotspots in Australia can be found along the eastern and northern coastal zone. Within this region, hotspots occurs in Queensland-New South Wales border region, Cape York Peninsula and north of the Northern territory (Hill et al. 2003).

2.6.4 Cycads in Asia

Only one single genus of cycads is found in Asia, which is the genus *Cycas* that consists of 63 species (Hill et al. 2003). The main biodiversity hotspot for cycads in Asia are Vietnam, which contain 24 species, China with 21 species, Thailand containing 10 species, Indonesia with 7 species, while Papua New Guinea had 6 species, Philippines having 5 species and Malaysia with 3 species (Donaldson 2003).

2.6.5 Cycads in the New World

Five genera of cycads are represented in the new world. These are *Dion*, *Ceratozamia*, *Zamia*, *Microcycas* and *Chigua* (Stevenson et al. 2003). These genera are represented in 21 countries, which includes the tropical and subtropical regions of the new world (Donaldson 2003). Cycads in general are always confined to restricted regions and the new world is not left out of these in which four genera occur in one country which is Mexico (Stevenson et al. 2003). One species of *Macrocycas* is found in Cuba. *Chigua* is represented by two species in north central Colombia, Mexico harbour 18 species of *Ceratozamia,* while 57 species are found in the neotropics (Hill et al. 2003).

2.6.6 Cycads in Africa

Africa is one of the centres of diversity of cycads, with cycads species distributed across southern Africa, Sudan, central and east Africa, Angola, and to West African countries like Benin, Ghana and Nigeria (Figure 2.2). Two genera of cycads are endemic to Africa, *Stangeria* and *Encephalartos*. *Encephalartos* contains 66 species, while *Stangeria* contains one species (Rousseau 2012). Seventy percent of African cycads are found in South Africa, which is one of the cycad global hotspots (Figure 2.2; Hill et al. 2003)

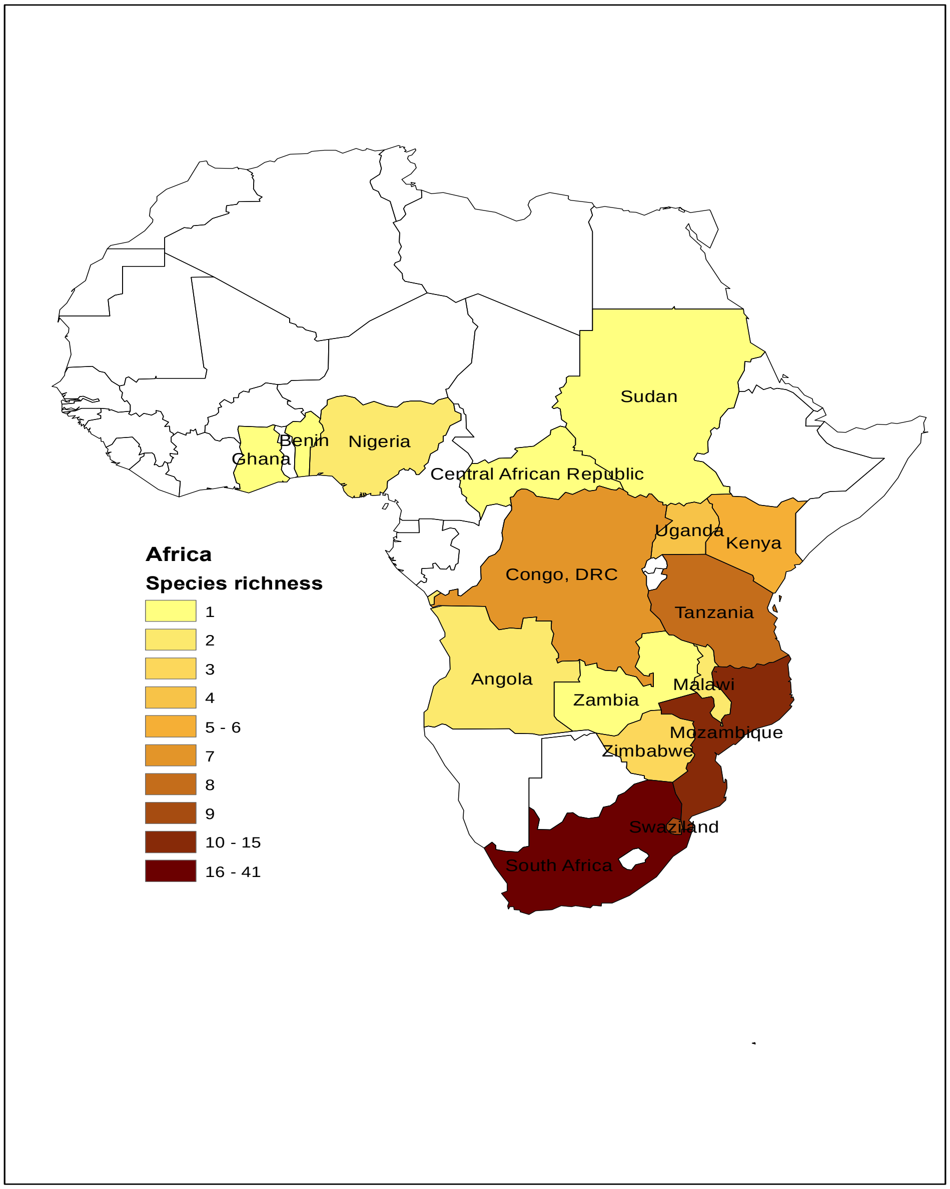

Figure 2.2: Map showing the species richness and distribution of African cycads with the data obtained from Golding and Hurter (2003).

2.6.7 *Encephalartos*

Encephalartos are dioecious perennial plants, whose habitat distribution ranges from forest to grassland to savanna (Donaldson 2008). The genus *Encephalartos* is the largest cycads in Africa, containing 66 species (Donaldson 2003), and distributed across 15 countries in Africa (figure 2.2; Golding & Hurter 2003). *Encephalartos* species can be found in Angola, Democratic Republic of Congo, Central Africa Republic, Ghana, Nigeria, Malawi, Mozambique, Republic of Benin, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe (Rousseau 2012). The main centre of diversity for *Encephalartos* is South Africa, with 70% of the total number of *Encephalartos* species found (Golding & Hurter 2003).

2.6.8 *Stangeria*

Stangeria contains only one species, namely *Stangeria eriopus* (Donaldson 2003). *Stangeria eriopus* is a slow growing perennial plant, which is endemic to South Africa (Golding & Hurter 2003). It is found in the coastal grassland and inland forests along the east coast of South Africa, from the Bathhurst District in the Eastern Cape to just south of the Mozambique border (Rousseau 2012).

2.6.9 Extinction risk in cycads with emphasis on cycads hotspot nations (Australia, Mexico and South Africa)

Cycads are categorized as the most threatened plant species globally, with 60% of them threatened (International Union of Conservation of Nature 2010). A recent study carried out on the taxonomic selectivity of endemic flora of southern Africa also shows that cycads are the most threatened vascular plant species in southern Africa (Mukwevho 2014).

The small population size along with their rare, scattered and isolated occurrence in cycads is a factor that has increased the various threats to these species (Donaldson 2003). Cycads are dioecious plants with a long juvenile stage, and they cone infrequent (Donaldson 2003).

Some cycad species are also insect pollinated, specifically by beetles (Oberprieler 2004; Proches & Johnson 2009). Pollination in cycads is species specific; for instance certain species of beetles are responsible for pollination of some *Encephalartos* species, and some of these pollinators are already extinct, thus limiting cycad population growth (Treutlein et al. 2005).

Illegal complete removal of individuals of cycads for commercial purpose (poaching) to be sold at the international market is one of the main causes of cycads' global decline

(Donaldson 2003, 2008, 2010). This practice is highly detrimental to cycads, with the endangered species being valued more at unregulated international trade. Other factors such as habitat destruction, and invasive problems also contribute to cycads' decline globally (Rousseau 2012). Global hotspots for cycads (Australia, Mexico and South Africa) are also the centre of major extinction crisis to these taxa.

In Australia, fire occurrences in certain woodland increase the threat level to cycads (Donaldson 2003). Certain woodlands are prone to fire occurrences as a result of land management practices, which in turn destroy certain cycads seeds, thus limiting their reproductive capacities in such areas (Hill et al. 2003). Land clearing for agricultural and industrial purposes is the main cause of cycads decline in Australia, with several populations of these species being affected (IUCN 2014).

In Mexico, cycads are threatened mainly due to agricultural practices, habitat destruction, fire occurrence, grazing, urbanization and illegal harvesting of individuals (Pulido et al. 2015; IUCN 2014).

Illegal removal of cycad individuals from the wild (poaching) is one of the main threats responsible for their decline in South Africa (Donaldson 2010). Habitat loss which is a major problem in other cycads hotspots of the world, is however, a lesser problem in South Africa (Donaldson 2010). But the greatest threat to cycads existence in South

Africa is harvest for medicinal purpose (Donaldson 2006: Williams et al. 2014). Most mortalities of cycads in South Africa are due to harvesting for medicinal purpose (Donaldson 2006, 2010).

2.6.10 Cycads in Soutpansberg Biodiversity hotspot in Limpopo, South Africa

The Soutpansberg mountain range is located at the northern side of South Africa, and lie between 23° 05' S - 29° 17' E and 22° 25' S - 31° 20' E (Berger et al. 2003). This mountain range is characterized with high cliffs and deep valley topography (Schonhofer 2008). The complex interaction between the climate and topography of this vegetation community makes it suitable for this region to accommodate a diverse flora and fauna community (Berger et al. 2003). Topography of Soutpansberg covers about 6 800 km^2 in Limpopo Province in South Africa streching about 250 km from east to west, with a width of north to south of about 15 to 60 km (Berger et al. 2003).

The Soutpansberg mountain range is a major biodiversity hotspot, and centre with the highest plant generic and family level diversity among the 18 recognized plant endemism centres in South Africa (Van Wyk & Smith 2001). A botanical study conducted in Soutpansberg mountain range in 2002 estimated the total number of plant species in Soutpansberg mountain range to be 3 000 species and the total number of genera to be

1066 (Hann 2002). This unique biodiversity hotspot contains two cycads taxa, which are: *Encephalartos hirsutus* and *Encephalartos transvenosus* (Hann 2002).

Encephalartos transvenosus Stapf & Burtt Davy is a tall growing, dark green coloured cycads species that can grow higher than 6 m in height (Giddy 1984). The name *transvenosus* depict the network of veins, which can be seen in a leaf when held against the sun (Giddy 1984). This species is restricted to South Africa, but limited to the Limpopo Province (Letty 1962). This species is quite abundant in some nature reserves, but is experiencing population declines (IUCN 2014).

Encephalartos hirsutus P.J.H. Hurter is endemic to the Soutpansberg mountain range in Limpopo Province, South Africa (Hurter & Glen 1996). This plant grows in semi-deciduous mixed scrub, with rainfall range between 350 to 650 mm per annum, and the vegetation type is mainly mountain bushveld (Hurter and Glen 1996). When this species was discovered only 500 individuals were identified on Soutpansberg Mountain (Hurter and Glen 1996). Illegal collection of the individuals wiped out the whole population of this species (IUCN 2014). *Encephalartos hirsutus* is locally extinct in the wild in South Africa based on the current observations from the Limpopo Economic Development Environment and Tourism (LEDET 2016).

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CHAPTER THREE

REVIEW OF EXTINCTION RISK IN AFRICAN CYCADS

This chapter has been published in *Phyton International Journal of Experimental Botany* 85(1): 333-336

Abstract

Over a long period of time cycads endemic to Africa have been facing a high risk of extinction. Several conservation efforts have been put in place to reduce the risk of losing these highly endangered species. In this study we review the current risk of extinction of all African cycad species. The percentages of each category of species found in African cycads was calculated using the IUCN (International Union of Conservation of Nature) red list of threatened species 2014 version. Result were compared with that of Donaldson (2003) on percentages of different categories of IUCN for cycads in Africa, which was carried out a decade ago. The percentage of population trend in African cycads was also calculated. Using the IUCN geographic range, threatened and extinct cycads found in Africa were determined. In comparing these results it was discovered that over one decade there has been no improvement in cycads conservation despite several conservation efforts over this period to conserve cycads in Africa. The geographic occurrence of African cycads also showed that the majority of these threatened cycad taxa in Africa occur in South Africa, and all extinct cycads are also found in South Africa.

The results of the population trend also show that African cycads are experiencing population decline. These results hereby shows that the risk of extinction of African cycads is still very high, and much conservation effort is still required to properly tackle ecological and anthropogenic factors pushing these endangered species to extinction.

Keyword: African cycads, extinction, IUCN categories, threat.

3.1 Introduction

Cycads are categorized as the most threatened plant species in the world. In 2010, 303 species of cycads were assessed and 63% were found to be threatened with extinction (International Union of Conservation of Nature 2010). Africa is one of the centre of diversity of cycads (Hill et al. 2003), which harbours 66 species of genus *Encephalartos* and one species of genus *Stangeria* (Roussseau 2012), making a total of 67 species endemic to Africa. The IUCN Red list provides vital information on the risk of extinction of all species (Lamoureux et al. 2003). This listing is based on several criteria including species biology, ecology, population size, distribution range, population dynamic, etc. (International Union of Conservation of Nature 2001). Several factors such as illegal collection of cycads (Donaldson 2003, 2008), climate change (Bamigboye 2013), and presence of invasive species (Donaldson 2008) are responsible for extinction risk of cycads in Africa. Several conservation efforts such as compacting poaching, issuing of regulating permit for cycads collection have been put in place to reduce the risk of its extinction in Africa (Donaldson 2010; International Union of Conservation of Nature 2010).

Donaldson (2003), on published work of cycads status, survey and conservation plan presented IUCN report of different percentages of IUCN status of African cycads, raising concern on the rate of rapid loss of cycads in Africa. Donaldson (2003), identified that the threatened status of cycads arise from natural rarity and declines. Naturally, cycads grow in isolated population which makes them very rare, making them require high level of conservation and regeneration plan (Hill et al. 2003). Causes of threats identified by

Donaldson (2003), include habitat destruction, over collection, traditional uses, and reproductive failure. It is therefore of great necessity to evaluate the current status of African cycads after about one decade, to gain a better picture of the trend in conservation of African cycads.

In this study, a review on the risk of extinction of these species was conducted in order to determine if there has been improvement in the status of cycads in Africa, by comparing the current conservation status with the conservation status reported by Donaldson (2003).

3.2 Methodology

Using the 2014 version of IUCN (International Union of Conservation of Nature) red list of threatened species, the status of all cycads endemic to Africa was evaluated. This was done by calculating the number of African cycads species in each category of IUCN status which includes Critically Endangered, Vulnerable, Endangered, Extinct in the wild, Near Threatened and Least Concern. The total number of African cycads in each category was multiplied by 100 and divided by 67 which is the total number of cycads species in Africa in order to get the categorical percentages. The population trend of all the cycads endemic to Africa was also obtained by calculating the total number of African cycads decreasing and the stability of population trend. Each of the three categories of population trend was multiplied with 100 and divided by 67 to find the exact percentages of population decrease and stability using the IUCN 2014. The results of the IUCN threat categories (Critically endangered, Vulnerable, Endangered, extinct in the wild, Near threatened and least concern) for 2014 was compared with the result of such classification carried out by Donaldson (2003), which is one decade before the current IUCN version to evaluate the threat trend of African cycads. Report on IUCN status of cycads presented by Donaldson (2003) were based on combined data from sources including cycads trade, permit records and the study of matched photographs of cycads hotspot over a long period of time. This data was used to assess the status of cycads species endemic to Africa. The geographic range of all African cycads was also used to generate distribution maps for threatened and extinct African cycads using ArcGIS 10.1 based on IUCN 2014 data. This was done in order to show current regions of high extinction risk in African cycads.

3.3 Results and Discussion

Reviewing the status of cycads in Africa, has enabled this research to evaluate the current position of African cycads relating to risk of extinction. Currently the majority (86%) of all African cycads are of conservation concern (Threatened + Near Threatened) (Figure 3.2). Comparing the IUCN status of Donaldson (2003) with the 2014 version of the IUCN for African cycads enabled this study to detect a slight increase in all the threatened African cycads in one decade (Table 1.0). Cycads that have gone extinct have increased by 3.2%, critically endangered cycads have increased by 1%, endangered cycads have increased by 3%, vulnerable ones have decreased by 2% and the ones that are near threatened have increased by 4% (Figure 3.1, 3.2; Table 3.1). Chi-squared test on the data in Table 3.1 showed that the changes are not significant. Chi-squared value = 2.31, 4 degrees of freedom, $p = 0.68$ $p > 0.05$. Although the differences are insignificant, losing one species is losing ecosystem productivity, population distribution and genetic diversity (Mukwevho 2014). Donaldson (2003), showed that 2.8% of African cycads were already extinct, 26% critically endangered, 12% endangered, 26% vulnerable and 16% least concern as at the time of the report of his assessment.

Another important aspect of this research is the population trend. Currently a very large number of African cycads are still experiencing population declines which will increase extinction risks in future (Figure 3.3).

The evaluation from geographical perspective revealed that 60% of threatened African cycads are found in South Africa and also all (100%) currently extinct cycads in Africa based on current IUCN are found in South Africa (Figure 3.4 and Figure 3.5). This shows that cycads conservation in South Africa will have a lot of impact on the whole African cycads conservation. Additional efforts might be required in cycads conservation in South Africa, to salvage African cycads extinction crisis.

3.4 Conclusion

There is still a great need for much effort to be concentrated on conserving and preserving African cycads. But it is also suggested that ecological forces that have not been given high priority should be given close consideration in cycad conservation. For instance, in South Africa, which contains the highest percentage of threatened cycads in Africa, combating poaching and illegal collections has been the major focus of cycads conservation. But other factors such as climate change, pollination problems and reproductive failure which could adversely affect these species should be given close consideration and there should be a plan to integrate how these factors will addressed in cycads conservation plan in Africa. Maybe, if some of these ecological factors are also given close consideration, this might reduce the risk of extinction of this threatened species. Also, since 60% of threatened cycads taxa are represented in South Africa and all extinct cycads in Africa are found in South Africa (Figure 3.4 and 3.5), conservation effort to salvage cycads extinction should be intensified in South Africa as this will help cycads conservation in Africa.

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Figures and tables as appendix

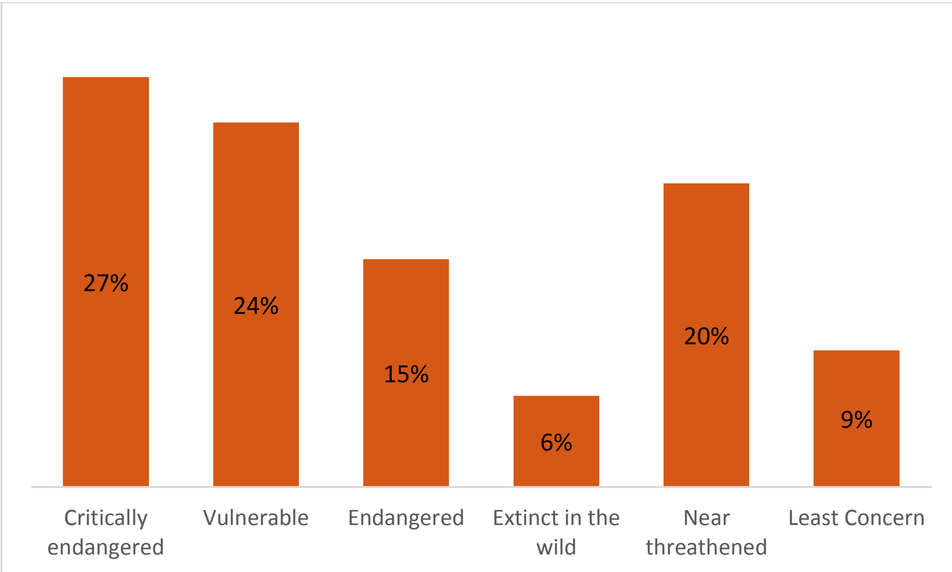

Figure 3.1: Figure showing the percentage of each categories of IUCN status of African cycads in 2014 version of IUCN red list of threatened species. Categories include the percentage of African cycads that are Critically Endangered, Endangered, Vulnerable, Extinct in the wild, Near Threatened and least concern.

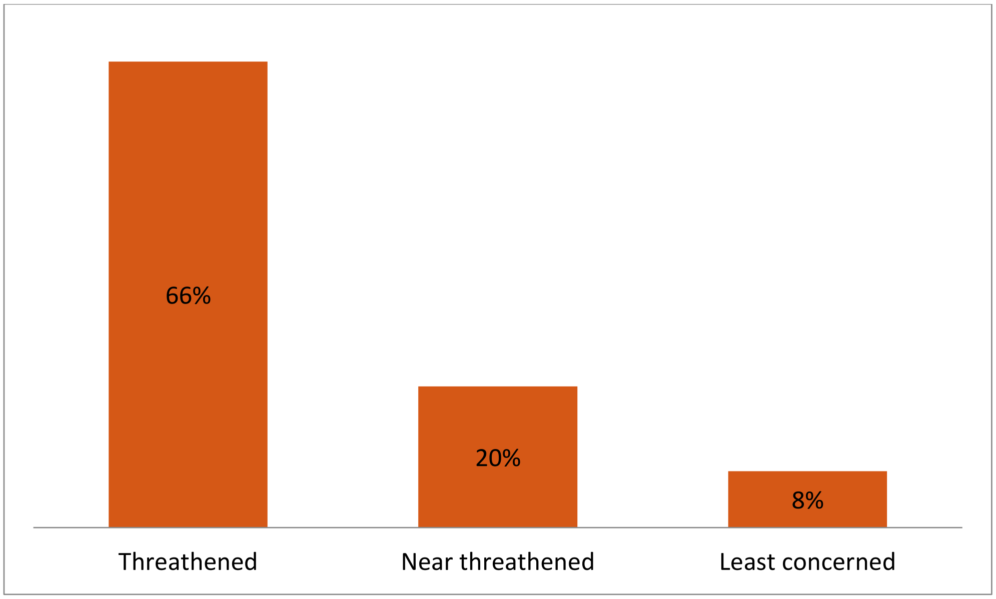

Figure 3.2: Figure showing result of the percentages of African cycads that are threatened (Critically Endangered, Endangered, Vulnerable), Near Threatened and Least Concern on IUCN red list status 2014 version.

Table 3.1. Comparing different categories of African cycads between Donaldson (2003) and IUCN (International Union of Conservation of Nature) red list 2014 version.

Conservation status	% of categories according to Donaldson (2003)	% of categories according to IUCN red list 2014 version
Extinct	2.8%	6%
Critically endangered	26%	27%
Endangered	12%	15%
Vulnerable	26%	24%
Near threatened	16%	20%

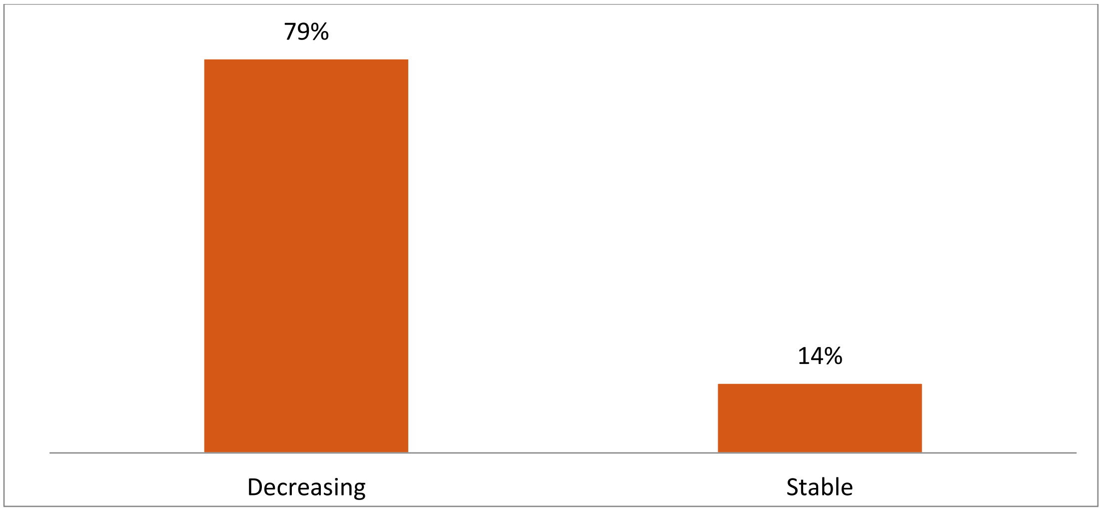

Figure 3.3: Figure showing the percentages of population trend in African cycads on IUCN red list 2014 version.

