Ecological Assessment and Biogeography of Coastal Vegetation and Flora in Southern Mozambique

by

Alice Obed Massingue

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NELSON MANDELA UNIVERSITY

DECLARATION BY CANDIDATE

NAME: Alice Obed MASSINGUE

STUDENT NUMBER: 213231573

QUALIFICATION: PhD - Botany

TITLE OF PROJECT: Ecological Assessment and Biogeography of coastal vegetation and Flora in southern Mozambique

DECLARATION:

In accordance with Rule G5.6.3, I hereby declare that the above-mentioned treatise/ dissertation/ thesis is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

SIGNATURE: Alice MASSINGUE

DATE: 22. March 2019

Abstract

This study considered aspects of the vegetation of the coastal zone of southern Mozambique, an area with a rich biodiversity. The vegetation and flora were assessed in their current state including the associated anthropogenic pressures. The environmental conditions that determined the distribution of the vegetation were evaluated. A hierarchical classification, description and ecological interpretation of the vegetation and flora of the coastal zone in southern Mozambique are presented. Analysis was based on 242 sample quadrats that were distributed in a stratified manner throughout the study area. The vegetation could be grouped into six distinct types of vegetation: Dune Forest, Coastal Forest, Coastal Grassland, Coastal Miombo, Coastal Savanna and Coastal Woodland. Species diversity was high for the all the vegetation types, particularly in the woody elements. A total of 673 species in 410 genera was recorded. They represented 104 families with Fabaceae and Rubiaceae being the most common. Of these, 6.6% were endemic or near-endemic to the coastal zone of southern Mozambique with Coastal Forest being the habitat with the greatest endemism. All soils from different vegetation types had poor agricultural potential. Soil properties were the strongest defining environmental feature separating the vegetation types: e.g. pH was high in Dune Forest compared to the others.

Results from *Maxent* modelling suggest that the distribution of endemic species is influenced by a combination of climatic and non-climatic variables. Soil type, temperature annual range and precipitation of the driest month were the most important predictor variables. Overlaying the potential distributions of the seven selected species indicated two areas of abundance of endemic species – these should be given attention for conservation. Endemic species are not well protected in southern Mozambique – their sampled and potential habitats are largely outside protected areas. Hence, additional reserves should be created to improve their protection. Most endemic and near-endemics species were found in the south, from Ponta de Ouro (Matutuine, south of Maputo Province) to Manhica district (north of the Maputo Province) forming part of the Maputaland Centre of Endemism. A second concentration of endemism was found in the Inhambane Province, specifically the Inhassoro and Vilanculos districts. This is proposed to be an Important Plants Area (IPA).

Because most endemics and near-endemics are found in the Coastal Forest, their main threat is harvesting for charcoal production, although none of the endemic species are specifically targeted for charcoal production. In Inhambane they are also threatened by the tourism industry,

agriculture and settlements. The impact of the habitat destruction on endemic species is expected to cause severe declines in the near future.

The tourism industry and harvesting of trees for charcoal production and over-frequent fires are the main drivers of vegetation loss in this region. Shifting agriculture, harvesting for firewood and construction materials, cattle grazing (at a minor scale) are also impacts, but these were only observed in a small area of Maputo Province.

Although the study was done in coastal zone of southern Mozambique, effective management of whole coastal zone of the country will be required to maintain a functioning and diverse ecosystem. Priorities for management are to ensure that forests are protected, in particular, Dune Forest. Actions are required to minimise degradation of coastal vegetation. Further research on Coastal Forest restoration should be planned, as field observations in this study confirm that forest in the coastal zone of southern Mozambique has resilience.

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Dedication

People say "IT TAKES A VILLAGE TO RAISE A CHILD" and my village was full of many elders who have no idea of how important school is, but moulded me into who I am. I dedicate this thesis to my father Obed Massingue, in memory and my mother Celina Zimba, in gratitude for the many sacrifices they made so that we could live better lives. They taught me the importance of family, education and community service. To my daughter Stynna Massingue Manjate, for the all encouragement she provided even in her young age.

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1. General introduction

This thesis covers the main botanical and vegetation findings from a study on the coastal area of southern Mozambique (Save River mouth to Ponta de Ouro).

The coastal zone represents the transition from marine to terrestrial influences and vice versa. These environments influence each to a greater or lesser extent, and their influences may also change over time (Carter, 1988). The coastal zone comprises not only shoreline ecosystems, but also the upland watersheds draining into coastal waters as well as the nearshore sub-littoral ecosystems influenced by land-based activities. Functionally, it is a broad interface between land and sea that is strongly influenced by both (Ray et al., 2014). This zone includes vegetation that is influenced both by the ocean and its associated climate (Lubke et al., 1997). Many definitions are used to characterize coastal vegetation, but this study uses an adaptation of the definition of Timberlake et al. (2011) to be the vegetation found between the sea and roughly 100 km inland.

Coastal vegetation is complex (Cresswell & Bridgewater, 1985). It comprises communities that perform a variety of functions of vital importance to the natural environment but also to society (Martínez et al., 2007). Among these is the control of soil erosion including the significant role vegetation plays in reducing the severity of tsunami waves and dissipating the energy associated with them (Dahdouh-Guebas et al., 2005). These complex and ecologically sensitive environments are linked to the catchments associated with them. In the past, due to anthropogenic disturbance, a large amount of coastal vegetation has been removed (Gilmore et