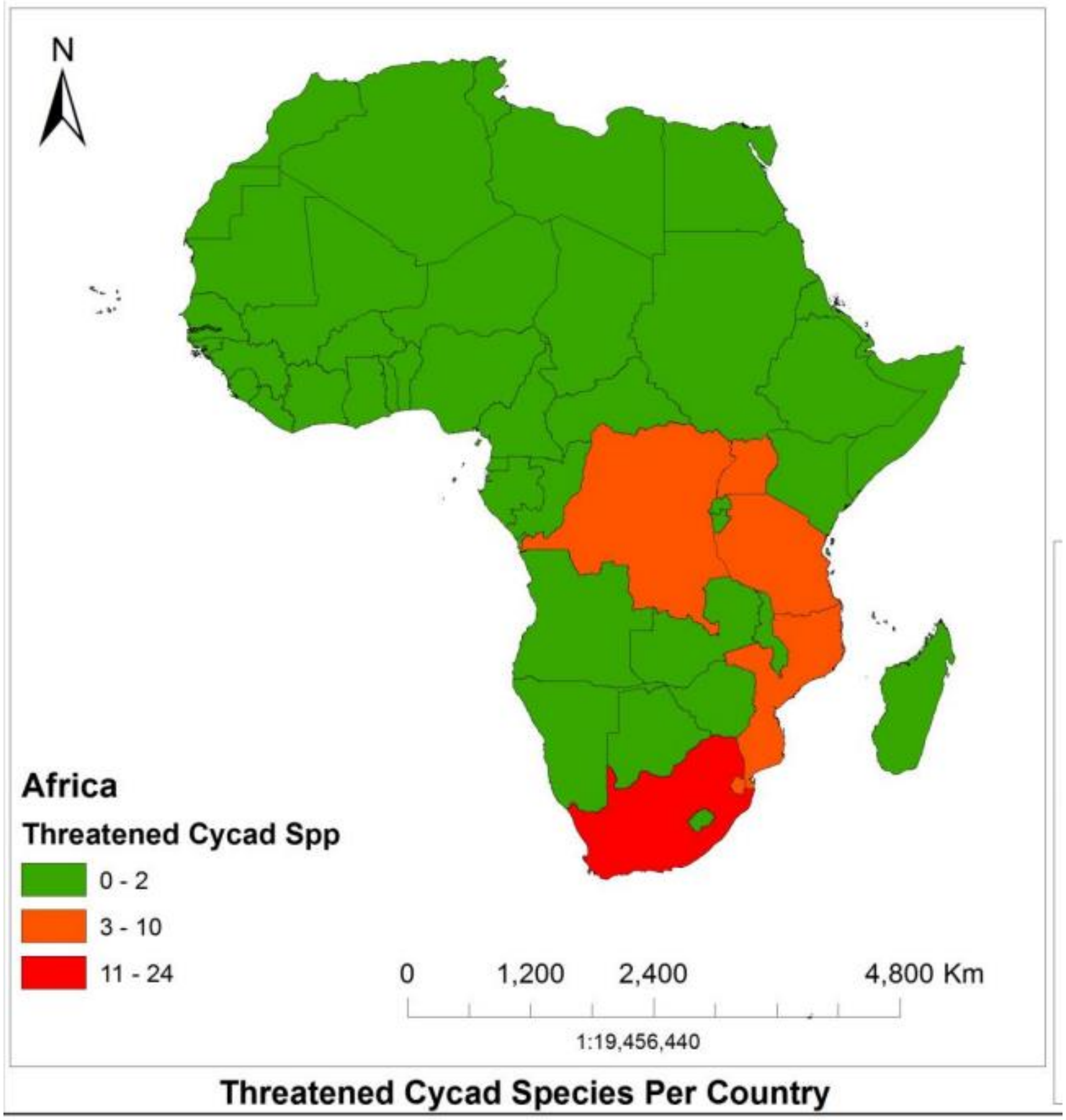

Figure 3.4: Map showing the geographic range of threatened (Critically Endangered + Endangered + Vulnerable) African cycads on IUCN 2014 version.

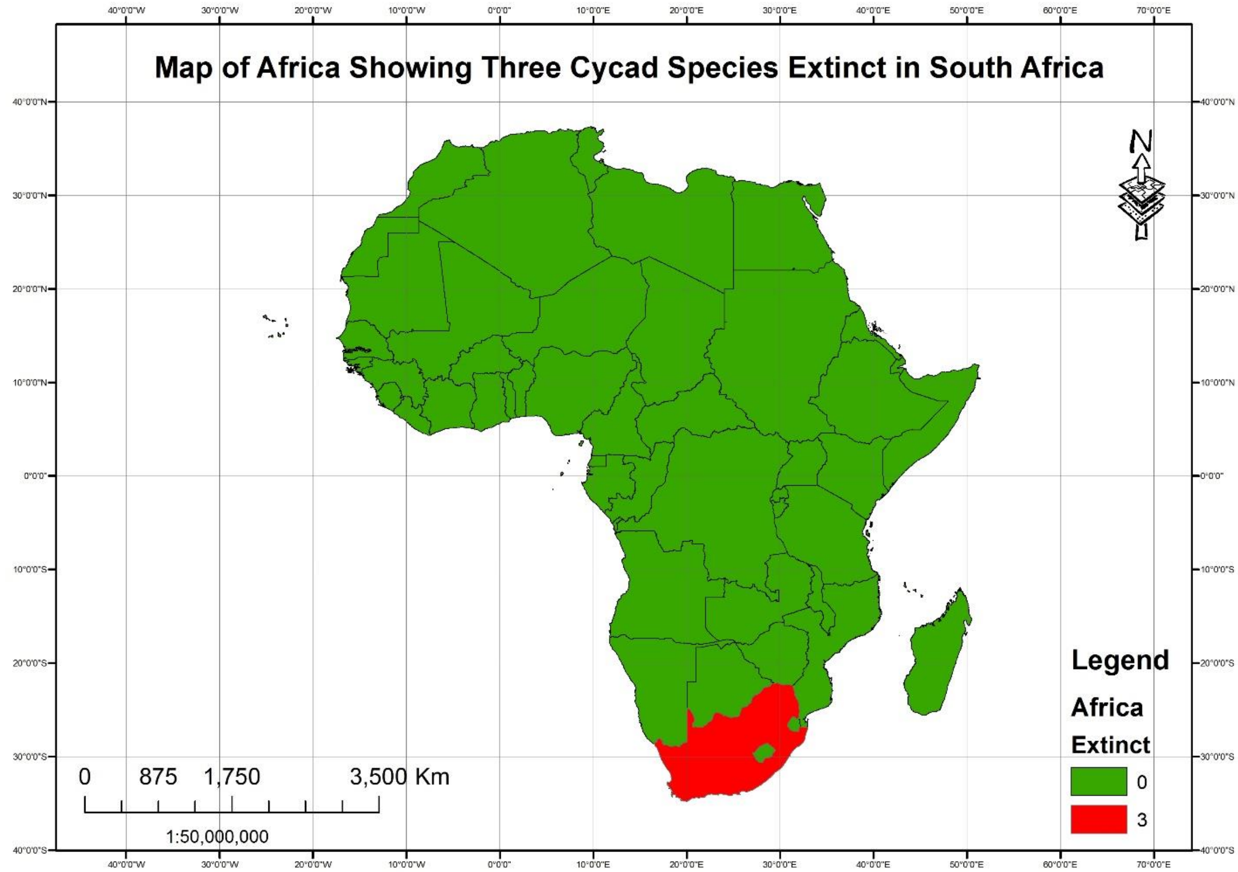

Figure 3.5: Map showing the geographic range of Extinct African cycads on IUCN 2014 version.

Table 3.2: A list of all African cycads species showing their families and their IUCN status. N/A- Signifies Not Applicable

Family	Species	IUCN 2014 status	Population trend on IUCN 2014
Zamiaceae	*Encephalartos aemulans* Vorster	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos altensteinii* Lehm	Vulnerable	Decreasing
Zamiaceae	*Encephalartos aplanatus* Vorster	Vulnerable	Decreasing
Zamiaceae	*Encephalartos arenarius* R.A.Dyer	Endangered	Decreasing
Zamiaceae	*Encephalartos barteri* Carruth. ex Miq.	Vulnerable	Decreasing
Zamiaceae	*Encephalartos brevifoliolatus* Vorster	Extinct in the wild	N/A
Zamiaceae	*Encephalartos bubalinus* Melville	Near Threatened	Stable
Zamiaceae	*Encephalartos caffer* (Thunb.) Lehm.	Near Threatened	Decreasing
Zamiaceae	*Encephalartos cerinus* Lavranos & D.L.Goode	Ctitically Endangered	Decreasing
Zamiaceae	*Encephalartos chimanimaniensis* R.A.Dyer & Verdoorn	Endangered	Decreasing
Zamiaceae	*Encephalartos concinnus* R.A.Dyer & Verdoorn	Endangered	Decreasing

Zamiaceae	*Encephalartos cupidus* R.A.Dyer	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos cycadifolius* (Jacq.) Lehm.	Least Concern	Stable
Zamiaceae	*Encephalartos delucanus* Malaisse, Sclavo & Crosiers	Endangered	Decreasing
Zamiaceae	*Encephalartos dolomiticus* Lavranos & D.L.Goode	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos dyerianus* Lavranos & D.L.Goode	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos equatorialis* P.J.H.Hurter	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos eugene-maraisii* Verd.	Endangered	Decreasing
Zamiaceae	*Encephalartos ferox* G.Bertol.	Near Threatened	Decreasing
Zamiaceae	*Encephalartos friderici-guilielmi* Lehm.	Near Threatened	Decreasing
Zamiaceae	*Encephalartos ghellinckii* Lem.	Vulnerable	Decreasing
Zamiaceae	*Encephalartos gratus* Prain	Vulnerable	Decreasing
Zamiaceae	*Encephalartos heenanii* R.A.Dyer	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos hildebrandtii* A.Braun & Bouché	Near Threatened	Decreasing
Zamiaceae	*Encephalartos hirsutus* P.J.H.Hurter	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos horridus* (Jacq.) Lehm.	Endangered	Decreasing

Zamiaceae	*Encephalartos humilis* Verd.	Vulnerable	Decreasing
Zamiaceae	*Encephalartos inopinus* R.A.Dyer	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos ituriensis* Bamps & Lisowski	Near Threatened	Stable
Zamiaceae	*Encephalartos kanga* Pócs & Q.Luke	Critically Endangered	Stable
Zamiaceae	*Encephalartos kisambo* Faden & Beentje	Endangered	Decreasing
Zamiaceae	*Encephalartos laevifolius* Stapf & Burtt Davy	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos lanatus* Stapf & Burtt Davy	Near Threatened	Stable
Zamiaceae	*Encephalartos latifrons* Lehm.	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos laurentianus* De Wild.	Near Threatened	Stable
Zamiaceae	*Encephalartos lebomboensis* Verd.	Endangered	Decreasing
Zamiaceae	*Encephalartos lehmannii* Lehm.	Near Threatened	Decreasing
Zamiaceae	*Encephalartos longifolius* (Jacq.) Lehm.	Near Threatened	Decreasing
Zamiaceae	*Encephalartos mackenziei* L.E.Newton	Near Threatened	Stable
Zamiaceae	*Encephalartos macrostrobilus* Scott Jones & Wynants	Endangered	Decreasing
Zamiaceae	*Encephalartos manikensis* (Gilliland) Gilliland	Vulnerable	Decreasing
Zamiaceae	*Encephalartos marunguensis* Devred	Vulnerable	Decreasing

Zamiaceae	*Encephalartos middelburgensis* Vorster, Robbertse & S.van der Westh.	Crtically Endangered	Decreasing
Zamiaceae	*Encephalartos msinganus* Vorster	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos munchii* R.A.Dyer & Verdoorn	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos natalensis* R.A.Dyer & Verdoorn	Near Threatened	Decreasing
Zamiaceae	*Encephalartos ngoyanus* Verd.	Vulnerable	Decreasing
Zamiaceae	*Encephalartos nubimontanus* P.J.H.Hurter	Extinct in the wild	N/A
Zamiaceae	*Encephalartos paucidentatus* Stapf & Burtt Davy	Vulnerable	Decreasing
Zamiaceae	*Encephalartos poggei* Asch.	Least Concern	Stable
Zamiaceae	*Encephalartos princeps* R.A.Dyer	Vulnerable	Decreasing
Zamiaceae	*Encephalartos pterogonus* R.A.Dyer & Verdoorn	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos relictus* P.J.H.Hurter	Extinct in the wild	N/A
Zamiaceae	*Encephalartos schaijesii* Malaisse, Sclavo & Crosiers	Vulnerable	Decreasing
Zamiaceae	*Encephalartos schmitzii* Malaisse	Vulnerable	Decreasing
Zamiaceae	*Encephalartos sclavoi* De Luca, D.W.Stev. & A.Moretti	Critically Endangered	Decreasing

Zamiaceae	*Encephalartos senticosus* Vorster	Vulnerable	Decreasing
Zamiaceae	*Encephalartos septentrionalis* Schweinf. ex Eichler	Near Threatened	Stable
Zamiaceae	*Encephalartos tegulaneus* Melville	Least Concern	Stable
Zamiaceae	*Encephalartos transvenosus* Stapf & Burtt Davy	Least Concern	Decreasing
Zamiaceae	*Encephalartos trispinosus* (Hook.) R.A.Dyer	Vulnerable	Decreasing
Zamiaceae	*Encephalartos turneri* Lavranos & D.L.Goode	Least Concern	Decreasing
Zamiaceae	*Encephalartos umbeluziensis* R.A.Dyer	Endangered	Decreasing
Zamiaceae	*Encephalartos villosus* Lem.	Least Concern	Decreasing
Zamiaceae	*Encephalartos whitelockii* P.J.H.Hurter	Critically Endangered	Decreasing
Zamiaceae	*Encephalartos woodii* Sander	Extinct in the wild	N/A
Stangeriaceae	*Stangeria eriopus* (Kunze) Baill.	Near Threatened	Decreasing

CHAPTER FOUR

EVALUATING EXTINCTION RISK IN SOUTH AFRICAN CYCADS USING IUCN RED LIST

This chapter is under review in *Phyton International Journal of Experimental Botany*

Abstracts

South Africa is one of the global hotspots of cycads as it contains the third largest number of cycad taxa in the world. It's also the main cycads hotspot in Africa, with 70% of the total number of African cycads represented. Past records showed that cycads extinction risk have been high in South Africa. This therefore, calls for study that evaluate the current extinction risk in South African cycads, and look into geographical regions where cycads have been facing threats in South Africa. This study evaluated the threat status of cycad taxa endemic to South Africa using IUCN (International Union of Conservation of Nature) red list 2016 version. The current position of threatened South African cycads among threatened African cycads was determined using IUCN red list. The provinces where threatened cycads occur in South Africa were also determined using their geographic range obtained from IUCN. The results in this study showed that majority of South African

cycads are still currently threatened, and in South Africa, these threatened taxa are distributed in few provinces. It is therefore recommended that provinces that have been within the geographic range of high extinction risk and decline of cycad taxa in South Africa, should be given more priority in terms of cycads conservation.

Keyword: Cycads, Extinction risk, IUCN, Population trend, Threats, South Africa.

4.1 Introduction

Cycads are rare species and the most threatened among all plant groups in the world with over 60% of them threatened to extinction (Donaldson 2003; IUCN 2010). Factors threatening these species ranges from illegal harvesting for commercial purposes (poaching), harvesting for medicinal purposes, presence of invasive competing with them in their natural habitats (Donaldson 2003) and climate change (Norstog & Nicholls, 1997).

Extinction risk in Africa have been very high (Bamigboye et al. 2016) and South Africa that contain the third largest number of cycad taxa in the world (Hill et al. 2003) and the largest number of cycad taxa in Africa (Golding & Hurter 2003) might have been greatly affected. Unlike other nations of the world where habitat destruction is the prominent threat to cycads, cycads in South Africa are threatened mainly due to harvest for medicinal and horticultural purpose (Donaldson 2006). Due to high extinction crisis in South African cycads in the past (Donaldson 2003), it is of great necessity to evaluate the current extinction risk of cycads in South Africa and also look at this from a bio-geographical point of view.

The IUCN red list provides access to data on different flora and fauna taxa that can be processed to guide and assist in making informed decisions in conservation planning and prioritizing species conservation (IUCN 2001, 2010). This also serves as a template to evaluate trends in extinction risk (Rodrigues et al. 2006; Mace et al. 2008). When certain taxa move from one IUCN threat status to a higher threat status is referred to as increase in extinction risk based on IUCN criteria (Rodrigues et al. 2006). This study collated data on cycads in South Africa and in Africa from IUCN red list 2016 version to evaluate current extinction risk in South African cycads and also look at geographic regions where extinction risk is higher in South African cycads.

4.2 Methodology

There are two cycad genera in South Africa which are *Encephalartos* and *Stangeria* (Osborne et al. 2012). The current conservation status of all the cycad taxa endemic to South Africa were obtained from the IUCN red list 2016 version. Percentages of IUCN threat categories of cycads taxa that have their geographic range in South Africa were calculated. The record of the provinces with cycad taxa in South Africa were obtained from IUCN red list 2016 version. ArcGIS 10.1 was used to generate a distribution map for threatened cycads (with status Critically Endangered, Endangered, Vulnerable) in South Africa, based on the distribution record obtained from IUCN 2016. Previously published 2003 IUCN cycads status in South Africa which is available on the IUCN 2016 red list was compared with the status of each cycad taxa in South Africa. This enabled the determination of cycads taxa that have experienced change of status in South Africa between 2003 and 2016 IUCN status.

4.3 Results and Discussion

There are 37 *Encephalartos* species and 1 *Stangeria* species whose geographic range occur in South Africa as obtained from IUCN red list 2016 version (Table 4.1). The results of the categorical percentages calculation from IUCN 2016 data for cycads in South Africa showed that 65.8% of all cycads taxa in South Africa are currently threatened (Critically Endangered + Endangered + Vulnerable) and a significant percentage of them are already Extinct in the wild (Figure 4.1). Using a benchmark of 10%, Critically Endangered, Endangered, Vulnerable and Near Threatened categories which are higher threat categories contains the larger percentages of South African cycads, while Least Concern which is a category of cycads not threatened contains a very low percentage of South African cycads (Figure 4.1). Population trend result also showed that less than 10% of South African cycads have stable population while the larger percentage are currently experiencing population decline (Figure 4.2). These signals that these taxa are still tending towards higher extinction crisis. Also looking at the geographic range of cycads in South Africa from IUCN 2016, out of nine provinces in South Africa threatened cycads taxa are concentrated to five provinces which are Eastern-Cape, Gauteng, KwaZulu-Natal, Limpopo and Mpumalanga (Figure 4.3; Table 4.1).

Majority of cycad species in South Africa are Critically Endangered which implies that the larger percentage of cycads in South Africa are highly threatened and already at the brink of extinction (Figure 4.1). These Critically Endangered cycad taxa are found in three provinces in South Africa and they are Limpopo, Mpumalanga, and KwaZulu-Natal (Table 4.1). Extinct in the wild cycads had their occurrences in 2 provinces which are Limpopo and Kwazulu-Natal (Table 4.1).

Two out of three South African cycads that are currently Extinct in the wild had their occurrences in Limpopo Province (Table 4.1) which makes this province the one with largest number of Extinct in the wild cycads in South Africa (Figure 4.4). Five Critically Endangered cycads taxa are found in Limpopo Province which is the largest number of Critically Endangered cycads in a single province in South Africa (Table 4.1). These revealed that cycads extinction risk might possibly be higher in Limpopo than any other provinces in South Africa. This also correlates with the study of Okubamichael et al. (2016) which showed that the highest decline in cycads based on repeated photographs of some cycads population in South Africa occurred in Limpopo Province. It is advisable that much conservation effort should be channelled towards cycads in Limpopo Province as there are indications of higher threats to cycads in this province than any other province in South Africa.

KwaZulu-Natal is the next province where Extinct in the wild cycads occurred after Limpopo in South Africa which is one species (Figure 4.4; Table 4.1). It also contain the second largest number of Critically Endangered cycads that occur in a single province in South Africa (Table 4.1). This province also contains the largest number of threatened cycads in South Africa (Table 4.1). Okubamichael et al. (2016) also revealed that after

Limpopo one of the next two provinces that have witnessed alarming decline in cycads based on repeated photo study they carried out on some cycads population in South Africa is KwaZulu-Natal. This placed KwaZulu-Natal among provinces with high extinction risk and decline in cycads in South Africa.

Mpumalanga Province contain the second largest number of threatened cycads taxa in South Africa (Table 1). It contains 4 Critically Endangered cycads which is the second largest number of cycads with such conservation status in a single province in South Africa (Table 4.1). This makes Mpumalanga Province one of the few provinces with threat to cycads taxa in South Africa.

Comparing the results of IUCN status of cycads taxa that occurred in South Africa previously published in 2003 with the current 2016 IUCN status (Table 4.1), it was discovered that 4 cycad taxa have experienced change of status to higher threat status which implies increase in extinction risk within this period (Table 4.1). The increase in extinction risk in 4 cycad taxa which is 10.5% of the total South African cycads between 2003 IUCN status and 2016 IUCN status must have had a significant impact on overall increase in extinction risk in South African cycads within this period. The change of status in these taxa increased the number of Threatened, Near Threatened and Extinct in the wild cycads in South Africa during this period. The geographic range of these taxa might also give a clue on where increase in extinction risk is higher among South African provinces. *Encephalartos brevifoliolatus* experienced increase in extinction risk by changing status from Critically Endangered in IUCN 2003 to Extinct in the wild in IUCN 2016 and its geographic occurrence is Limpopo Province in South Africa (Table 4.1). The justification behind this change of status was due to activities of poachers that have wiped out majority of the population and the fragment left were removed by conservation officials for protection (Donaldson 2010). *Encephalartos ferox* experienced increase in extinction risk changing from the status of Least Concern in IUCN 2003 to Near Threatened in IUCN 2016 and its geographic range in South Africa is in KwaZulu-Natal (Table 1). The justification behind this reclassification was habitat destruction (Donaldson 2010). *Encephalartos nubimontanus* experienced increase in extinction risk by changing status from Critically Endangered in IUCN 2003 to Extinct in the wild in IUCN 2016 and its geographic range is in Limpopo (Table 4.1). The justification for the change of status is poaching activities in Limpopo Province in South Africa (Rogers & Pillay 2010). *Stangeria eriopus* experienced increase in extinction risk by changing status from Least Concern in IUCN 2003 to Near Threated in IUCN 2016 and its geographic range it's in Eastern cape and KwaZulu-Natal (Table 4.1). The justification behind increase in threat of this species was mainly illegal harvest for medicinal purpose coupled with habitat destruction (Williams et al. 2010). These factors that lead to the justification of the change of status of these taxa might have led to population decline as the taxa are decreasing in population on their population trend. This further support extinction risk in recent times is possibly higher in Limpopo, KwaZulu-Natal, and Mpumalanga than the rest of the provinces.

Though cycads in South Africa are threatened everywhere they occur but based on the analysis in this study and additional support from study carried out by Okubamichael et al. (2016), This study concluded that cycads decline and extinction risk in South Africa in recent times was higher in 3 provinces which are Limpopo, KwaZulu-Natal and Mpumalanga in that respective order than the rest of the provinces in South Africa.

4.4 Conclusion

The analysis in this study showed that extinction risk in South African cycads is very high and efforts is still needed to be intensified to reduce this extinction crisis rocking cycad taxa in this country. Because majority of cycads are threatened (Marler & Marler 2015) all taxa in this plant order needs to be well conserved and efforts need to be harnessed to decrease their extinction risk. But despite this, looking at where threatened taxa are more concentrated and also determining regions where increase in extinction risk occurrences is higher might give directional support on where much efforts is needed to be channelled to decrease extinction crisis in the face of limited conservation resources. Although in all regions of South Africa where cycads occur there is a need to intensify cycads conservation efforts, but this study still identified three provinces that needs much attention in terms of cycads conservation in South Africa and these are Limpopo, KwaZulu-Natal and Mpumalanga, because of large decline and higher extinction risk in cycads in these provinces in respect to other provinces. Higher conservation efforts in these provinces might reduce cycads extinction risk in South Africa and in Africa because majority of threatened African cycads are in South Africa. Also factors that have been discovered to be major threats to cycads in these provinces should be well controlled. For instance it was discovered that increase in threat in certain taxa mentioned in this study were mainly due to poaching, harvest for medicinal purpose and habitat destruction. Such threats should be given close consideration in conserving South African cycads. Studies to identify other threats not yet known that might be declining cycads in these 3 provinces should also be encouraged.

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Table and figures as appendix

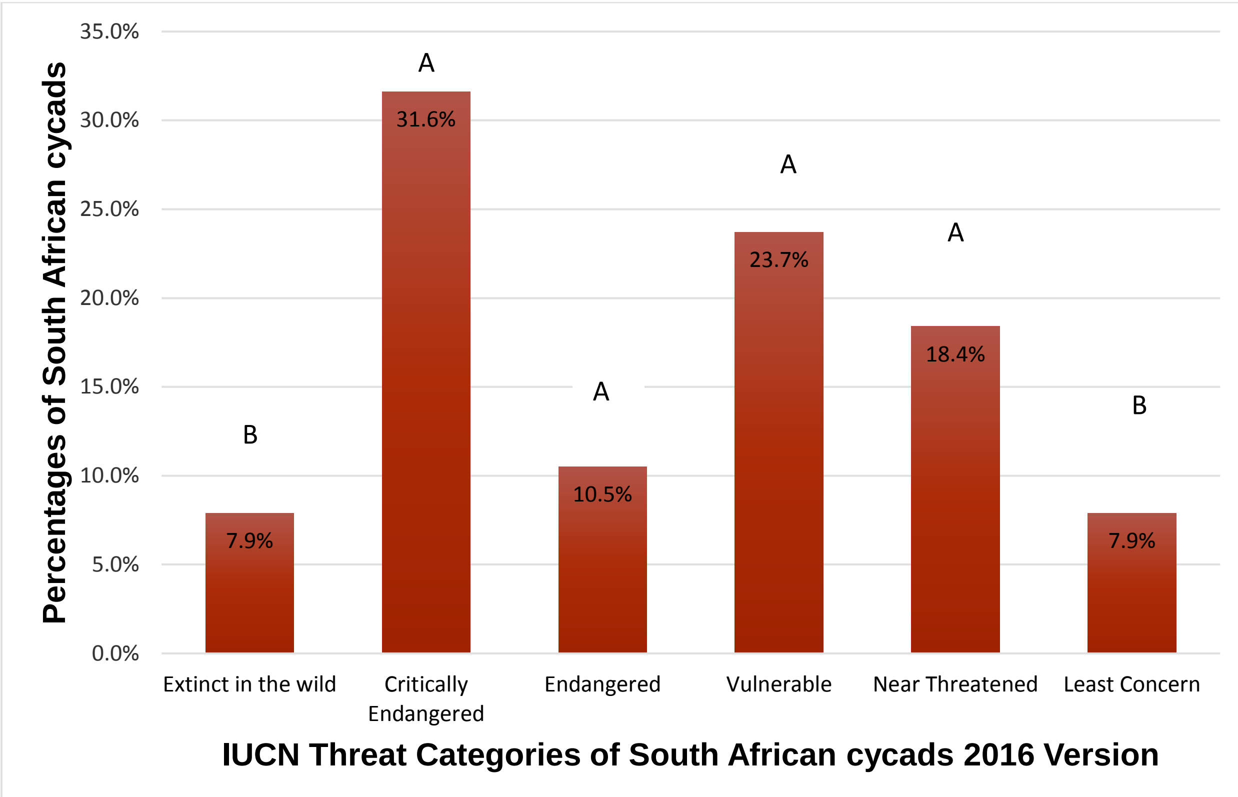

Figure 4.1: Figure showing percentages of IUCN categories of cycads in South Africa based on IUCN 2016 red list.

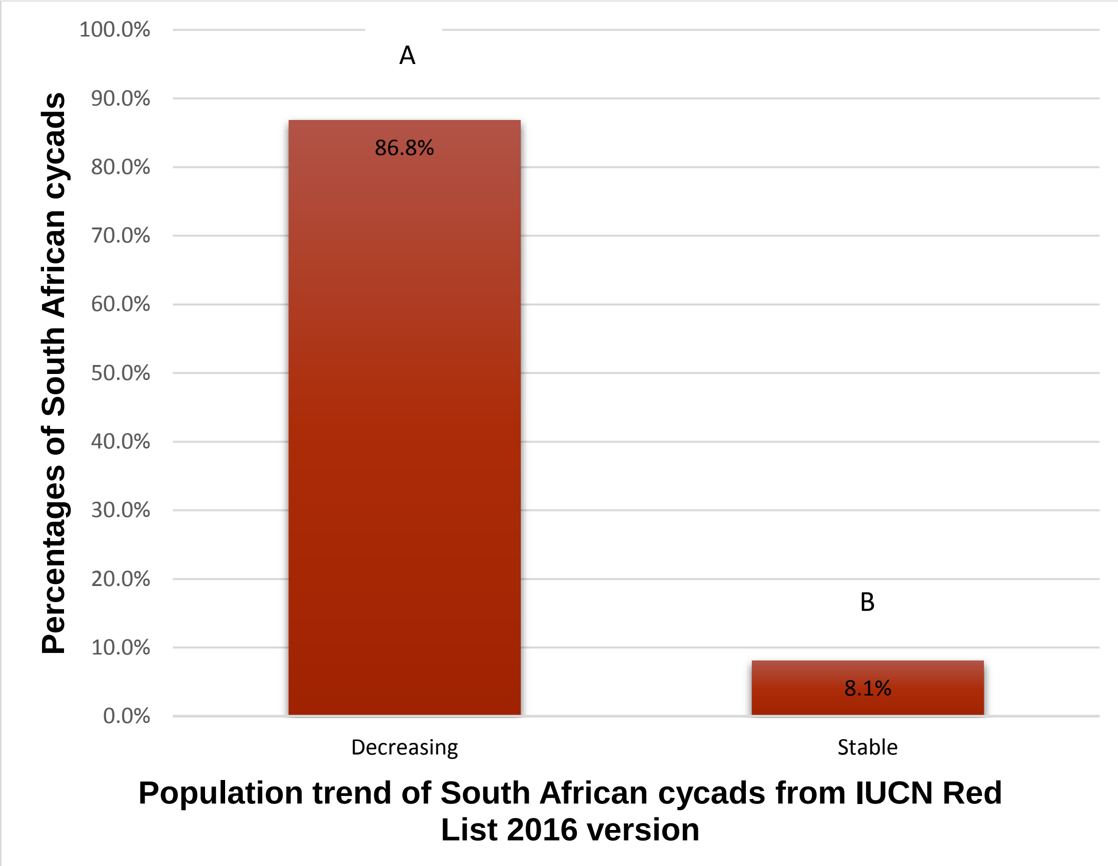

Figure 4.2: Figure showing the percentages of South African cycads experiencing population decreases and stability on IUCN red list 2016 version.

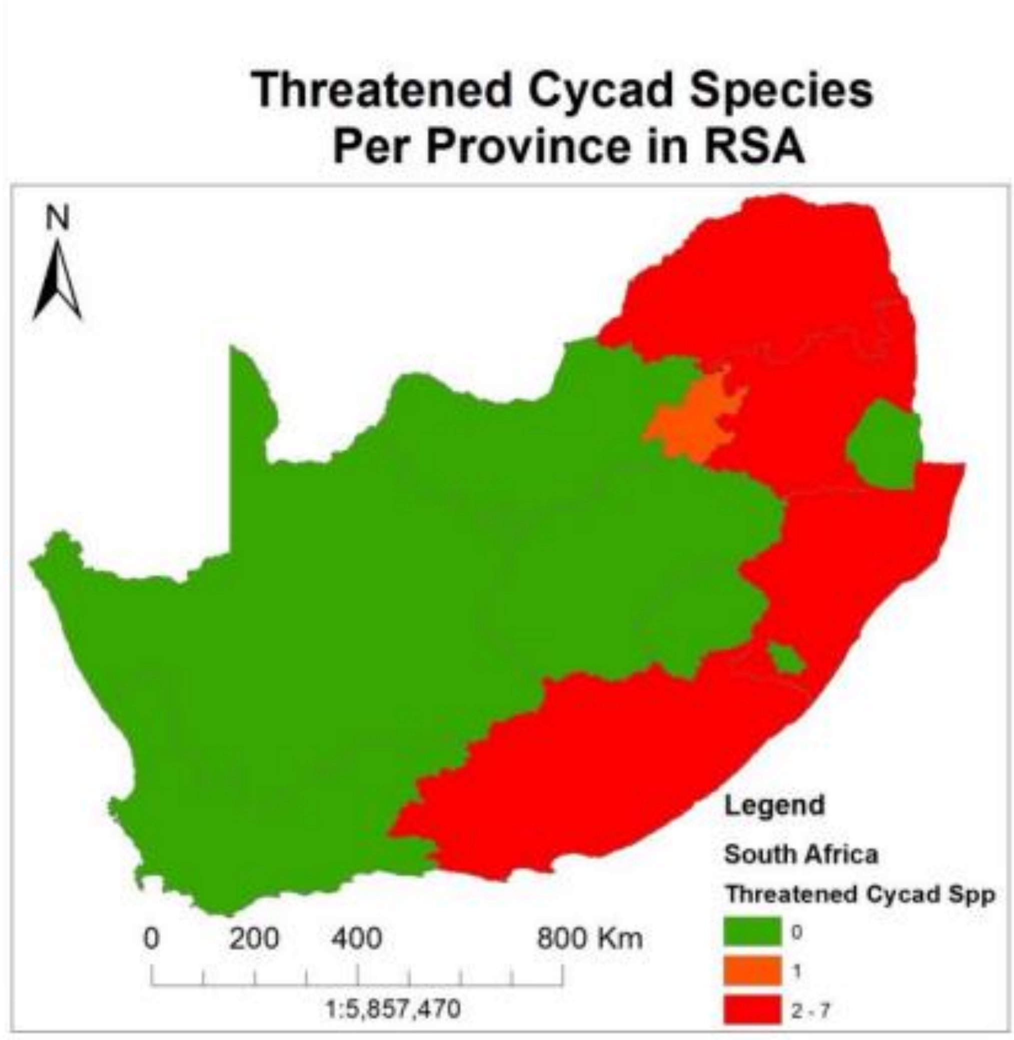

Figure 4.3: Map showing the distribution of threatened cycads in South Africa based on their geographic range on IUCN red list 2016 version.

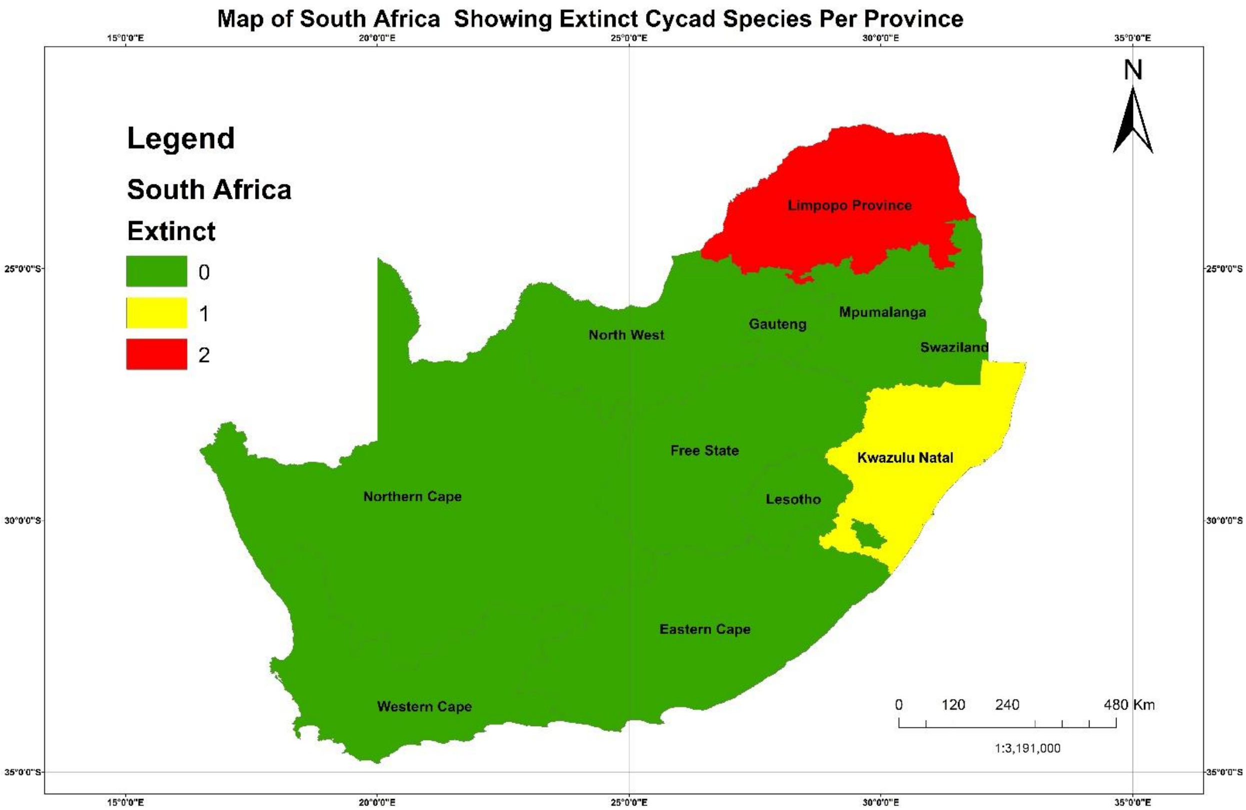

Figure 4.4: Map showing the geographic range of Extinct in the wild South African cycads based on IUCN 2016.

Table 4.1: Cycad taxa in South Africa, their IUCN status, and their geographic range in South Africa.

Family	Species	Previously published IUCN Status 2003 version	IUCN Status 2016 version	Population trend on IUCN 2016	Geographic Range in South Africa on IUCN
Zamiaceae	*Encephalartos aemulans* Vorster	Critically Endangered	Critically Endangered	Decreasing	KwaZulu-Natal
Zamiaceae	*Encephalartos altensteinii* Lehm	Vulnerable	Vulnerable	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos arenarius* R.A.Dyer	Endangered	Endangered	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos brevifoliolatus* Vorster	Critically Endangered	Extinct in the wild		Limpopo
Zamiaceae	*Encephalartos caffer* (Thunb.) Lehm.	Near threatened	Near Threatened	Decreasing	Eastern-Cape, KwaZulu-Natal

Zamiaceae	*Encephalartos cerinus* Lavranos & D.L.Goode	Critically Endangered	Critically Endangered	Decreasing	KwaZulu-Natal
Zamiaceae	*Encephalartos cupidus* R.A.Dyer	Critically Endangered	Critically Endangered	Decreasing	Mpumalanga
Zamiaceae	*Encephalartos cycadifolius* (Jacq.) Lehm.	Least Concern	Least Concern	Stable	Eastern-Cape
Zamiaceae	Encephalartos dolomiticus Lavranos & D.L.Goode	Critically Endangered	Critically Endangered	Decreasing	Limpopo
Zamiaceae	*Encephalartos dyerianus* Lavranos & D.L.Goode	Critically Endangered	Critically Endangered	Decreasing	Limpopo
Zamiaceae	*Encephalartos eugene-maraisii* Verd.	Endangered	Endangered	Decreasing	Limpopo
Zamiaceae	*Encephalartos ferox* G.Bertol.	Least Concern	Near Threatened	Decreasing	KwaZulu-Natal

Zamiaceae	*Encephalartos friderici-guilielmi* Lehm.	Near Threatened	Near Threatened	Decreasing	Eastern-Cape, KwaZulu-Natal
Zamiaceae	*Encephalartos ghellinckii* Lem.	Vulnerable	Vulnerable	Decreasing	Eastern-Cape KwaZulu-Natal
Zamiaceae	*Encephalartos heenanii* R.A.Dyer	Critically Endangered	Critically Endangered	Decreasing	Mpumalanga
Zamiaceae	*Encephalartos hirsutus* P.J.H. Hurter	Critically Endangered	Critically Endangered	Decreasing	Limpopo
Zamiaceae	*Encephalartos horridus* (Jacq.) Lehm.	Endangered	Endangered	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos humilis* Verd.	Vulnerable	Vulnerable	Decreasing	Mpumalanga
Zamiaceae	*Encephalartos inopinus* R.A. Dyer	Critically Endangered	Critically Endangered	Decreasing	Limpopo
Zamiaceae	*Encephalartos laevifolius* Stapf & Burtt Davy	Critically Endangered	Critically Endangered	Decreasing	KwaZulu-Natal, Limpopo, Mpumalanga

Zamiaceae	*Encephalartos lanatus* Stapf & Burtt Davy	Near Threatened	Near Threatened	Stable	Gauteng, Mpumalanga
Zamiaceae	*Encephalartos latifron* Lehm.	Critically Endangered	Critically Endangered	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos lebomboensis* Verd.	Endangered	Endangered	Decreasing	KwaZulu-Natal, Mpumalanga
Zamiaceae	*Encephalartos lehmannii* Lehm.	Near Threatened	Near Threatened	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos longifolius* (Jacq.) Lehm.	Near Threatened	Near Threatened	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos middelburgensis* Vorster, Robbertse & S.van der Westh.	Critically Endangered	Critically Endangered	Decreasing	Gauteng, Mpumalanga
Zamiaceae	*Encephalartos msinganus* Vorster	Critically Endangered	Critically Endangered	Decreasing	KwaZulu-Natal

Zamiaceae	*Encephalartos natalensis* R.A.Dyer & Verdoorn	Near Threatened	Near Threatened	Decreasing	Eastern-Cape, KwaZulu-Natal
Zamiaceae	*Encephalartos ngoyanus* Verd.	Vulnerable	Vulnerable	Decreasing	Kwazulu-Natal
Zamiaceae	*Encephalartos nubimontanus* P.J.H. Hurter	Critically Endangered	Extinct in the wild		Limpopo Province
Zamiaceae	*Encephalartos paucidentatus* Stapf & Burtt Davy	Vulnerable	Vulnerable	Decreasing	Mpumalanga
Zamiaceae	*Encephalartos princeps* R.A. Dyer	Vulnerable	Vulnerable	Decreasing	Eastern-Cape
Zamiaceae	*Encephalartos senticosus* Vorster	Vulnerable	Vulnerable	Decreasing	KwaZulu-Natal
Zamiaceae	*Encephalartos transvenosus* Stapf & Burtt Davy	Least Concern	Least Concern	Decreasing	Limpopo
Zamiaceae	*Encephalartos trispinosus* (Hook.) R.A.Dyer	Vulnerable	Vulnerable	Decreasing	Eastern-Cape

Zamiaceae	*Encephalartos villosus* Lem.	Least Concern	Least Concern	Decreasing	Eastern-Cape, KwaZulu-Natal
Zamiaceae	*Encephalartos woodii* Sander	Extinct in the wild	Extinct in the wild		KwaZulu-Natal
Zamiaceae	*Stangeria eriopus* (Kunze) Baill.	Near Threatened	Vulnerable	Decreasing	Eastern-Cape, KwaZulu-Natal

CHAPTER FIVE

DETECTING THREAT TO *Encephalartos transvenosus* Stapf & Burtt Davy (LIMPOPO CYCAD) IN LIMPOPO PROVINCE, SOUTH AFRICA THROUGH INDIGENOUS KNOWLEDGE

This chapter has been published in Indian Journal of Traditional Knowledge 16(2): 251-255.

Abstract

Indigenous knowledge contains valuable information which is often essential to biodiversity and species conservation. The traditional knowledge of people in local communities can enhance conservation policies and planning and also reveal local perspectives in relation to endangered species. Cycads as a vascular plant group contain the highest percentage of threatened species, at global, regional, national and community levels. This study focused on *Encephalartos transvenosus* Stapf & Burtt Davy, a cycad species endemic to Limpopo Province in South Africa. Despite every effort to conserve this highly endangered species the threats keep increasing and the population trends keep decreasing. Through indigenous knowledge, it was discovered a location of this species not yet conserved within Vhembe district on the Soutpansberg Montane range in Limpopo Province, South Africa. Practices such as bark harvesting, and uprooting of young seedlings were discovered at this population. All these practices noticed at this

location are detrimental to *in situ* conservation of the cycads. This study hereby revealed that indigenous knowledge has a great role in cycads' conservation. Through the local communities, factors that are threatening cycads existence can be determined and the local community can also be integrated into an effective conservation plan that discourages illegal harvesting of cycads.

Keywords: Cycads, Conservation, *Encephalartos transvenosus*, Indigenous Knowledge Systems, Traditional knowledge, Endangered species, Threat.

5.1 Introduction

Indigenous knowledge is defined as specific information from local communities based on culture, lifestyle and practices that are passed from one generation to another (Osunade 1994; Warren 1991; Lunga & Musarurwa 2016). This knowledge is not only important to local indigenes but also useful for scientists and planners in the area of improving the environment, well-being of people and also sustaining natural resource management (Arun 1999; Mundy & Compton 1991). The indigenes of certain local communities have an understanding of the ecosystem functioning of their localities from a number of perspectives. Through long term uses they possess vast knowledge of certain locations of endemic plant species. For instance certain plant species are identified in local communities through local names by reason of their uses for food and medicine (Tshisikhawe 2002; Gangan et al. 2014). This local knowledge can also be very useful in the area of plant conservation.

Cycads are amongst some of the oldest living representative of gymnosperms and they have existed for about 300 million years (Gao and Thomas 1989; Anderson et al. 2007). Davis and Schaefer (2011) suggested a need for integration of the fossil records in a better way in order to improve our understanding of the rate and mode of diversification in the family tree of gymnosperm. They are also the most threatened plant taxon globally containing the highest percentage of threatened plant species (International Union of Conservation of Nature 2010, 2015). Despite conservation efforts there have been steady increase of the threat status and decrease in the population trend in all continents where they occur (International Union of Conservation of Nature 2015). These globally threatened species demands conservation attention to prevent their total extinction. Unlike some other nations of the world where habitat loss is a major cause of cycad extinction risk, South Africa cycads are facing extinction mainly due to bark harvest (Donaldson 2010; Williams et al. 2014). Three species of cycads are extinct in South Africa due to bark harvesting for medicinal purpose (Donaldson 2006). This threat is at global, national, regional and community levels (Bamigboye 2014).

Encephalartos transvenosus Stapf & Burtt Davy is a species of cycad endemic to Limpopo Province in South Africa (Hurter and Glen 1996). This species was once listed as a rare species by Hilton-Taylor (1996) but currently some of them are abundant in places such as Modjadji Nature Reserve which contains about 15,000 individuals alongside some other subpopulations (Donaldson 2009). It was listed as Least Concern by Raimondo et al. (2009) with the population trend decreasing due to wild harvesting of individuals and habitat destruction (International Union of Conservation of Nature 2015). This species is nominally protected under the National Environmental Management Biodiversity act of South Africa (NEM: BA 2004) and also under Limpopo Environmental Management act (LEMA) of South Africa (LEMA, 2004). This study focused on determining threat to these species due to illegal harvest by local communities through indigenous knowledge.

5.2 Materials and Methods

This study was conducted at Mahunguwi in Limpopo Province, South Africa. Mahunguwi is a small rural village of 394 people which falls within Thulamela Local Municipality (Thulamela Local Municipality 2016). According to Acocks (1988), the study site is situated within a sourish mixed bushveld vegetation type of the savanna biome. The annual rainfall of the area as per Tshitavha Weather Station data is 698 mm (Samsam Weather Climate Tool 2016). It is an area geographically characterized by the Soutpansberg mountain range which geology is made up of Makgabeng Plateau, Blouberg Mountains, Pink erosion-resistant quartzite and sandstone with pebbles as the major dominating rocks (Hann 2002). A population of *Encephalartos transvenosus* was found on the east facing slope of the mountain in this location. *Encephalartos transvenosus* population was identified by one of the male traditional knowledge holders through the local Tshivenda name of *Tshifhanga*. Through the local name it was easier to communicate to informant on the plant species and the required information about it.

Ethnobotanical survey was conducted in order to determine the knowledge of the villagers about utilization of this species. Informants above 25 years of age who were willing to participate were randomly selected after prior consent regarding the use of their information for research purposes was sought with them. Twenty nine people selected based on their availability and willingness to participate were interviewed in Tshivenda which is their local language. It was ensured that the people interviewed are people who originate from and reside in this village and they also get their livelihood in Mahunguwi village.

5.3 Results and Discussion

5.3.1 Informants profile and their harvesting perceptions

In the household survey conducted 55% of the informants were males while 45% were females. Convenient approach on selection of informants was adopted after obtaining prior consent from them. Amongst the informants youth (<40 years old) made up 45% while adults constituted 55% (40 years old and above). The adults group in this study consist of people between the age of 40 to 44 years old, middle age people between 45 to 49 years old, while Elderly are people that are 50 years old and above. The statistical test to compare response of males versus females showed Chi-square = 2.9268, 3 degrees of freedon, p = 0.4. Since the pvalue> 0.05, it was concluded there are no significant differences between the response of the male and the female (Table 5.1).

The survey also revealed that the majority of the informants (93.2%) were aware that harvesting of *Encephalartos transvenosus* was illegal, whereas only 2 individuals (6.8%) indicated that they were not aware of its conservation status. This might be probably driven by their needs of making a living out of its harvesting. This should therefore call for a community integrated conservation plan either through nursery propagation or reintroduction (Vovides et al. 2010) which might take people away from the wild harvesting of these plants.

The informants indicated that seedlings from this population had been previously removed and sold resulting in the absence of juvenile individuals. Total removal of the species particularly seedlings for horticultural purposes was also not ruled out.

5.3.2 *Encephalartos tranvenosus* bark utilization

The population of *Encephalartos transvenosus* found in this location has been highly disturbed with bark harvesting on all individuals observed (Figure 5.1 a-d). Harvest for medicinal use is one of the major factors threatening cycad existence in South Africa (Donaldson 2006; Donaldson 2010) and in particular bark harvest is the main factor contributing to cycad extinction in South Africa (Cousins et al. 2014). It was certainly the main threat to the individuals of *Encephalartos transvenosus* found in this population. Some individuals also showed sign of decay as a result of internal stem exposure from this practice (Figure 5.1d).

The informants confirmed that the motive behind harvesting of cycads was mainly medicinal. According to them the reason why the upper part of the bark of *Encephalartos transvenosus* is always being harvested is due to the traditional belief that this part specifically works magic and drives evil spirits away (Figure 5.1a). It was also reported that the rest of the bark parts (excluding the upper part) being harvested are for other medicinal purposes which include anticancer therapy in treatment of females with breast cancer. Poaching of cycads materials has been reported to be influenced by people who want to produce hard drugs prepared by international community. Individuals are therefore completely removed to satisfy the demand of international communities. The informants confirmed that the harvesting of these plants in the wild by the local communities has been unsustainable.

The household survey conducted confirmed that *Encephalartos transvenosus* bark was the most mentioned of all the part used followed by leaves (see figure 5.2). This still support that bark harvest is the greatest threat to cycads in South Africa (Donaldson 2006: Donaldson 2010: Cousins et al., 2012: Cousins et al. 2013: Williams et al. 2014) (Figure 1a, b, c, d) because 48% of the people interviewed mentioned bark as the main part used (Figure 5.2). In figure 5.3, the majority of the respondents (37.5%) mentioned that the inner part of the bark (Figure 5.1a) are taken as hard drugs either through sniffing or smoking. It is being ground into powder and mixed with some other (unknown) substances to be taken as hard drugs. This is a major finding in this study as many studies have only supported that the bark are harvested for medicinal purpose (Donaldson 2006; Donaldson 2010; Cousins et al. 2011; Cousins et al. 2012; Cousins et al. 2013; Williams et al. 2014). This revealed another reason for which the bark of these plants are being harvested, and further studies are recommended to determine the active chemical compound found in this plant that possibly support this use.

5.3.3 *Encephalartos tranvenosus* leaf utilization

The leaf harvest (35%) for roofing huts (25%) and for medicinal use (25%) was detected in this study (Figure 5.2). A study by Krishnamurthy et al. (2013) showed that a population of *Cycas circinalis* L. experienced reproductive decline due to leaf harvest. It can be the case for other cycads species. This means leaf harvest might possibly be a threat to this species especially when the intensity of harvest is very high.

5.3.4 *Encephalartos tranvenosus* roots utilization

The roots of *Encephalartos transvenosus* are also being harvested although at a minimal scale (3%) (Figure 5.2) and will have a negative effect on the recovery process of the plants. Harvesting of roots might lead to death of some of the individuals in the population. According to informants roots of *Encephalartos transvenosus* are only harvested for medicinal purposes. Roots harvest for medicinal purpose is a common practice in Limpopo with majority of the plants harvested for their roots being threatened with extinction (Moeng, 2010; Tshisikhawe et al. 2012). Root harvest is highly detrimental to plants growth and development, and a species of plants like cycads will experience serious decline due to the nature of its slow growing rate which can lead to the species being unable to recover from such practice.

5.4 Conclusion

The present study supports that the practice of cycads harvesting is still ongoing in parts of South Africa. However, quantifying the sustainability of bark harvest of this species was not part of this study because the practice of harvesting cycads for any purpose is a practice not encouraged in South Africa at provincial and national level (LEMA 2004; NEMBA 2004). The location discovered in this study coupled with the surveys from the village where this population is found revealed people are still practicing illegal harvesting of cycads in the wild and there appears to be little impact on reducing this activity from government initiatives aimed at conservation. The role of local indigenous knowledge in identifying locations of cycads and also unravelling the threat through local uses should be respectfully acknowledged and incorporated in designing effective conservation plans. According to Vovides et al. (2010), in their studies in Mexico they concluded that species conservation can be strengthened by looking at species with economic interests of local people and include them in rural nurseries. Rare species like cycads can be rescued, transplanted and reintroduced in natural areas with minimal anthropogenic impacts with community involvement. Such effective community participation in conservation plan could possibly reduce threat to cycads and limit wild harvest (Krishnamurthy et al. 2013). This study also recommend that such conservation plan with community involvement should be implemented in areas such as this in a unique way that it might take the community people away from illegal wild harvest of this species. The local community also needs to be sensitized on the need to restrict people from collecting these plants because of its implication of losing them in the future. This can be in the form of conservation education so as to enlighten the community people on the value that should be placed on these plants that they are privileged to have in their community.

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Figures and tables as appendix

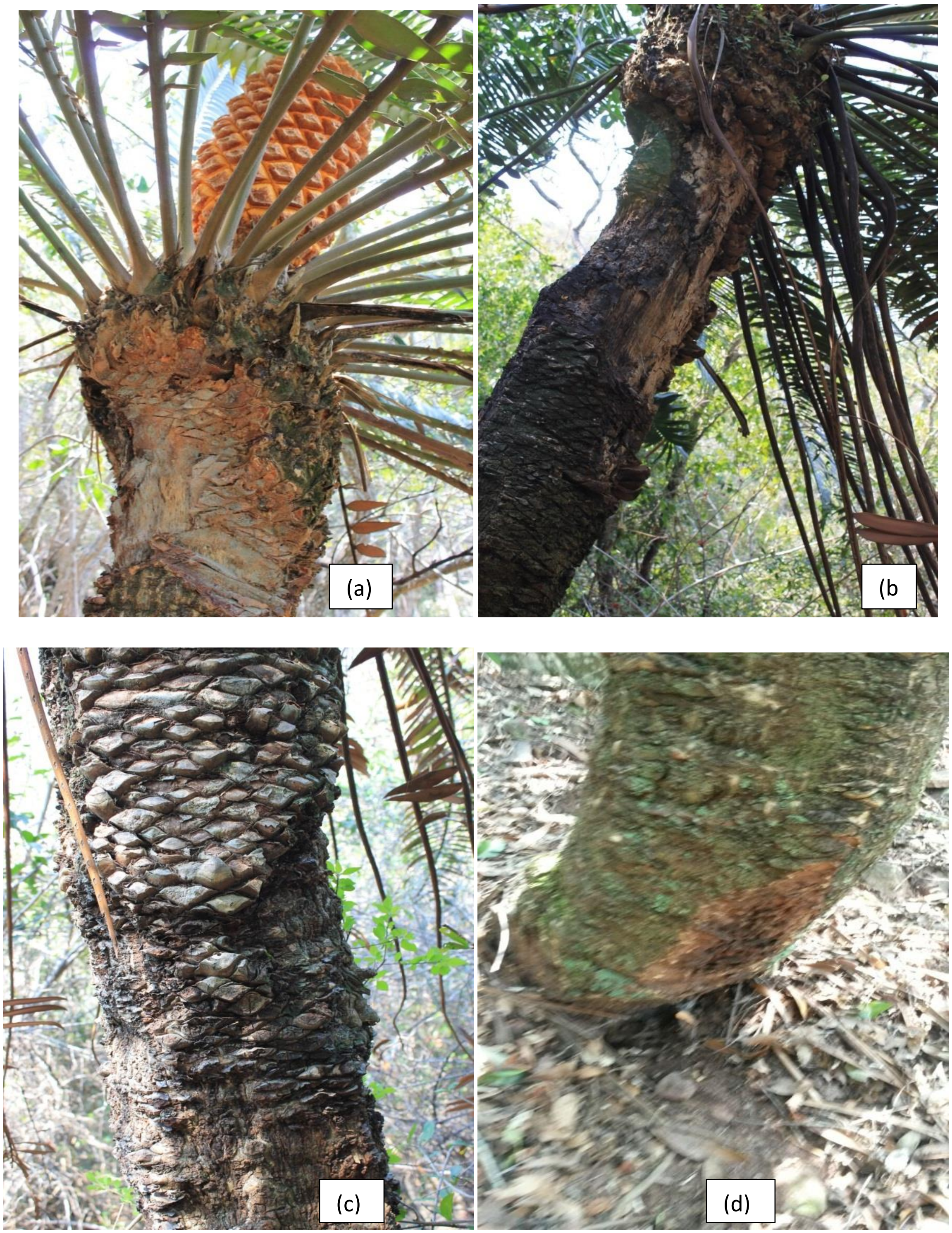

Figure 5.1: Debarking of *Encephalartos transvenosus* for medicinal purposes.

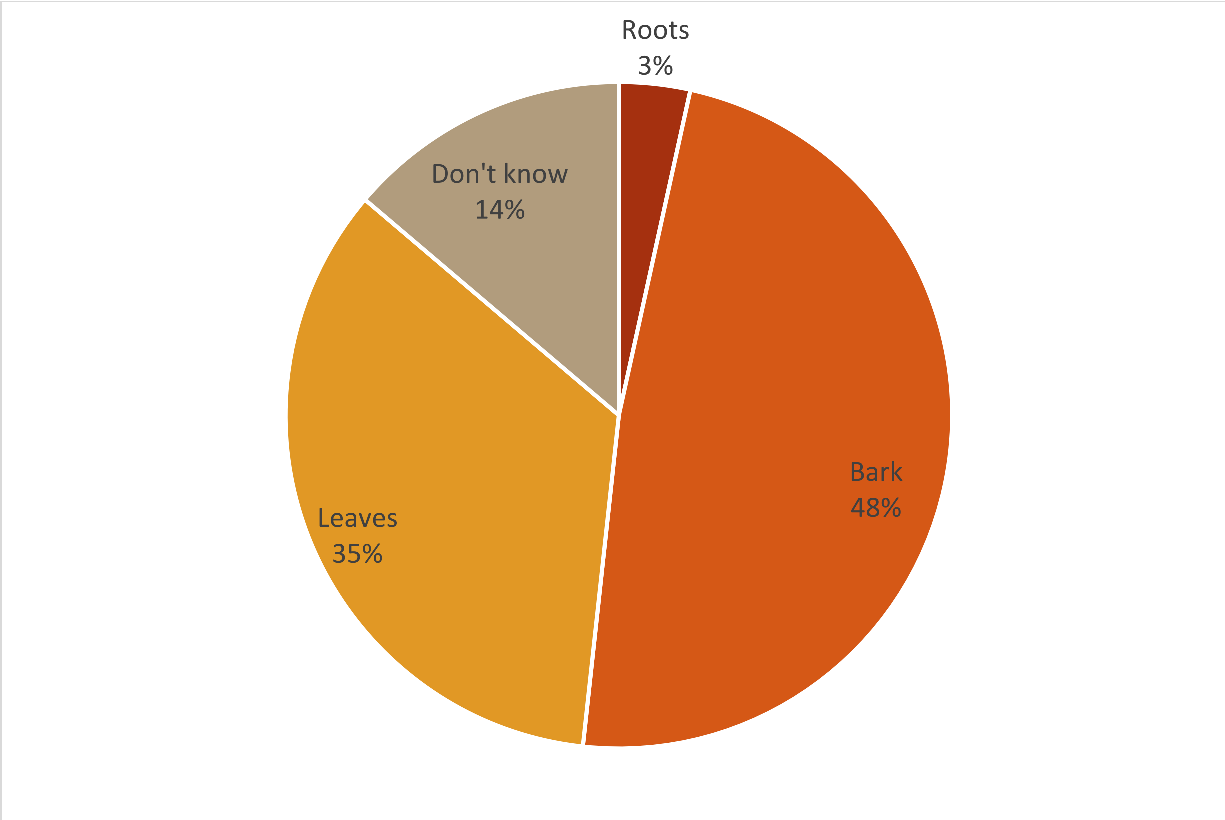

Figure 5.2: Informants responses on *Encephalartos transvenosus* parts utilization frequencies.

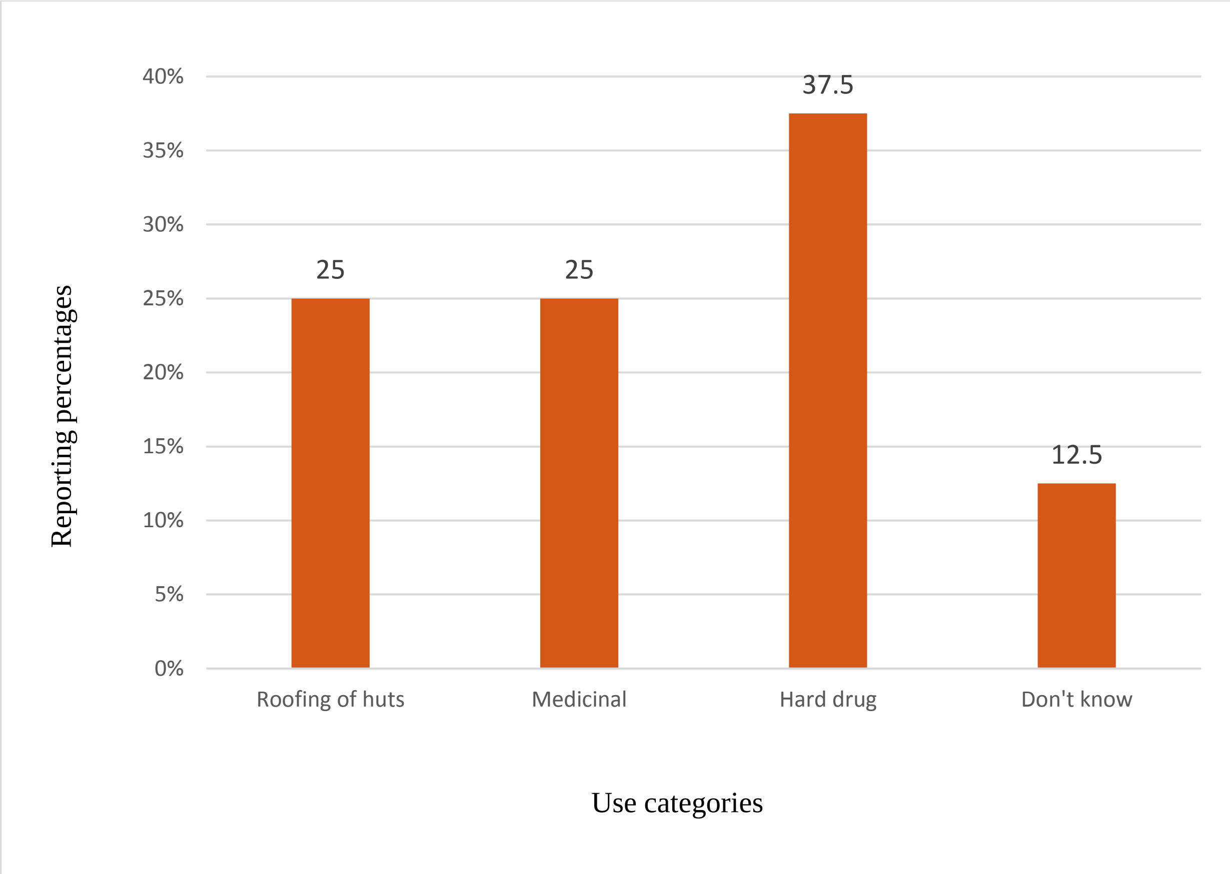

Figure 5.3: Informants responses on *Encephalartos transvenosus* use category frequencies.

Table 5.1: An inventory of responses on the utilization of *Encephalartos transvenosus*.

		Roofing huts	Hard drugs	Medicine	Don't know
Male	Youth		2		1
	Elder	3	3	3	
	Middle Age	2		1	1
Male (Total additions)		5	5	4	2
Female	Youth		2		
	Elder	2	5	1	
	Middle Age				1
Female (Total additions)		2	7	1	1

CHAPTER SIX

UNRAVELLING THREAT TO AN *Encephalartos transvenosus* Stapf & Burtt Davy (LIMPOPO CYCADS) POPULATION IN MUTALE MUNICIPALITY IN LIMPOPO PROVINCE SOUTH AFRICA

This chapter is under review in *Acta Botanica Hungarica*

Abstract

Cycads are the most threatened plant species in the world and there are a wide range of ecological and anthropological forces responsible for the extinction risk of these taxa. South Africa is one of the main cycad global hotspots and the cycads in this country are facing high extinction risk. This study sampled a population of *Encephalartos transvenosus* Stapf & Burtt Davy, a cycad species endemic to Limpopo Province in South Africa. The population was found on Soutpansberg mountain range in Mutale municipality in Limpopo Province. Individuals in the population were sampled to determine the threats they are facing and also to quantify the degree of the threats. This study revealed that the majority (47%) of the plants have been damaged by bark harvesting. A significant mortality rate (9%) was also noticed in the population sampled. This study revealed current threats this species is facing based on the individual sampling and the study

therefore recommend further population studies to give a broader understanding of impacts and population trends for reassessment of threat status of this species.

Keywords: Cycad, Conservation, *Encephalartos transvenosus*, Population, Threat

6.1 Introduction

Cycads are a rare group of species with the highest threats among all plant groups in the world (International Union of Conservation of Nature 2010). Factors threatening cycad species range from illegal harvesting for horticultural purpose, harvesting for medicinal purpose, the presence of alien and invasive species and climate change (Donaldson 2003; Donaldson 2010). Extinction risk for African cycads has increased in recent times (Bamigboye et al. 2016) and South Africa, which harbours 70% of cycad species in Africa (Golding & Hunter 2003), is highly affected with current assessment showing that out of 37 cycad taxa in South Africa, 12 are critically endangered, 4 endangered, 8 vulnerable while 10 are Near Threatened or Least Concern which implies only 10 (27%) of them are not threatened according to IUCN categories of threatened species (Donaldson 2008; Raimondo et al. 2009; IUCN 2010).

Okubamichael et al*.* (2016) in their study using repeated photographs of cycad population discovered that cycads were declining more in Limpopo Province than any other province in South Africa. This suggests that there might be a higher extinction risk for cycads occurring in Limpopo.

Encephalartos transvenosus Stapf & Burtt Davy is a species of cycads endemic to Limpopo Province (Hurter & Glen 1996). It is nominally protected under the Limpopo

Environmental Management Act (LEMA 2003) and the National Environmental Management Act 2004 of South Africa in terms of threatened and protected species (NEMBA 2004). Hitlton-Taylor listed this species as rare in about two decades back but it is currently abundant in some places such as Modjaji nature reserves with other subpopulations with its total populations containing about 15,000 individuals hence currently listed as Least Concern (Donaldson 2009). Though this species is being classified as not threatened but it is experiencing population decline due to habitat destruction and illegal collection (Donaldson 2009). This can possibly increase the threat status if this population decline trend continues over certain periods of time except conservation measures are taken to reverse the trend. The bark of this species has been reported to be traded at *Muthi* (traditional medicine) shops and street vendors for medicinal purposes in different districts of Limpopo Province in South Africa (Moeng 2010; Tshisikhawe 2002; Tshisikhawe et al. 2012). Also some other publications (Ravele & Makhado 2009; Bamigboye et al. 2017) have revealed that this species is being harvested for medicinal, horticultural, hard drugs, and roofing hut purposes with the bark, leaves and the roots being harvested for these purposes. In this study field survey was conducted to determine the possible threat to one population of *E. transvenosus* found in Mutale Local Municipality in Limpopo Province, South Africa.

6.2 Methodology

This study surveyed 34 individuals of a population of *E. transvenosus* which is located on the east facing slope of Mahunguwi village in Mutale Municipality in Limpopo Province in South Africa. The population sampled is a discrete population located on a mountain which is within the Soutpansberg mountain range and all the individuals in this population were sampled. Measurements of the height of individuals and the diameter of the stems were taken. A size class distribution curve for this population was constructed. Size class distribution is a method of determining the status of a population if it is healthy or not and also a way of assessing impact of harvesting in a population (Cunningham 2001; Tshisikhawe & Van Rooyen 2012). Size class distribution of a population also shows the reproductive capacity, new individuals' recruitment, chances of one class surviving to the other and ability of the population to survive ecological disturbance (Shaukat et al. 2012). According to Cunningham (2001), hypothetical intervals can be selected based on the sizes of the diameter of the stem of vascular plants individuals in a certain population in order to plot a curve that shows the state of a population. This is to show different growth stage of individuals in a certain population. For instance, the class interval can show whether some set of individuals are seedlings, juveniles, young adults and matured adult. The individuals in the population sampled were classified into size classes with 19 cm intervals for size class differences based on their stem diameter, and the frequency of individuals in each size class were plotted on a graph to determine the status of the population.

Iindividuals of this species in this population were observed to find out the threats they are facing. Bark harvesting is one major threat found in most of the individuals sampled (Figure 6.2), and this study determined the percentage of individuals that have suffered bark damage and also quantified the extent of the bark damage by categorizing them based on the percentage of the stem that had been damaged. Individuals that have suffered mild damage have 5% to 30% of their stem already damaged, individuals with severe bark damage have 40% to 50% of their stem already damaged, while individuals with very severe damage have 60% and above of their stem already damaged (Figure 6.2). Crown damage was noticed (Figure 6.4) and the percentage of individuals affected by this was also determined. The number of individuals that have suffered insect and fungal attacks were quantified and test of significance between the stem attacked and and stem harvested were calculated.

6.3 Results

The result of the size class distribution shows a rough bell shaped curve (Figure 6.1). A J-shaped curve in a tree population size class distribution based on the stem circumference indicates presence of seedlings, continuous recruitments of young individuals and presence of juveniles, a straight line indicates relatively low number of seedlings and young individuals while the bell shaped curve indicates lack of seedlings and young individuals. The two former curve types are relatively better population types than the latter curve which signifies unhealthy population. Due to the nature of the population based on the curve of individuals in different size classes in this study, it was concluded that the population sampled was an unhealthy population (Figure 6.1). Three dead individuals (8.8%) were recorded (Figure 6.3) while fifteen individuals (44.1%) suffered no bark damage (Table 6.1), with three individuals (8.8%) showing mild bark damage, four individuals (11.8%) showing severe bark damage and nine individuals (26.5%) of the population showing highly severe bark damage (Table 6.1). Four individuals had suffered complete crown damage in which everything that should be found on the crown such as cone, leaves have been damaged (Table 6.1; Figure 6.4).

Evidences of insects and fungal attack were noticed on 32% of the individuals of the population. Insect/fugal attack was related to tree de-barking, since none of the 15 trees that were not de-barked were attacked, whereas 37.5% of the 16 de-barked individuals showed insect or fungal attack (Table 6.1). Moreover, individuals showing evidence of fungal or insect attack (n=10) had significantly greater extent of damage, in terms of the proportion of tree diameter (10.5%), compared to individuals without observed damage (1.6%, n=21) (t=5.4; p< 0.001). There were no significant differeces between the age/size of the individuals as there was no difference in tree diameter with evidences of insect and fugal attack and the one without insect and fungal attack.

6.4 Discussions and Conclusion

Bark harvesting is a major threat to cycads in South Africa (Donaldson 2006; Donaldson 2010; Cousin *et al.* 2011; Cousin *et al.* 2012; Cousins *et al.* 2013; Cousins *et al.* 2014; Bamigboye et al. 2017) and was also the main threat found in the cycad population studied (Table 6.1; Figure 6.2). Close to half of the population has been severely damaged by bark harvesting (Table 6.1). From the observations on the field, individuals may have died due to bark harvesting and insect and fungal attack (Figure 6.3). The result showing significant correlation between insect and fungal attack with bark harvesting suggest that the bark damage migh likely be exposing these individuals to these insect and fungal attack. This might have resulted into the unhealthy state of this population (Figure 6.1) as size class distribution curve also shows impact of harvesting on a population (Shaukat et al. 2012; Tshisikhawe & Van Rooyen 2012). The poor state of this population might be due to the bark harvesting noticed in this population sampling. The field observations revealed that the majority of individuals sampled that have not yet been debarked are located on the topmost region of the mountain which is difficult to access. Lack of easy access to these individuals must have shielded them from these threat.

The causes of crown damage noticed in this study could not be ascertained, but Ravele and Makhado (2009) noted that monkeys and baboons eat the cones and leaves of *E. transvenosus*. This might also be the reason behind the crown damage noticed on some individuals in this population as baboons presence were noticed on the mountain during this field survey and individuals with crown damage have their leaves and cones completely destroyed (Figure 6.4). This is also detrimental to the survival of individuals of this species.

Broader population sampling of this species is encouraged to provide population data, which would be valuable for re-assessing the threat status of this species. This study can provide additional data that can assist in re-assessing this species. This should lead to future research of sampling large populations of *Encephalartos transvenosus*. This study also gave a picture of damage being experienced by individuals located outside the reserves.

Bark harvest and crown damage not specifically mentioned on IUCN as a threat to this species should be listed as threats or potential threats as this were the threats found in the population sampling. This study might be an awakening to possible need of reassessment of this species and also the need for additional effort to enforce protection of this species. Conservation efforts will need to be intensified in the area of working with the communities where the population of this species are found to ensure protection and sustainability of this species as this might possibly reduce the risk of extinction of this species.

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Figures and table as appendix

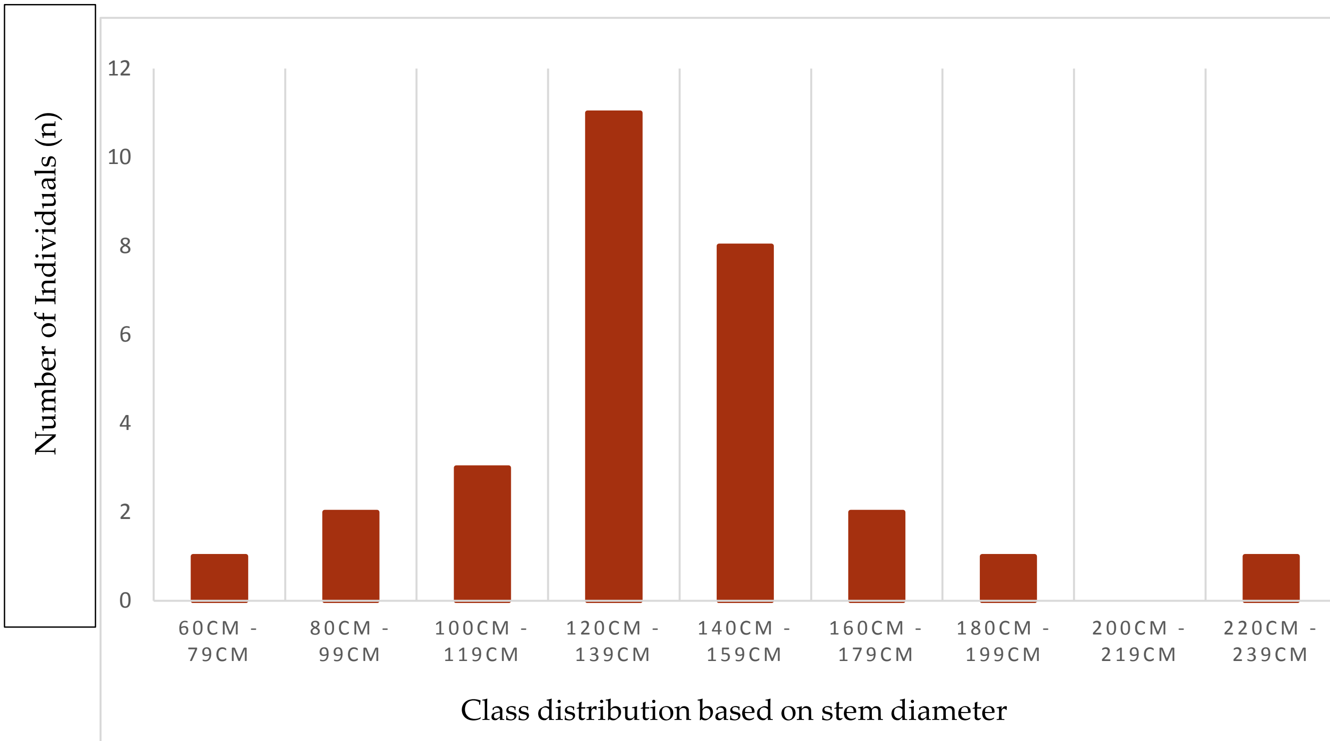

Figure 6.1: Figure showing the pattern of size class distribution of a population of *Encephalartos transvenosus* in Mutale Municipality in Limpopo Province, South Africa.

Figure 6.2: Pictures showing bark damage on some individual of *Encephalartos transvenosus.*

Figure 6.3: Pictures of dead individuals of *Encephalartos transvenosus* which showed they have suffered bark damage and disease infestation.

Figure 6.4: Picture showing crown damage of *Encephapartos transvenosus.*

Table 6.1: Number of individuals, their stem circumference, category of damage noticed on the individual or not, and whether there is crown damage on the individual or not. *[In the category of stem damage column, A- Stands for individuals with no bark damage (0% of the total area of the stem affected), B- stands for individuals with mild bark damage (5 to 30% of the total area of the stem affected), C- stands for individuals with severe bark damage (40 to 50% of the total area of the stem affected) and D- stands for individuals with highly severe bark damage (60% and above of the total stem area affected). Note that individuals that are completely dead were assigned "No record" for each column on the table].*

Individuals numbering	**Basal stem diameter (cm)**	**Category of extent of stem damage of individuals**	**Crown damage or no crown damage on individuals**	**Insect/Fungal attack due to bark harvesting**
1	130	A	No crown damage	No insect/Fungal attack
2	140	D	No crown damage	Fungal attack
3	130	D	No crown damage	Insect attack
4	170	A	No crown damage	No insect/fungal attack

5	70	A	No crown damage	No insect/fungal attack
6	180	B	No crown damage	Insect attack
7 (Dead Individual)	No record	No record	No record	No observation
8	130	C	No crown damage	No insect/ fungal attack
9	120	D	No crown damage	No observation
10	130	C	No crown damage	No insect/fungal attack
11 Dead Individual	No record	No record	No record	No observation
12	140	B	No crown damage	No insect/ fungal
13	108	D	No crown damage	No insect/fungal attack

14	110	B	No crown damage	No insect/fungal attack
15 (Dead Individual)	No record	No record	No record	No observation
16	140	D	No crown damage	No inset/fungal attack
17	90	D	Complete crown damage	Fungal attack noticed
18	140	D	Complete crown damage	Fungal attack noticed
19	120	D	Complete crown damage	Insect attack noticed
20	140	D	No crown damage	Fungal attack
21	140	C	Complete crown damage	No insect/fungal attack
22	130	C	No crown damage	Insect attack noticed

23	160	A	Complete crown damage	No insect/fungal attack
24	120	A	No crown damage	No insect/fungal attack
25	100	A	No crown damage	No insect/fungal attack
26	90	A	No crown damage	No insect/fungal attack
27	110	A	No crown damage	No insect/fungal attack
28	120	A	No crown damage	No insct/fungal attack
29	150	A	No crown damage	No insect/fungal attack
30	130	A	No crown damage	No insect/fungal attack
31	150	A	No crown damage	No insect/fungal attack

32	160	A	No crown damage	No insect/fungal attack
33	120	A	No crown damage	No insect/fungal attack
34	220	A	No crown damage	No insect/fungal attack

CHAPTER SEVEN

INVESTIGATING CORRELATION BETWEEN EXTINCTION CRISIS AND SPECIES RICHNESS IN SOUTH AFRICAN CYCADS

Abstract

Extinction crisis in South African cycads which is a global hotspot for cycads have been very high in recent times. Several ecological and anthropological forces pose threats to the survival of these taxa in South Africa. This study used comprehensive distribution records on cycads in South Africa obtained from the South African National Biodiversity Institute (SANBI) to determine the correlation between species richness and extinction risk in South African cycads. The threat status of the herbarium taxa were obtained from IUCN 2016 version and were analysed. Also threats to these taxa were extracted from IUCN and the number of taxa facing each threats were determined to unravel the prominent threats to these taxa. The herbarium records were used to construct a species distribution map for all the cycads in South Africa and another map for Critically Endangered and Extinct South African cycads. This study revealed that regions of high species richness for cycads are not the same as regions with highly threatened and extinct South African cycads. Also prominent threats found in these taxa are also the major threats to these highly threatened and extinct cycads concentrated to few provinces

in a particular region in South Africa. This study therefore recommend that conservation efforts should be intensified to control threats in this hotspots of highly threatened and extinct South African cycads to minimize their extinction crisis caused by threats that are mainly human induced.

7.1 Introduction

Cycads are made up of long lived woody gymnosperms that possess a perennial caudex or trunk and leaves that are shed and renewed over a long period of years (Davis & Schaefer 2011). They are ancient plants with long evolutionary history dated back to about 300 million years ago (Stevenson 1990; Makhegu 2007) and they are referred to as living fossils (Klavins et al. 2003). Though cycads are believed to be ancient, majority of the extant cycads have recent origin with their radiation dated back to Pleistocene era (1.75 million year to 10,000 years ago) (Crisp & Cook 2011; Nagalingum et al. 2011).

Initially cycads were placed in three families which are Cycadaceae Stangeriaceae and Zamiaceae (Johnson 1959), but due to lack of generic confidence only two of them are currently recognized, which are Zamiaceae and Cycadaceae (Donaldson 2003). The genera represented in Zamiaceae are *Bowenia* Hook ex. Hook f., *Ceratozamia* Brongn., *Dioon* Lindl., *Encephalartos* Lehm., *Lepidozamia* Lehm., *Macrozamia* Miq., *Microcycas* (Miquel) A.DC., *Stangeria* T.Moore, and *Zamia* L., while Cycadaceae has only one genus *Cycas* L. (Christenhusz et al. 2011). Cycadaceae geographical distribution is along the coast of Africa, Madagascar, and Australasia (Donaldson 2003; Hill et al. 2003). Zamiaceae is more diverse geographically compared to Cycadaceae with its distribution spanning between North and South America, Australia, and Africa (Donaldson 2003; Hill et al. 2003). Though cycad species are found in 59 nations of the world over 70% of them are represented in three countries which are; Australia, Mexico and South Africa (Stevenson et al. 2003).

Cycads are the most threatened plant taxa globally (International Union of Conservation of Nature 2010). Factors threatening their existence include illegal harvest to be traded for horticultural purpose (poaching), harvest for medicinal uses, habitat destruction, invasive species presence in areas of cycad populations (Donaldson 2003: Hill et al. 2003) and climate change (Donaldson 2003). These have contributed immensely to decline of these endangered species in the past years.

In recent time there has been a significant increase in extinction risk in African cycads (Bamigboye et al. 2016). South Africa has been greatly affected as in contains 70% of African cycads (Golding & Hurter 2003) and also the third largest number of cycads taxa in the world (Osborne et al. 2012).

This stidy used the South African National herbarium records coupled with IUCN data to determine the correlation between extinction risk and species richness in South African cycads, and also determined the major threats responsible for extinction crisis in South African cycads.

7.2 Methodology

Comprehensive herbarium records of 38 South African cycads were obtained from the South African National Biodiversity Institute (SANBI). The totality of the distribution records as made available from the South Affrican National herbarium totals 285 reords for all the species. The IUCN status of all the taxa were obtained from the IUCN red list 2016 version. Also the threats to each species were obtained from IUCN red list 2016 version. The categorical percentages of IUCN for South African cycads was calculated by determining how many percentages of South African cycads are Extinct in the wild, Critically Endangered, Endangered, Vulnerable, Near Threatened and of Least Concern. Percentages of South African cycads facing each threat found on IUCN were also calculated. ArcGIS (www.gis.com) was used to construct a quarter degree grid species richness map for all the South African cycads using coordinates of all South African cycads obtained from the above-mentioned herbarium database. A map was also constructed using the SANBI records for South African cycads that are Extinct in the wild and Critically Endangered on IUCN 2016 version. The reason for focusing on these two categories of South African cycads was to determine the spatial distribution of extinction risk in South Africa. Extinct in the wild are taxa that no more occur in their natural habitat and also Critical Endangered taxa are the most threatened taxa at the brink of extinction based on IUCN categories. These two groups are good representation of taxa that are experiencing and have experienced higher extinction crisis. The reason for generating the two maps is to determine the correlation between extinction crisis and species richness in South African cycads. Percentages of South African cycads facing each threat found on IUCN were calculated. Also, percentages of Critically Endangered and Extinct in the wild South African cycads facing different kind of threats identified on IUCN red list were calculated. This is to determine the cause of extinction crisis of these extinct and highly threatened (Critically Endangered) South African cycads.

7.3 Results and Discussions

In the result of the threat categories of South African cycads on IUCN, the majority of the South African cycads are Critically Endangered while three of them are already extinct in the wild (see figure 7.1). Among categories of threatened South African cycads (Critically Endangered, Endangered and Vulnerable), Critically Endangered category which is the most threatened category contains the highest percentage of South African cycads (Figure 7.1). This shows that this category (Critically Endangered) is a good representation of South African cycads facing extinction risk problem. These Extinct cycads taxa and the highly threatened ones (Critically Endangered) are in Limpopo Province in South Africa (Figure 7.3). Species richness in South African cycads is highest in Eastern Cape decreasing towards Kwazulu-Natal and north to Limpopo Province (Figure 7.2). But the Critically Endangered and Extinct in the wild cycads are more in Limpopo decreasing down southward direction to Mpumalanga, Gauteng and Kwazulu-Natal with few in Eastern-Cape (Figure 7.3). These two trends are in opposite directions (Figure 7.2 and 7.3). There are 7 categories of threat to South African cycads obtained from IUCN 2016 version (Figure 7.4). These are individual’s collection from the wild, ornamental uses, uses for medicinal purposes, habitat destruction, reproductive failure, drought and fire occurrences, and damages done to cones, leaves and stems of these plants by animals such as baboons and porcupines (Figure 7.4). But out of these seven categories, four are more prominent and they are individual's collection, habitat destruction, ornamental purpose and reproductive failure (Figure 7.4). Also the four prominent threats among all South African cycads are more prominent among the extinct and critically endangered South African cycads concentrated more to the upper north region of South Africa (Figure 7.3 and 7.5). This showed a strong correlation between these prominent threats and extinction crisis in South Africa which occurred at the upper regions in opposite direction to high species richness (Figure 7.3 and 7.5). It can therefore be infered that these regions of extinct and highly threatened South African cycads are more prone to these prominent threats than regions with higher species richness. Vulnerability of these region to these threats might have made them hotspots of Extinct and the most threatened (Critically Endangered) cycad taxa in South Africa hence becoming regions of cycads higher extinction crisis in South Africa.

7.4 Conclusion

The global extinction crisis is largely due to anthropogenic activities and some geographic areas are more vulnerable to this factor than others (Turvey 2009; Barnosky et al. 2011; Mukwevho 2014). Also extinction crisis within different taxonomic groups occurs more in certain geographical regions than others (Mukwevho 2014). Cycads generally are experiencing extinction crisis and decline everywhere they occur and to date this group still contains the largest percentage of threatened and vulnerable plant species among plant taxa that have been assessed globally (IUCN 2010). But despite that majority of the taxa in this group are threatened, certain geographic areas witness higher extinction occurrences of these taxa than others. Out of nine provinces in South Africa, this study identified three provinces which are Limpopo, Mpumalanga and Kwazulu-Natal as provinces that is experiencing higher extinction crisis in South Africa than the rest of the provinces but with major extinction problem in Limpopo. It was also discovered in this study that the up north movement trend of increasing order of extinction crisis does not correlate with the downward south movement of species richness increase with majority in Eastern Cape in South African cycads. Prominent threats to South African cycads are also the main forces found as causes of extinction of the highly threatened and extinct cycad taxa in South Africa. This study therefore recommend stronger conservation practices to minimize these prominent threats (individual's collection, habitat destruction, ornamental purpose and reproductive failure) in these provinces with more extinction occurrences in this plant group in order to minimize cycads extinction crisis in South Africa.

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Figures and Table as Appendix

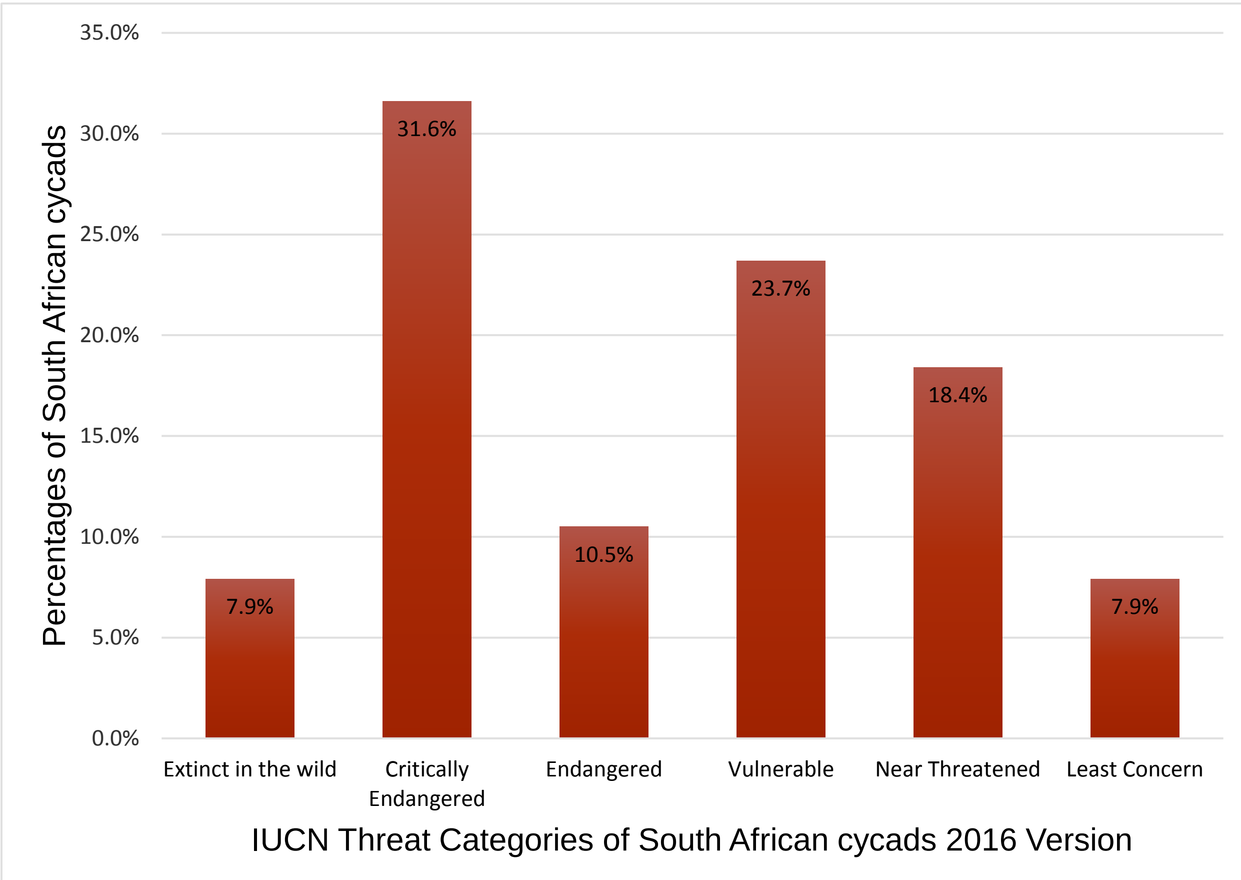

Figure 7.1: Figure showing the percentages of South African cycads in each IUCN threat categories.

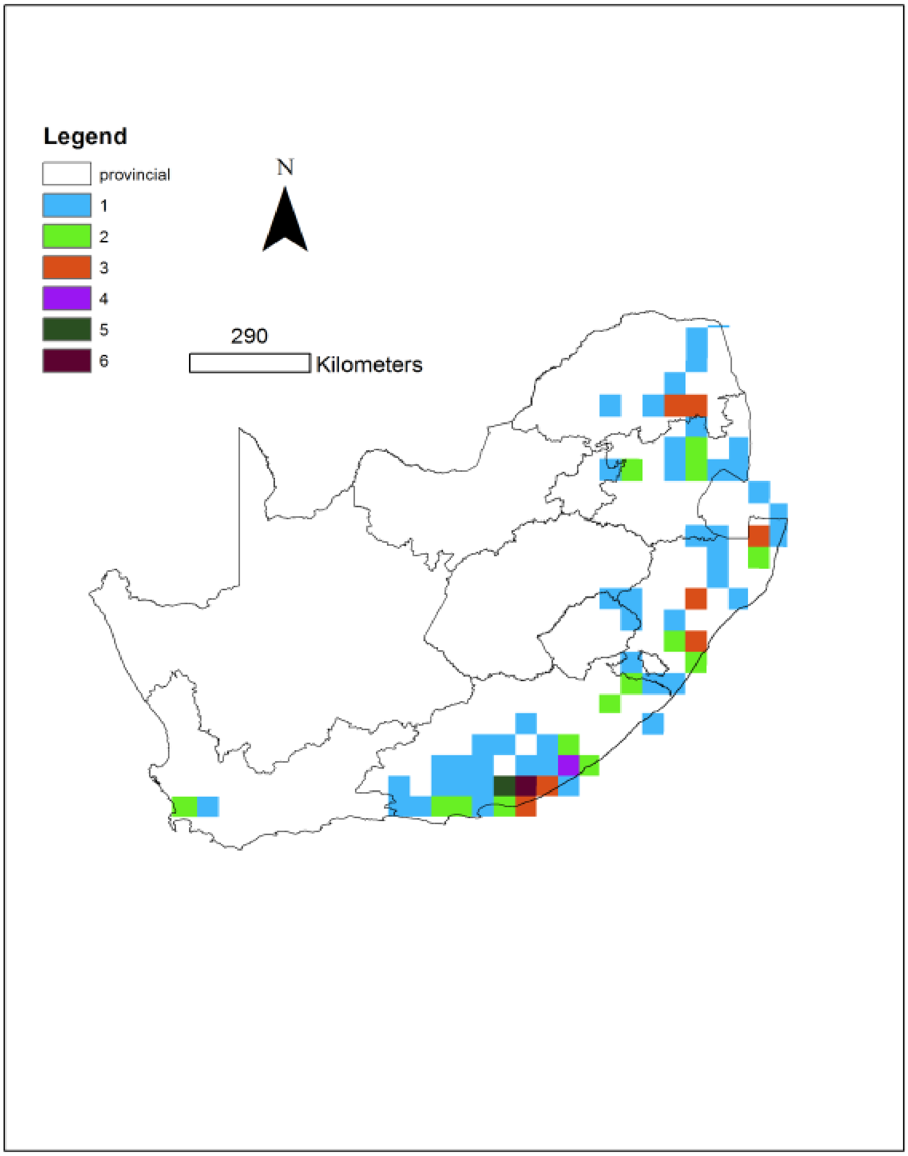

Figure 7.2: Map of species richness (quarter degree grid) for 38 species of cycads in South Africa using herbarium records (coordinates) from South African National Biodiversity institute (SANBI). All species (colours in legend represent number of species per grid).

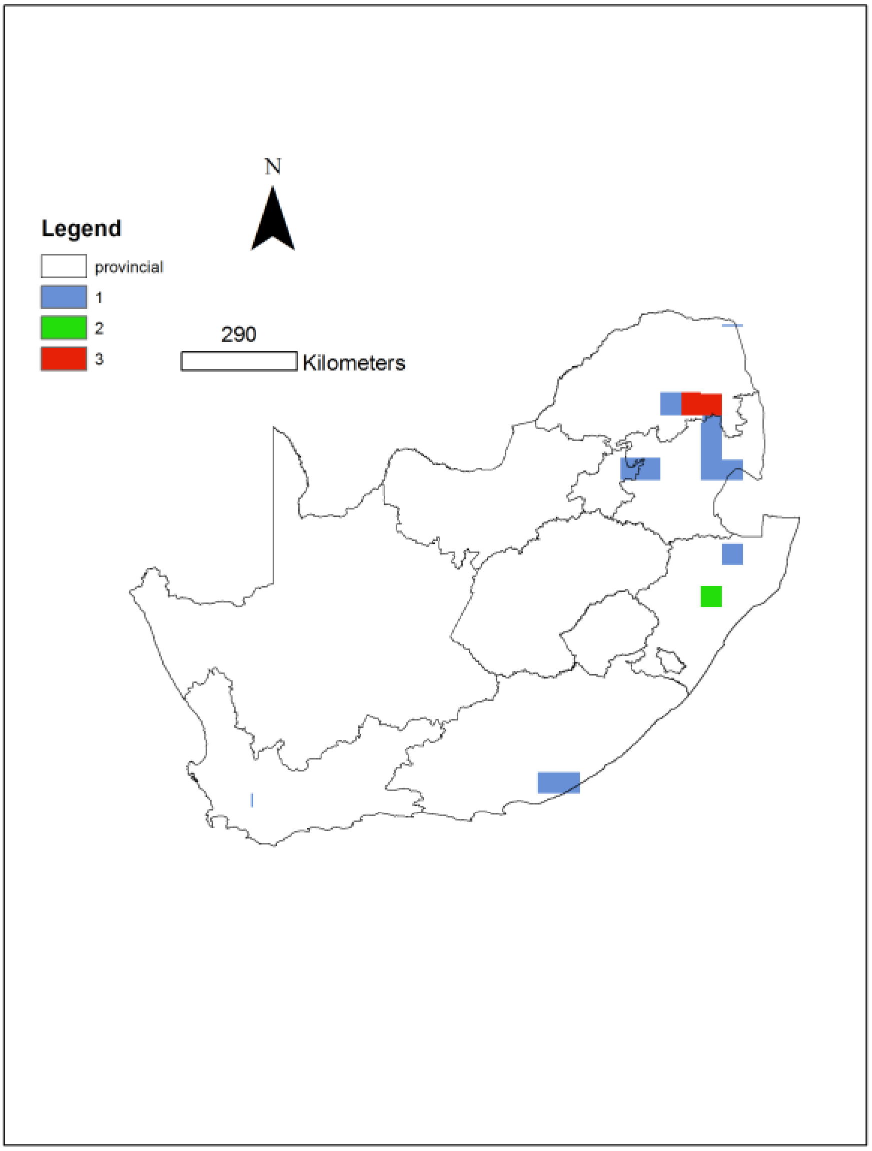

Figure 7.3: Map of Critically Endangered and Extinct South African cycads (colours in legend represent number of species per grid) using herbarium record from South African National Biodiversity Institute.

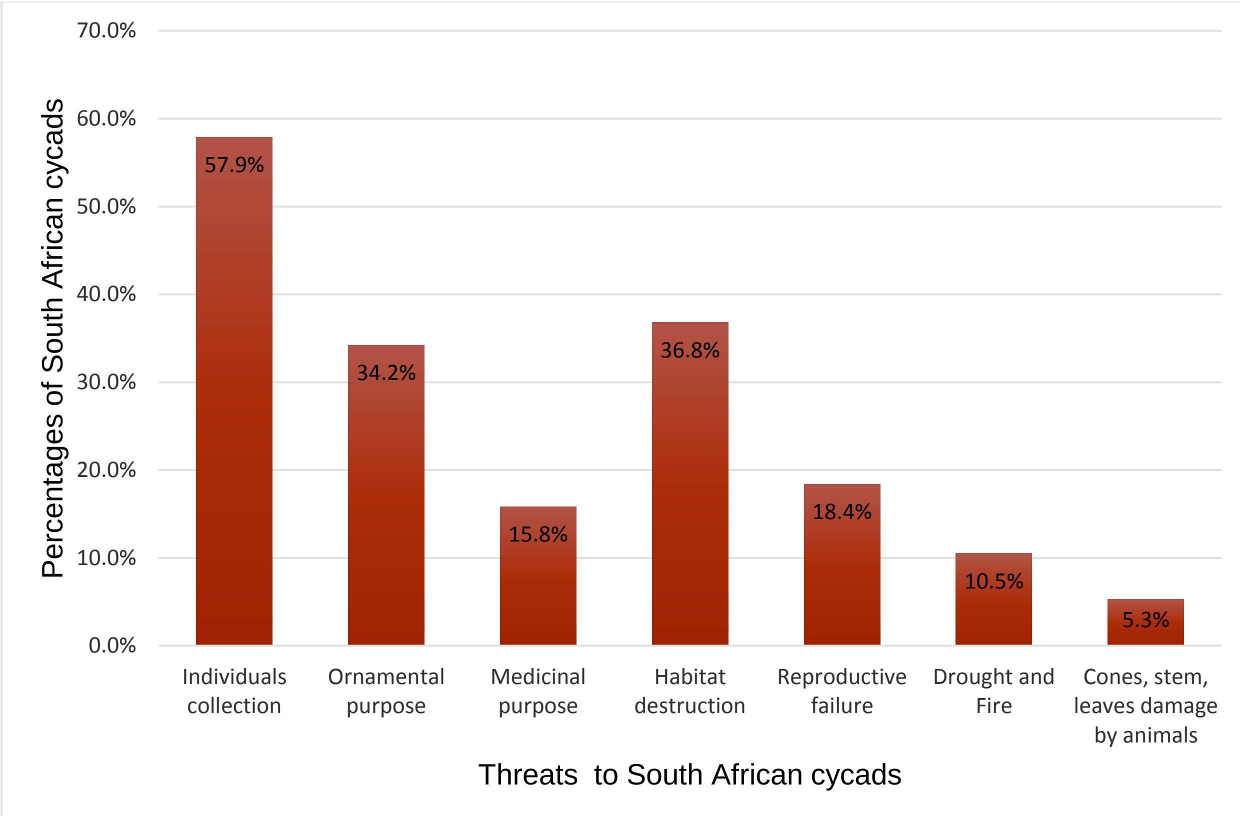

Figure 7.4: Figure showing percentages of South African cycads facing each threats based on data obtained from IUCN red list 2016 version.

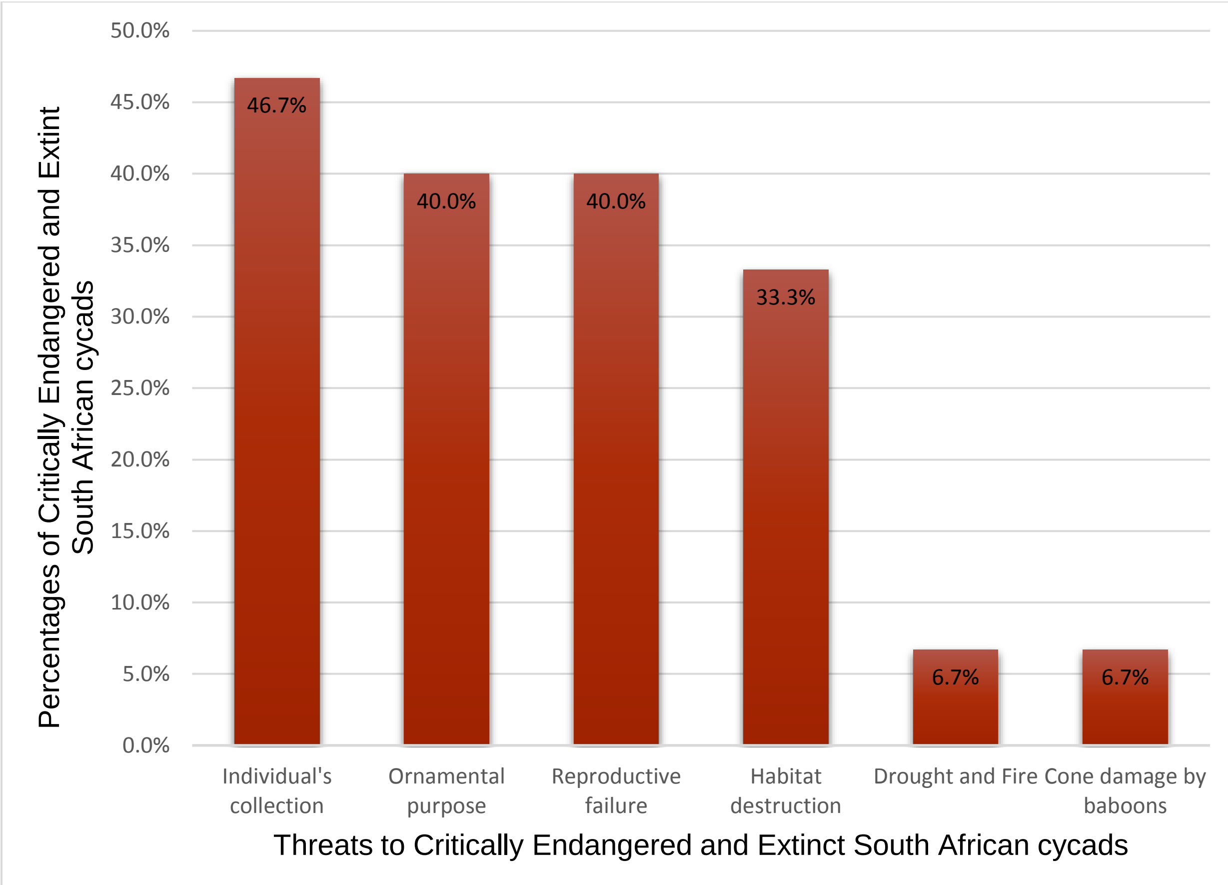

Figure 7.5: Figure showing percentages of Critically Endangered and Extinct South African cycads facing each threats based on data obtained from IUCN red list 2016 version.

Table 7.1: Total number of South African cycads obtained from SANBI records, their current IUCN status and their threats on IUCN.

Species	**IUCN Status 2016 version**	**Threats to South African cycads on IUCN for each species obtained from IUCN 2016 version**
Encephalartos aemulans Vorster	Critically Endangered	Illegal collection of individuals.
Encephalartos altensteinii Lehm	Vulnerable	Habitat destruction, Illegal collection of individuals, harvest for medicinal purposes.
Encephalartos arenarius R.A.Dyer	Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos brevifoliolatus Vorster	Extinct in the wild	Illegal collection of individuals.
Encephalartos caffer (Thunb.) Lehm.	Near Threatened	Habitat destruction, Ornamental use.
Encephalartos cerinus Lavranos & D.L.Goode	Critically Endangered	Ornamental use, reproductive failure.

Encephalartos cupidus R.A.Dyer	Critically Endangered	Ornamental use, drought and fire, reproductive failure.
Encephalartos cycadifolius (Jacq.) Lehm.	Least Concern	Cone and newly emerged leaves damage by baboons and porcupines, Fire occurrences.
Encephalartos dolomiticus Lavranos & D.L.Goode	Critically Endangered	Illegal collection of individuals.
Encephalartos dyerianus Lavranos & D.L.Goode	Critically Endangered	Reproductive failure.
Encephalartos eugene-maraisii Verd.	Endangered	Ornamental use, reproductive failure.
Encephalartos ferox G.Bertol.	Near Threatened	Ornamental use, habitat destruction.
Encephalartos friderici-guilielmi Lehm.	Near Threatened	Ornamental use, use for traditional medicine.
Encephalartos ghellinckii Lem.	Vulnerable	Ornamental use, fire occurrences.
Encephalartos heenanii R.A.Dyer	Critically Endangered	Ornamental use, habitat destruction, reproductive failure.
Encephalartos hirsutus P.J.H. Hurter	Critically Endangered	Ornamental use.

Encephalartos horridus (Jacq.) Lehm.	Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos humilis Verd.	Vulnerable	Ornamental use.
Encephalartos inopinus R.A. Dyer	Critically Endangered	Illegal collections of individuals, cone damage due to presence of baboons.
Encephalartos laevifolius Stapf & Burtt Davy	Critically Endangered	Use for traditional medicine, Ornamental use, habitat destruction.
Encephalartos lanatus Stapf & Burtt Davy	Near Threatened	Habitat destruction.
Encephalartos latifron Lehm.	Critically Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos lebomboensis Verd.	Endangered	Illegal collection of individuals, traditional medicine use, habitat destruction.
Encephalartos lehmannii Lehm.	Near Threatened	Drought, illegal collection of individuals, Stem leaves destruction by porcupines and goats.
Encephalartos longifolius (Jacq.) Lehm.	Near Threatened	Illegal collection of individuals.

Encephalartos middelburgensis Vorster, Robbertse & S.van der Westh.	Critically Endangered	Illegal collection of individuals, habitat destruction, fire occurrences, reproductive failure.
Encephalartos msinganus Vorster	Critically Endangered	Ornamental use, habitat destruction, reproductive failure.
Encephalartos natalensis R.A.Dyer & Verdoorn	Near Threatened	Illegal collection of individuals, use for traditional medicine.
Encephalartos ngoyanus Verd.	Vulnerable	Illegal collection of individuals, fire occurrences.
Encephalartos nubimontanus P.J.H. Hurter	Extinct in the wild	Illegal collection of imdividuals.
Encephalartos paucidentatus Stapf & Burtt Davy	Vulnerable	Illegal collection of individuals, habitat destruction.
Encephalartos princeps R.A. Dyer	Vulnerable	Illegal collection of individuals, habitat destruction.
Encephalartos senticosus Vorster	Vulnerable	Illegal collection of individuals.
Encephalartos transvenosus Stapf & Burtt Davy	Least Concern	Illegal collection of individuals, habitat destruction.

Encephalartos trispinosus (Hook.) R.A.Dyer	Vulnerable	Illegal collection of individuals.
Encephalartos villosus Lem.	Least Concern	Ornamental use, habitat destruction.
Encephalartos woodii Sander	Extinct in the wild	Illegal collection of individuals.
Stangeria eriopus (Kunze) Baill.	Vulnerable	Illegal collection of individuals, habitat destruction, use for traditional medicine.

CHAPTER EIGHT

CLIMATIC PREDICTIONS MAY NOT ACCELERATE DECLINE IN SOUTH AFRICAN CYCADS

Abstract

In recent decades climate change has emerged as one of the major forces driving biodiversity loss and species extinction. And this makes it important to test the most threatened plant group on how they will react to certain climatic predictions in the future as this might make some contribution to informed decisions on how to prevent such group of plants from going extinct. Cycads are highly threatened and South Africa, which is a global hotspot, possess the most threatened cycad taxa in the world. This study tested four typical cycad taxa endemic to South Africa (*Encephalartos* spp) and having reasonable sample sizes of occurrence points on how they will possibly respond to climate change in the future. The results revealed that climate change might possibly not be a major problem to *Encephalartos* conservation in the future but human influenced factors that have been identified might represent the main extinction threats to South African cycads in the future.

8.1 Introduction

Human anthropogenic activities, invasive spread and habitat destruction have been factors responsible for species extinction in the past 400 years with the extinction crisis over a thousand times higher than the globe has ever witnessed (Turvey 2009; Barnosky et al. 2011). This extinction crisis has wiped out one quarter of all species that have been assessed and there is a possibility of continuity of these trends in decades to come (Hoffmann et al. 2011). But in the 21st century, climate change emerged as a great force promoting species extinction crisis resulting in ecosystem disruption and loss of genetic diversity (Pounds et al. 2006; Thomas et al. 2006; Lawler et al. 2009; Foden et al. 2013; Pacifici et al. 2015). Climate change also interacts with other ecological forces to promote species extinction crisis (Mantyka-Pringle et al. 2015). For instance climate change interaction with land cover change have been shown to exacerbate biodiversity loss (Sala et al. 2000; Jetz et al. 2007; Visconti et al. 2016). This interaction has been found to also promote habitat loss and fragmentation, resulting in heightened susceptibility of fragmented species population to extinction (Sala et al. 2000; Jetz et al. 2007; de Chazal and Rounsevell 2009).

Among flora that have been assessed globally, the order Cycadales (representing all extant cycads) contain the largest percentage of threatened plant species (IUCN 2010). Taxa belonging to this plant group are facing threat everywhere they occur (Donaldson 2010). South Africa contains the third largest number of cycads in the world (Hill et al.

2003) with the majority of them being highly threatened and some already extinct in the wild (Donaldson 2008). A wide range of ecological and anthropological forces are responsible for the extinction crisis of cycads in South Africa and these include, illegal harvest for medicinal and horticultural uses, habitat fragmentation, disease infestation, invasive plant species competing with them in their natural habitats and also climate change (Donaldson 2003; Donaldson 2006; Donaldson 2010).

Due to the position of these endangered species in the current global floral extinction crisis and South Africa harbouring the third largest number of taxa of this plant order, it is critical to project how these taxa will respond to climate change in South Africa. This study modelled four well sampled cycad taxa endemic to South Africa and predicted future distribution on South African cycads under different climatic predictions suggested by the latest (5^{th}) IPCC report.

8.2 Methodology

Records of all South African cycads including 37 *Encephalartos* spp and 1 *Stangeria* spp were obtained from the South African National Biodiversity Institute (SANBI). A quarter degree grid species richness map for all South African cycads using ArcGIS 9.2 (www.esri.com/arcgis/) was generated. Maxent 3.3.3k (Phillips et al. 2006) was used to model both the current and future distribution of four taxa using their distribution records after first preparing and projecting to Albers equal area projection for Africa, the occurrence and environmental predictor layers in ArcGIS 9.2 at the same resolution of 30 arc seconds. Analyses were conducted using R version 3.0.3 (downloaded from https://cran.r-project.org on 6 March 2014) within RStudio Version 0.98.501 (downloaded from www.rstudio.com on 6 March 2014) and the following packages: raster, dismo, rgdal, rjava and maptools. Duplicates from the same grid were removed. Presence records were split, 70% for training and 30% for testing. Five replicates were run using cross validation, and median probabilities were reported. Otherwise, standard defaults were used for Maxent runs.

Due to limited records for South African cycads, only four reasonably well-sampled species were analysed, *Encephalartos natalensis* (n=15, reduced to 7 after removal of duplicates), *Encephalartos lehmannii*, (n=22, reduced to 12 after removal of duplicates), *Encephalartos altensteini* (n=35, reduced to 12 after removing duplicates) and *Encephalartos fredirici-guelielmi* (n=22, reduced to 9 after removal of duplicates to 9). In order to prevent problems of over-fitting or under-fitting, the background was selected using a mask for each species based on a polygon of all occurrence points with a 100 km buffer added. In order to display binary maps of predictions from continuous probability data, the equal training sensitivity and specificity threshold were used.

Following Laidlaw et al. (2012), four Bioclim climatic variables, Bio1 (Annual Mean Temperature), Bio4 (Temperature Seasonality), Bio12 (Annual Precipitation), Bio14

(Precipitation of the Driest Month) were obtained from the Worldclim database (www.worldclim.org; Hijmans et al. 2005), as well four additional categorical environmental predictors thought to be important for defining the ecological niche of cycads, landform (FAO 2006), lithography (FAO 2006), topographic roughness (calculated using SDMTools in ArcGIS from the GTOPO30 digital elevation model downloaded on 28/10/2016 from: http://www.arcgis.com/home/item.html?id=c891f64c13be4a2c96491 e386bfed8c5), and SANBI vegetation types (Mucina & Rutherford 2006). The importance of these variables to the *Encephalartos* species modeled in this study was confirmed based on their habitat and ecology as reported in relevant IUCN Redlist accounts. Maxent models were first trained based on all eight of the above predictor variables, using climatic data for the current climate scenario and then projected to two future representative concentration pathways scenarios of RP +26 (a more conservative emission scenario) and RP +85 (a more severe scenario), based on the latest projections contained in the Fifth Assessment IPCC report (https://www.ipcc.ch/report/ar5/). Bioclim data for these two future scenarios were also obtained from the Worldclim database.

8.3 Results

Figure 8.1 indicates that the area of maximum species richness of cycads occurs in the Eastern Cape and KwaZulu-Natal provinces of South Africa. Since species from these provinces also have larger sample sizes, four typical *Encephalartos* species from these provinces were selected for Maxent modeling. The results in this study did not show a reduction in habitat suitability for the taxa modelled based on the future climatic predictions (Figure 8.2). Based on area under the curve (AUC), all models performed well with AUC values varying from 0.779 to 0.978 (Figure 8.3). The lack of response to climate change in the species models is not surprising given the very low contributions of Mean Annual Temperature (Bio1) and Annual Precipitation (Bio4) in all the models (Figigure 8.3). Instead, temperature seasonality (Bio4), SANBI vegetation types, and lithography are by far the most important variables for the species modelled in Maxent in this study (Figure 8.3). The species prefers more seasonably stable climates nearer the Eastern Cape coast based on the species distribution map generated.

8.4 Discussions and Conclusion

Maxent has been proved to be an effective tool in predicting how taxa will respond to changes in climatic condition in future (e.g., Taylor et al., 2015, 2016). In four South African *Encephalartos* species modelled with Maxent, future predicted changes in temperature, precipitation and temperature seasonality do not result in decreased ranges and accelerated extinction risks but rather show a slight spread in favorable conditions in future distribution compared to the present distribution (Figure 8.2). There is therefore a possibility that these taxa may not to be affected by changes in climatic condition in the future. Though the number of taxa modelled represent about 10% of the total number of South African cycads (Figure 8.1 and 8.2), it is still possible for us to be able to draw inference based on the similarity in ecology and habitat of all South African cycads (Vorster 2004). This conclusion is supported in this study's results by the fact that mean annual temperature and minimum precipitation have little influence of the Maxent models. Temperature seasonality (Bio4) is an important variable, but future predictions for the study area do not show changes in this variable. The four taxa modelled are all represented in Eastern-Cape or KwaZulu-Natal which is the main centre of diversity of cycads in South Africa (Figure 1). Also drawing support from a study conducted by Yessoufou et al. (2014) on evolutionary history of African cycads, there might be possibility of all *Encephalartos* spp endemic to South Africa having the same reaction towards climate change. The most recent dated phylogenetic tree reconstructed by Yessoufou et al. (2014) showed that all identified *Encephalartos* spp in South Africa are monophyletic, i.e. they share the same ancestral lineage. The study also showed that all South African cycads originated in the Pliocene age, a period characterized by cooler and drier condition. Most South African *Encephalartos* spp share a high level of morphological similarity (Vorster 2004). This might also support why all South African *Encephalartos spp* might likely have the same experience in relation to climate change. Also Yessoufou et al. (2014) noted that the underground stem possessed by *Encephalartos* spp found in South Africa cycads is an adaptation to aridity and high temperature. This evolutionary further supports that all *Encephalartos* spp in South Africa might have similar experiences relating to climatic history. Konning (2016), grouped South African cycads based on their life history and trait. But the grouping doesn't show significant difference in the response of South African cycads to environmental factors. Also members of all the four groups of South African cycads based on life history and trait were represented in the South African clade of the phylogenetic tree constructed by Yessoufou et al. (2014). The results in this studyt therefore imply that human anthropogenic activities might be the primary forces pushing these endangered taxa to extinction in future.

However, Laidlaw et al. (2012) conducted a study on some *Macrozamia* taxa in Queensland in Australia using climatic predictions to determine how the taxa will respond to climate change in future. They found that change in climatic condition in 50 to 70 years from when the study was conducted will result in declines in cycads in Queensland. But contrary to this, this study showed otherwise. But also considering geographic differences and differences in taxonomic group between *Encephalartos* and *Macrozamia* we can justify the reason for the difference in the outcome of these two studies. For instance a study by Nagalingnum et al. (2011) showed that *Macrozamia* and *Encephalartos* originated in two different quaternary oscillation seasons which showed that these two genera might have different experiences in relation to climate. This study thereby predict that in these two cycad hotspots (Australia and South Africa) there might be divergent responses of different lineages of cycads in relation to climate change.

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Figures and tables as appendix

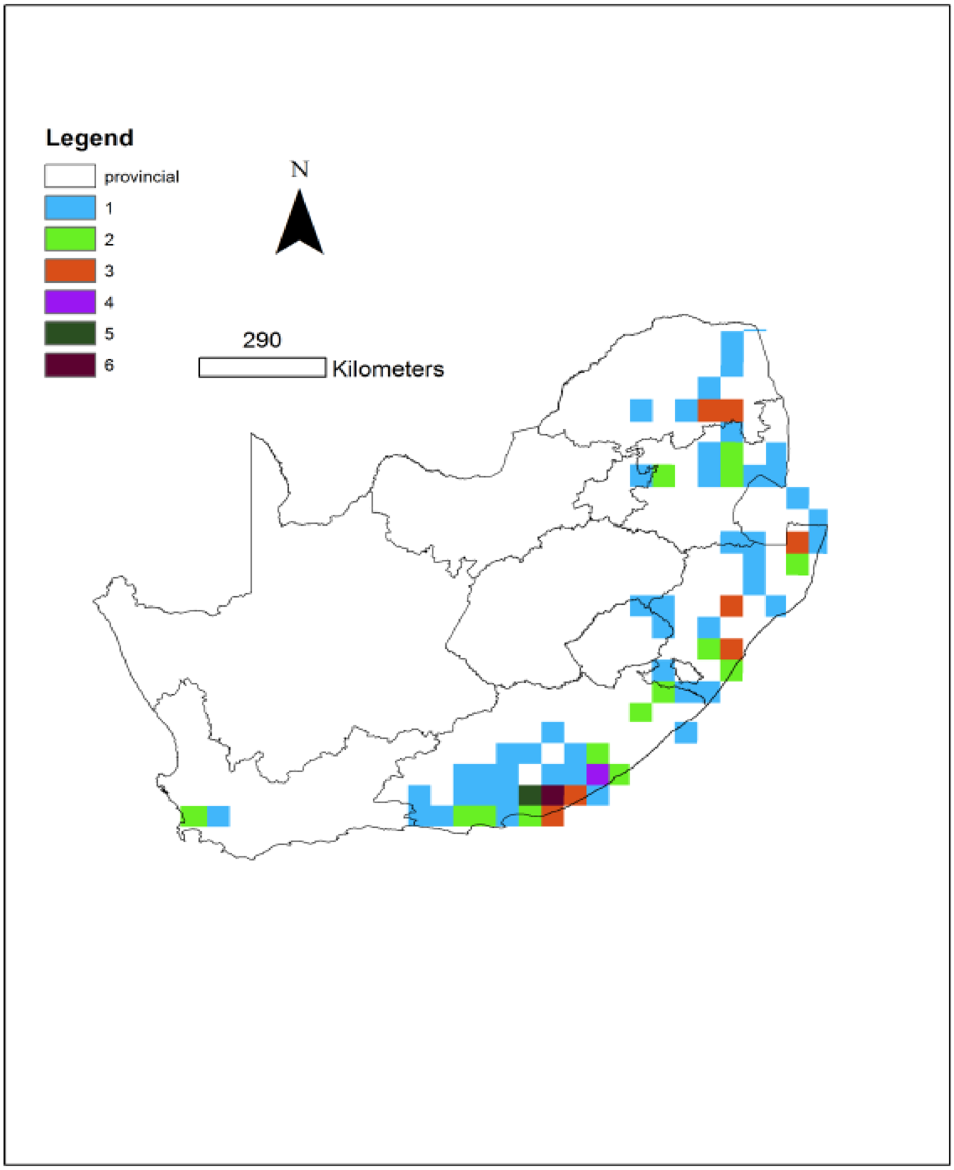


Figure 8.1: Summary maps of species richness (quarter degree grid) for 38 species of cycads.

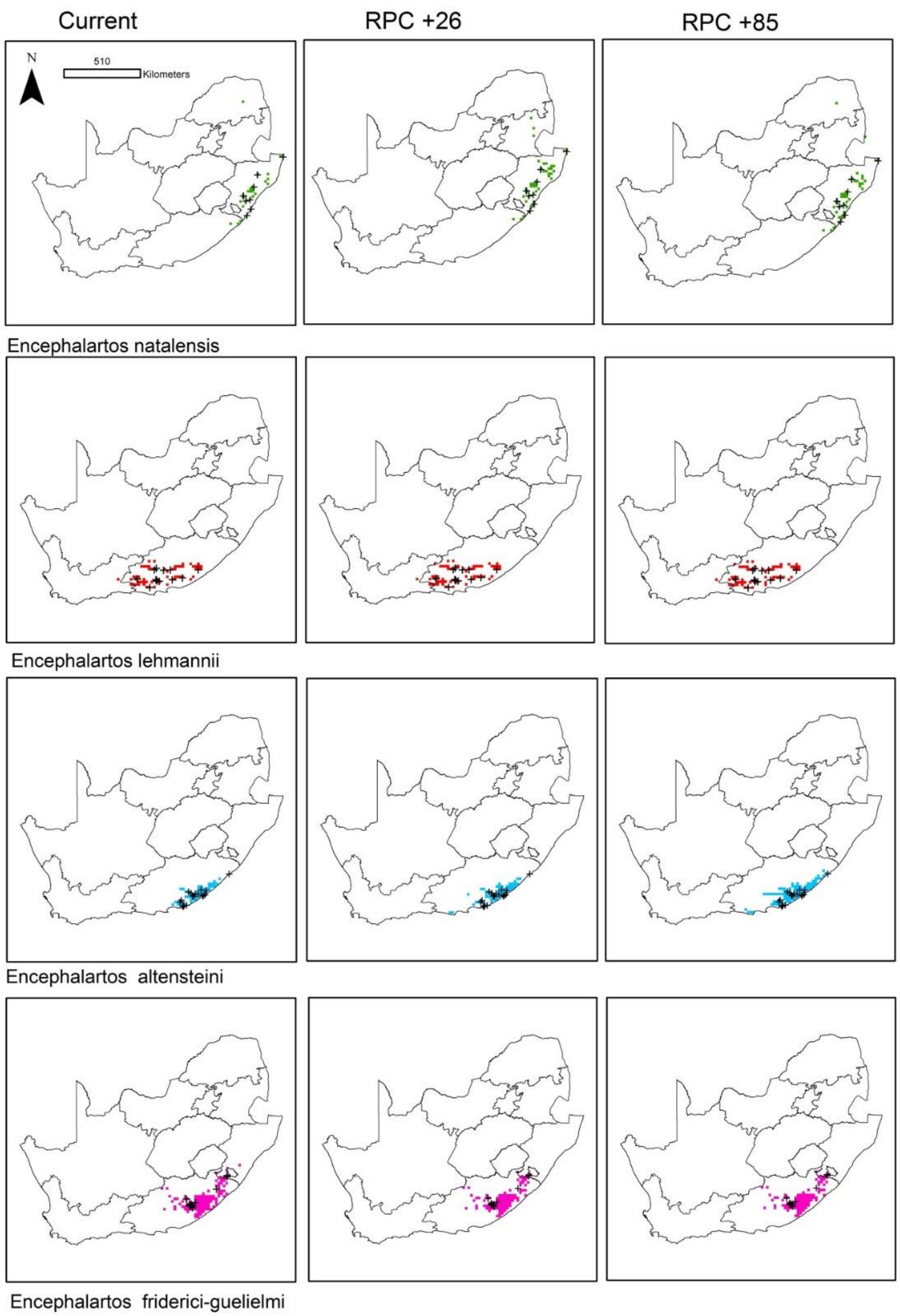
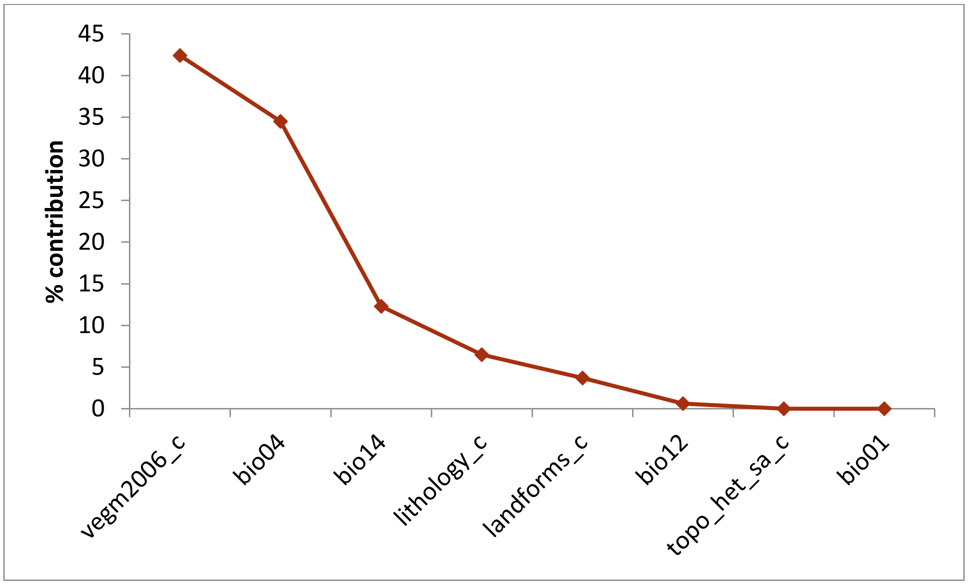
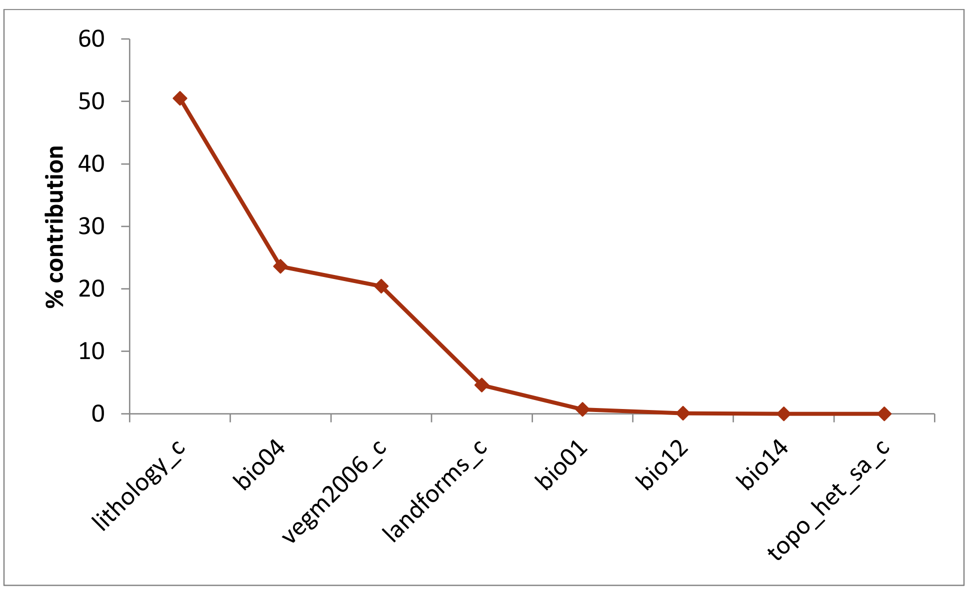


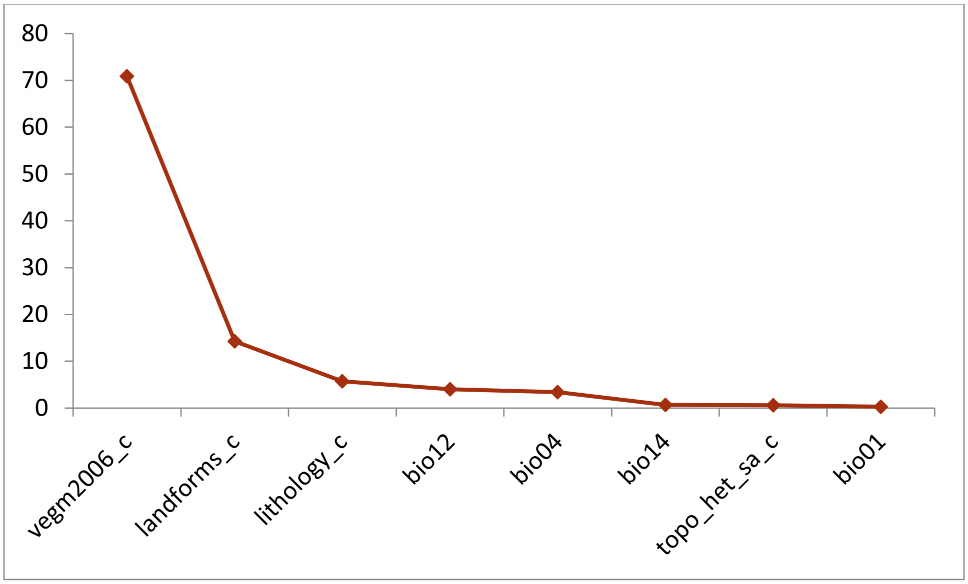
Figure 8.2: Maxent models (median from 5 replicates) for 4 species of *E. altensteini*, *E. fredirici-guelielmi, E. lehmanii* and *E. natalensis* using 100 km buffer masks as background for each species & 8 predictor variables.



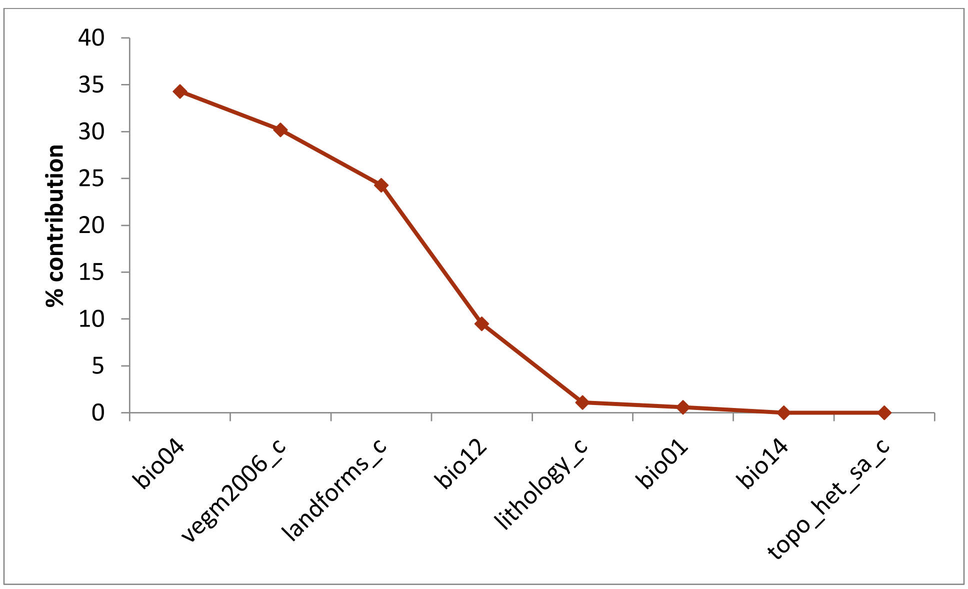
(A) Contribution of environmental predictors to Maxent model for *E. altensteini*. AUC 0.978.



(B) Contribution of environmental predictors to Maxent model for *E. fredirici-guelielmi*. AUC 0.973.



(C) Contribution of environmental predictors to Maxent model for *E. lehmannii* AUC 0.779



(D) Contribution of environmental predictors to Maxent model for *E. natalensis* AUC 0.966

Figure 8.3 (A-D): Contribution of environmental predictors for Maxent model for *E. altensteini*, *E. fredirici-guelielmi, E. lehmannii* and *E. natalensis.*

CHAPTER NINE

GENERAL SUMMARY

Cycads extinction crisis is a global concern and the loss of any singular species in this plant group is a loss of high evolutionary distinctiveness as this group is currently the oldest gymnosperm group in existence (Bamigboye 2014; Cousins and Witkowski 2017). A continuous evaluation of the threat trends, extinction pattern and population trend of the taxa in this plant group is necessary to ensure that the existence of such unique plant group with such evolutionary value does not become a thing of the past in subsequent generations. High extinction crisis is still present in the Cycadales (Marler and Marler 2015) and this study revealed that threats in cycads is across regions and even local communities in Africa with major occurrences in South Africa.

Patterns and trends are important aspect of conservation as it gives a clue about the past, present and possible future threats to existence of threatened taxa (Williams et al. 2013; Tingley et al., 2016). This study evaluated patterns of extinction in cycads in Africa, South Africa and in Soutpansberg Mountain which is a unique biodiversity hotspot in Limpopo Province in South Africa (Bamigboye et al. 2016, 2017).

This research revealed that extinction crisis in cycads in Africa, South Africa and Soutpansberg Mountain is currently high and these taxa are still tending towards higher extinction risk in future. The indigenous approach showed that *Encephalartos tranvenosus* on Soutpansberg Mountain are being exploited for various uses and this might possibly promote threat to this species. These uses leaves for roofing hut, roots for medicinal purposes and bark for medicinal and hard drugs purposes. Some recommendations such as rasing nurseries among local communities and integrating community involvement in cycads conservation in related chapters in this project were included in this study. Such recommendations if properly channelled and implemented might decrease cycads extinction crisis in Africa, South Africa and Soutpansberg Mountain range.

A major discovery in this study of patterns and trends in extinction crisis in South Africa is that majority of extinction crisis in South Africa tends more to Limpopo Province than the rest of the provinces in South Africa. Recommendations on further studies such as reintroduction of cycads to the wild, population ecology of cycads, response to fire and droughts and also more studies on anthropogenic problem in South Africa should be channelled more to Limpopo Province being a region with higher cycads extinction occurrences.

Effect of climate change was tested on some South African cycads to see if climate could possibly affect this species. It was discovered that change in climatic condition might not have impact on extinction crisis of South African cycads. It was suggested that effort should be intensified in factors already identified as threat especially anthropogenic activities.

One of the aim of this research is to produce chapters that are publishable in accredited Journals in ISI, EBSCO, SCOPUS and South African Department of Higher Education and training. Two chapters have been published in accredited Journals (chapter three and five) and they are attached to this thesis. Two of the chapters in this thesis are under review in accredited Journals (chapter four and six) while two is about to be submitted (chapter seven and eight). This thesis have successfully addressed extinction pattern in African, South African and Soutpansberg cycads.

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PUBLICATION APPENDICES

APPENDIX A

BAMIGBOYE S.O., TSHISIKHAWE M.P., & TAYLOR P.J. 2016. REVIEW OF EXTINCTION RISK IN AFRICAN CYCADS. ***Phyton International Journal of Experimental Botany*** **85(1): 333-336**

ΦYTON
REVISTA INTERNACIONAL DE BOTÁNICA EXPERIMENTAL
INTERNATIONAL JOURNAL OF EXPERIMENTAL BOTANY
FUNDACION ROMULO RAGGIO
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Review of extinction risk in African Cycads

Revisión del riesgo de extinción de las Cícadas Africanas

Bamigboye SO, PM Tshisikhawe, PJ Taylor

Abstract. Over a long period of time, cycads endemic to Africa have been facing high risk of extinction. Several conservation efforts have been made to reduce the risk of losing these highly endangered species. In this study we review the current risk of extinction of all African cycads species. We calculated the percentages of each category of species found in African cycads using the IUCN (International Union of Conservation of Nature) red list of threatened species 2014 version. We compared our result with that of Donaldson (2003) on percentages of different categories of IUCN for cycads in Africa which was carried out a decade ago. We also calculated the percentage of population trend in African cycads. When comparing these results, we discovered that over one decade there was no improvement in cycads conservation despite several conservation efforts that were made during this period. The results of the population trend also showed that the majority of African cycads are experiencing population decreases. These results highlight that the risk of extinction of African cycads is still very high and much conservation effort is still required to properly tackle ecological factors pushing these endangered species to extinction.

Keywords: African cycads; Extinction; IUCN categories; Threat.

Resumen. Las cicadáceas, endémicas de África, han estado expuestas a un alto riesgo de extinción durante un largo período de tiempo. Se han hecho varios esfuerzos de conservación para reducir el riesgo de perder estas especies en gran peligro de extinción. En este estudio revisamos el riesgo actual de extinción de todas las especies de cicadáceas Africanas. Calculamos los porcentajes de cicadáceas en cada una de las categorías de peligro en extinción usando la versión 2014 de la lista roja de la IUCN (Unión Internacional de Conservación de la Naturaleza) de especies amenazadas. Comparamos nuestros resultados con los de Donaldson (2003), obtenidos 10 años antes, respecto a los porcentajes de cicadáceas en África en las diferentes categorías de la IUCN. También calculamos el porcentaje de la tendencia poblacional de las cicadáceas Africanas. Comparando los resultados revisados, descubrimos que durante más de una década no hubo mejoras en la conservación de las cicadáceas a pesar que se hicieron varios esfuerzos de conservación durante este período. Los resultados de la tendencia poblacional también mostraron que las cicadáceas Africanas están experimentando reducciones en su población. Estos resultados destacan que el riesgo de extinción de las cicadáceas Africanas es aún muy grande y se necesitan muchos esfuerzos de conservación para abordar apropiadamente los factores ecológicos que están exponiendo a estas especies en peligro de extinción hacia su extinción.

Palabras clave: Cicadáceas Africanas; Extinción; Categorías IUCN; Amenaza.

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Received 28.III.2015. Accepted 1.VII.2015.

ΦYTON ISSN 0031 9457 (2016) 85: 333-336

INTRODUCTION

Cycads are categorized as the most threatened plant species in the world: in 2010, 303 species of cycads were assessed, and 63% were threatened to extinction (International Union of Conservation of Nature 2010). Africa is one of the centres of diversity of cycads (Hill et al., 2003). It harbours 66 species of the genus *Encephalartos* and one species of the genus *Stangeria* (Rousseau, 2012) making a total of 67 species endemic to Africa. The IUCN Red list provides vital information on the risk of extinction of all species (Lamoreux et al., 2003). This listing is based on several criteria including species biology, ecology, population size, distribution range, population dynamic, etc. (International Union of Conservation of Nature, 2010). Several factors such as illegal collection of cycads (Donaldson, 2003; Donaldson, 2008), climate change (Bamigboye, 2013), and presence of invasive species (Donaldson, 2008) are responsible for the extinction risk of cycads in Africa. Several conservation efforts have been put in place to reduce the risk of extinction of cycads in Africa.

Donaldson (2003) in his published work on cycads status, survey and conservation plan presented a IUCN report of different percentages of IUCN status of African cycads, raising concern on the rate of the rapid loss of cycads in Africa. Donaldson (2003) identified that the threatened status of cycads arises from natural rarity and decline. Cycads grow in isolated populations in nature which makes them very rare, hereby making them to require a high level of conservation and regeneration plan (Hill et al., 2003). Causes of threats identified by Donaldson (2003) include habitat destruction, over collection, traditional uses, and reproductive failure. It is hereby necessary to evaluate the current status of African cycads after about one decade to give a better picture of the trend in the conservation of African cycads.

In this study, we review the risk of extinction of these plant species to determine if there has been either any improvement in the status of cycads in Africa or not. This was made by comparing the IUCN 2014 status of African cycads with the results presented by Donaldson (2003).

MATERIALS AND METHODS

Using the 2014 version of the IUCN (International Union of Conservation of Nature) red list of threatened species, we evaluated the status of all cycads endemic to Africa. We did this by calculating the number of African cycads species in each category of the IUCN status, which includes species as Critically endangered, Vulnerable, Endangered, Extinct in the wild, Near threatened and of the Least concern. We multiplied the total number of African cycads in each category by 100 and divided it by 67, which is the total number of cycads species in Africa, in order to get the categorical percentages. We also calculated the population trend of all cycads endemic to Africa by calculating the total number of African cycads either decreasing or stable in population trend. We multiplied each of the categories of population trend by 100, and divided them by 67 to find the exact percentage of African cycads taxa experiencing population decrease or stability using the IUCN 2014. We compared our results of the IUCN threat categories (Critically endangered, Vulnerable, Endangered, Extinct in the wild, Near threatened and Least concern) for 2014 with the result of the classification carried out by Donaldson (2003). Donaldson's classification (2003) is one decade before the current IUCN version to evaluate the threat trend of African cycads. The report presented by Donaldson (2003) was based on combined data from sources including cycads trade, permit records and study of matched photographs of cycads hotspots over a long period of time. These data were used to assess the status of cycads species endemic to Africa. Donaldson's (2003) results showed that 2.8% of African cycads were already extinct, 26% critically endangered, 12% endangered, 26% vulnerable and 16% of least concern.

RESULTS

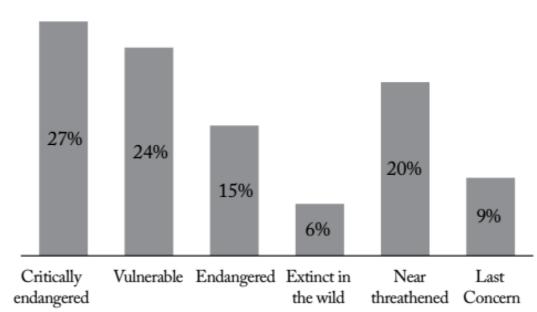

Fig. 1. Percentage of each categories of IUCN status of African cycads in the 2014 version of IUCN red list of threatened species. Categories include the percentage of African cycads that are Critically endangered, Endangered, Vulnerable, Extinct in the wild, Near threatened and Least concern.

Fig. 1. Porcentaje de cada una de las categorías de las Cícadas Africanas de acuerdo a la versión 2014 de la lista de especies amenazadas de la IUCN. Las categorías incluyen el porcentaje de las Cícadas Africanas que están críticamente amenazadas, amenazadas, vulnerables, extinguidas en condiciones naturales, próximas a ser amenazadas y de menor preocupación.

ΦYTON ISSN 0031 9457 (2016) 85: 333-336

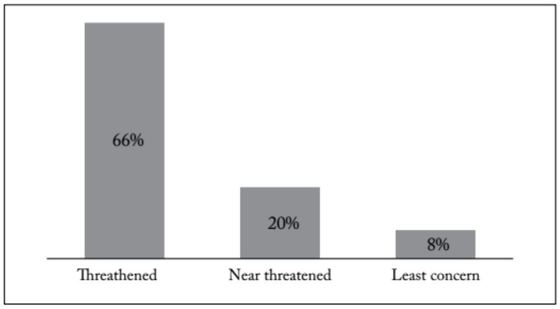

Fig. 2. Result of the percentages of African cycads that are threatened (Critically endangered, Endangered, Vulnerable), Near threatened and Least concern on the IUCN red list status 2014 version.
Fig. 2. Porcentaje de las Cicadas Africanas que están amenazadas (muy amenazadas, amenazadas, vulnerables), cerca de estar amenazadas y de menor preocupación en la versión 2014 de la lista roja de la IUCN.

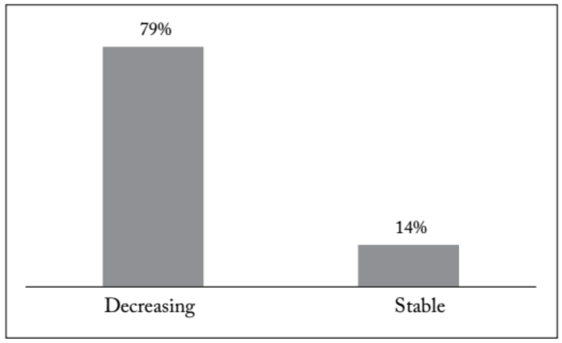

Fig. 3. Percentages of population trend in African cycads on IUCN red list 2014 version. The population trends show the percentage of African cycads species experiencing decreases in population and the ones that are stable.
Fig. 3. Porcentajes de tendencia de las poblaciones de las Cicadas Africanas en la versión 2014 de la lista roja de la IUCN. Las tendencias de las poblaciones muestran el porcentaje de las especies de Cicadas Africanas que está en disminución o se mantiene estable.

Table 1. Comparing different categories of African cycads between Donaldson (2003) and IUCN (International Union of Conservation of Nature) red list 2014 version.
Tabla 1. Comparación de diferentes categorías de las Cicadas Africanas entre el informe de Donaldson (2003) y la versión 2014 de la lista roja de la IUCN (Unión Internacional de Conservación de la Naturaleza).

African cycads species	% of categories according to Donaldson (2003)	% of categories according to IUCN red list 2014 version
Extinct	2.8%	6%
Critically endangered	26%	27%
Endangered	12%	15%
Vulnerable	26%	24%
Near threatened	16%	20%

DISCUSSION AND CONCLUSION

Reviewing the status of cycads in Africa has enabled us to evaluate their current position related to risk of extinction. We detected an increase in all threatened African cycads in one decade after comparing the IUCN status of Donaldson (2003) with the 2014 version of the IUCN (Table 1). Cycads that have gone extinct have increased by 3.2%, critically endangered cycads have increased by 1%, endangered cycads have increased by 3%, vulnerable ones have decreased by 2% and the ones that are near threatened have increased by 4% (Fig. 1; Table 1). These increases might look insignificant but losing one species is losing ecosystem productivity, population distribution and genetic diversity (Mukwevho, 2014).

Another important aspect of this research is the population trend. Currently, a very large number of African cycads are still experiencing a decrease in population which might lead these endangered species towards extinction in the future (Fig. 3).

Much effort is needed to preserve the African cycads. We also suggest that ecological forces that have not previously been given high priority should now be given close consideration. For instance, in South Africa combating poaching and illegal collections has been the major focus of cycads conservation. But other factors such as climate change which could adversely affect these species should also be taken into consideration. If some close consideration is given to these ecological factors, it might reduce the risk of extinction of this threatened species.

ACKNOWLEDGEMENTS

We acknowledge the Department of Science and Technology (DST) and the National Research Foundation (NRF) through the South African Research Chair Initiative (SARCHI) for Biodiversity Value and Change at University of Venda, South Africa for funding this project.

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ΦYTON ISSN 0031 9457 (2016) 85: 333-336

APPENDIX B

BAMIGBOYE S.O., TSHISIKHAWE M.P., & TAYLOR P.J. 2017. DETECTING THREAT TO *Encephalartos transvenosus* Stapf & Burtt Davy (LIMPOPO CYCAD) IN LIMPOPO PROVINCE, SOUTH AFRICA THROUGH INDIGENOUS KNOWLEDGE. *Indian Journal of Traditional Knowledge* 16(2): 251-255.

Indian Journal of Traditional Knowledge
Vol. 16(2), April 2017, pp. 251-255

Detecting threats to *Encephalartos transvenosus* (Limpopo cycad) in Limpopo province, South Africa through indigenous knowledge

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Received 09 March 2016, revised 09 August 2016

Indigenous knowledge contains valuable information which is often essential to biodiversity and species conservation. The traditional knowledge of people in local communities can enhance conservation policies and planning and also reveal local perspectives in relation to endangered species. Cycads as a vascular plant group contain the highest percentage of threatened plant species, at global, regional, national and community levels. In this study we focused on *Encephalartos transvenosus* Stapf & Burtt Davy, a cycad species endemic to Limpopo province in South Africa. Despite every effort to conserve this highly endangered species the threats keep increasing and the population keep decreasing. Through indigenous knowledge, we discovered a location of this species not yet conserved within Vhembe district on the Soutpansberg mountain range in Limpopo province, South Africa. Practices such as bark harvesting, and uprooting of young seedlings were discovered at this population. All these practices noticed at this location are detrimental to *in situ* conservation of the cycads. This study hereby revealed that indigenous knowledge has a great role in cycads' conservation. Through the local communities, factors that are threatening cycads existence can be determined and the local community can also be integrated in effective conservation plan that discourage illegal harvesting of cycads.

Keywords: Cycads, Conservation, *Encephalartos transvenosus,* Indigenous knowledge, Traditional knowledge, Endangered species, Threat

IPC Int. Cl.[8]: A61K 36/00, A01H 7/00, A61K 36/13-A61K 36/17

Indigenous knowledge is defined as specific information from local communities based on culture, lifestyle and practices that are passed from one generation to another[1-3]. This knowledge is not only important to local indigenes but also useful for scientists and planners in the area of improving the environment, well being of people and also sustaining natural resource management[4,5]. The indigenes of certain local communities have an understanding of the ecosystem functioning of their localities from a number of perspectives. Through long term uses they possess vast knowledge of certain locations of endemic plant species. For instance certain plant species are identified in local communities through local names by reason of their uses for food and medicine[6,7]. This local knowledge can also be very useful in the area of plant conservation.

Cycads are amongst some of the oldest living representative of gymnosperms and they have existed for about 300 million years[8,9]. Davis & Schaefer[10] suggested a need for integration of the fossil records in a better way in order to improve our understanding of the rate and mode of diversification in the family tree of gymnosperm. They are also the most threatened plant taxa globally containing the highest percentage of threatened plant species[11,12]. Despite conservation efforts there have been steady increase of the threat status and decrease in the population trend in all continents where they occur[12]. These globally threatened species demands conservation attention to prevent their total extinction. Unlike some other nations of the world where habitat loss is a major cause of cycad extinction risk, South Africa cycads are facing extinction mainly due to bark harvest[13,14]. Three species of cycads are extinct in South Africa due to bark harvesting for medicinal purpose[15]. This threat is at global, national, regional and community levels[16].

Encephalartos transvenosus Stapf & Burtt Davy is a species of cycad endemic to Limpopo province in South Africa[17]. This species was once listed as a rare species by Hilton-Taylor[18] but currently some of them

*Corresponding author

are abundant in places such as Modjadji nature reserve which contains about 15,000 individuals alongside some other subpopulations[19]. It's being listed as least concern by Raimondo *et al*.[20] with the population trend decreasing due to wild harvesting of individuals and habitat destruction[12]. This species is nominally protected under the National Environmental Management Biodiversity act of South Africa[21] and also under Limpopo Environmental Management act (LEMA) of South Africa[22]. In this study, we focused on determining threat to these species due to illegal harvest by local communities through indigenous knowledge.

Materials and methods

This study was conducted at Mahunguwi in Limpopo province, South Africa. Mahunguwi is a small rural village of 394 people which falls within Thulamela local municipality in Vhembe district[23]. According to Acocks[24] the study site is situated within a sourish mixed bushveld vegetation type of the savanna biome. The annual rainfall of the area as per Tshitavha Weather Station data is 698 mm[25]. It is an area geographically characterized by the Soutpansberg mountain range which geology is made up of Makgabeng Plateau, Blouberg Mountains, Pink erosion-resistant quartzite and sandstone with pebbles as the major dominating rocks[26]. A population of *Encephalartos transvenosus* was found on the east facing slope of the mountain in this location. *Encephalartos transvenosus* population was identified by one of the male traditional knowledge holder through the local Tshivenda name of *Tshifhanga*. Through the local name it was easier to communicate to informant on the plant species and the required information about it.

Ethnobotanical survey was conducted in order to determine the knowledge of the villagers about utilization of this species. Informants above 25 yrs of age who were willing to participate were randomly selected after prior consent regarding the use of their information for research purposes was sought with them. Twenty nine people were interviewed in Tshivenda which is their local language. We also ensure that the people interviewed are people who originated and reside in this village and they also get their livelihood in Mahunguwi village (Table 1).

Results and discussion

Informants profile and their harvesting perceptions

In the household survey conducted 55 % of the informants were males while 45 % were females. Convenient approach on selection of informants was adopted after obtaining prior consent from them. Amongst the informants youth made up 45 % while adults constituted 55 %. The survey also revealed that the majority of the informants (93.2 %) were aware that harvesting of *Encephalartos transvenosus* was illegal, whereas only 2 individuals (6.8 %) indicated that they were not aware of its conservation status. This might be probably driven by their needs of making a living out of its harvesting. This should, therefore, call for a community integrated conservation plan either through nursery propagation or re-introduction[27] which might take people away from the wild harvesting of these plants.

The informants indicated that seedlings from this population had been previously removed and sold resulting in the absence of juvenile individuals. Total removal of the species particularly seedlings for horticultural purposes was also not ruled out.

Encephalartos tranvenosus bark utilization

The population of *Encephalartos transvenosus* found in this location has been highly disturbed with bark harvesting on all individuals observed (Figs. 1 a-d). Harvest for medicinal use is one of the major factors threatening cycad existence in South Africa[14,15] and in particular bark harvest is the main factor contributing to cycad extinction in South Africa[13]. It was certainly the main threat to the individuals of *Encephalartos transvenosus* found in this population. Some individuals also showed sign of decay as a result of internal stem exposure from this practice (Fig. 1d).

The informants confirmed that the motive behind harvesting of cycads was mainly medicinal. According to them the reason why the upper part of the bark of *Encephalartos transvenosus* is always being harvested is due to the traditional belief that this part specifically works magic and drives evil spirits away (Fig. 1a). It was also reported that the rest of the bark parts (excluding the upper part) being harvested are for other medicinal purposes which include anticancer therapy in treatment of people with breast cancer. Poaching of cycads materials has been reported to be influenced by people who want to produce hard drugs prepared by international community. Individuals are, therefore, completely removed to satisfy the demand of international communities. The informants confirmed that the harvesting of these plants in the wild by the local communities has been unsustainable.

Table 1—An inventory of responses on the utilization of *Encephalartos transvenosus*

Respondents	Age groups	Gender	Parts harvested	Purpose	Awareness on illegal harvesting
1	Elder	Male	Leaves	For roofing hut	Aware
2	Elder	Male	Bark	Medicine	Aware
3	Youth	Female	Bark	Hard drugs	Aware
4	Elder	Female	Bark	Hard drugs	Aware
5	Youth	Male	Bark	Hard drugs/Medicine	Aware
6	Youth	Male	Bark	Hard drugs	Aware
7	Youth	Male	Bark	Hard drugs	Aware
8	Middle age	Male	Leaves	Roofing hurt	Aware
9	Elder	Male	Bark	Hard drugs/medicine	Aware
10	Elder	Male	Bark	Hard drugs	Aware
11	Elder	Male	Leaves	Roofing hut	Aware
12	Elder	Female	Bark	Hard drugs	Aware
13	Elder	Female	Don't know	Don't know	Aware
14	Elder	Female	leaves	Roofing hut	Aware
15	Elder	Female	Leaves	Roofing hut	Aware
16	Elder	Female	Bark	Hard drugs	Aware
17	Elder	Male	Leaves	Medicine	Aware
18	Elder	Female	Bark	Hard drugs	Aware
19	Middle age	Male	Leaves	Roofing hut	Aware
20	Youth	Female	Bark	Hard drugs	Aware
21	Elder	Male	Bark	Hard drugs/medicine	Aware
22	Elder	Female	Leaves	Medicine	Aware
23	Elder	Female	Leaves	Roofing hut	Aware
24	Middle age	Male	Don't't know	Don't know	Not Aware
25	Elder	Female	Bark	Drugs	Aware
26	Elder	Male	Leaves	Roofing hut	Aware
27	Youth	Male	Don't't know	Don't know	Not aware
28	Middle age	Male	Root/Bark	Medicine	Aware
29	Middle age	Female	Don't know	Don't know	Aware

The household survey conducted confirmed that *Encephalartos transvenosus* bark was the most mentioned of all the part used followed by leaves (Fig. 2). This still support that bark harvest is the greatest threat to cycads in South Africa[13-15,28-30] (Figs. 1a,b,c,d) because 48 % of the people interviewed mentioned bark as the main part used (Fig. 2). In Fig. 3, the majority of the respondents (37.5 %) mentioned that the inner part of the bark (Fig. 1a) is taken as hard drugs either through sniffing or smoking. It is being ground into powder and mix with some other unknown substances to be taken as hard drugs. This is a major finding in our study as many studies have only supported that the bark are harvested for medicinal purpose[13-15,28-30]. This revealed another reason for which the bark of these plants are being harvested for, and further studies are recommended to determine the active chemical compound found in this plant that possibly support this use.

Encephalartos tranvenosus leaf utilization

The leaf harvest (35 %) for roofing huts (25 %) and for medicinal use (25 %) was detected in this study (Fig. 2). A study by Krishnamurthy *et al.*[31] showed that a population of *Cycas circinalis* L. experienced reproductive decline due to leaf harvest. It can be the case for other cycads species. Which means leaf harvest might possibly be a threat to this species especially when the intensity of harvest is very high.

Encephalartos tranvenosus roots utilization

The roots of *Encephalartos transvenosus* are also being harvested although at a minimal scale (3 %) (Fig. 2) and will have a negative effect on the recovery process of the plants. Harvesting of roots might lead to death of some of the individuals in the population. According to informants roots of *Encephalartos transvenosus* are only harvested for medicinal purposes. Roots harvest for medicinal purpose is a common practice in Limpopo with majority of the plants harvested for their roots being

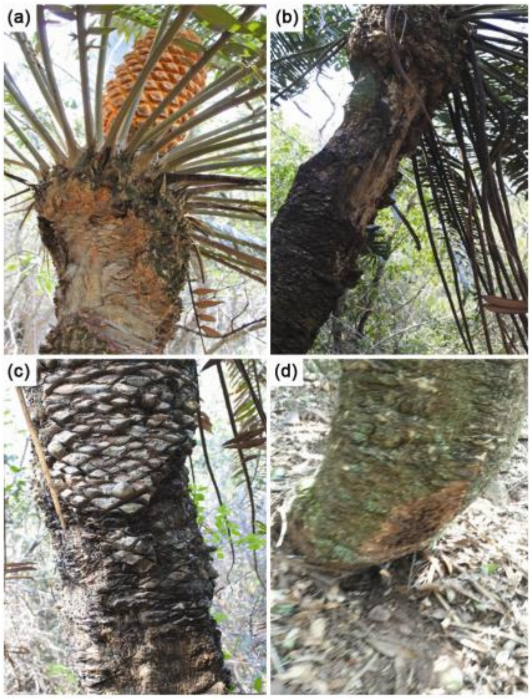

Fig. 1 — De-barking of *Encephalartos transvenosus* for medicinal purposes

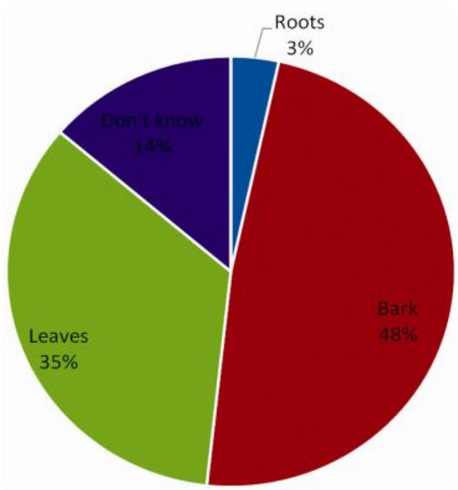

Fig. 2 — Informants responses on *Encephalartos transvenosus* parts utilization frequencies

threatened with extinction[32,33]. Root harvest is highly detrimental to plants growth and development, and a species of plants like cycads will experience serious decline due to the nature of its slow growing rate which can lead to the species being unable to recover from such practice.

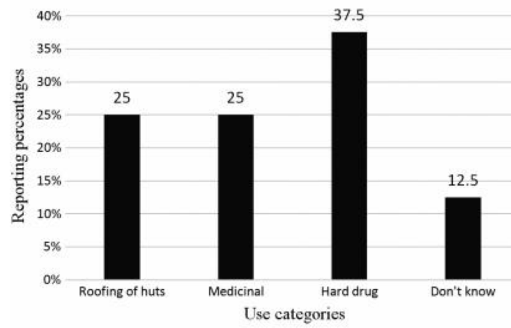

Fig. 3 — Informants responses on *Encephalartos transvenosus*use category frequencies

Conclusion

The present study supports that the practice of cycads harvesting is still ongoing in parts of South Africa. However, quantifying the sustainability of bark harvest of this species was not part of this study because the practice of harvesting cycads for any purpose is a practice not encouraged in South Africa at provincial and national level. The location discovered in this study coupled with the surveys from the village where this population is found revealed people are still practicing illegal harvesting of cycads in the wild and there appears to be little impact on reducing this activity from government initiatives aimed at conservation. The role of local indigenous knowledge in identifying locations of cycads and also unraveling the threat through local uses should be respectfully acknowledged and incorporated in designing effective conservation plans. According to Vovides *et al.*, in their studies in Mexico they concluded that species conservation can be strengthened by looking at species with economic interests of local people and include them in rural nurseries. Rare species like cycads can be rescued, transplanted and reintroduced in natural areas with minimal anthropogenic impacts with community involvement. Such effective community participation in conservation plan could possibly reduce threat to cycads and limit wild harvest. We also recommend that such conservation plan with community involvement should be implemented in areas such as this in a unique way that it might take the community people away from illegal wild harvest of this species. The local community also needs to be sensitized on the need to restrict people from collecting these plants because of its implication of losing them in the future. This can be in the form of conservation education so as to enlighten the community people on the value that should be placed on these plants that they are privileged to have in their community.

Acknowledgement

The authors acknowledge the indigenous knowledge holders that were generous in giving vital information for this research. The Department of Science and Technology (DST) and the National Research Foundation (NRF) through the South African Research Chair Initiative (SARCHI) for Biodiversity Value and Change at University of Venda, South Africa are acknowledged for funding the project. The authors also wish to thank Mr Muvhulawa Elias Mudau who assisted in locating the population of *Encephalartos transvenosus* at Mahunguwi village.

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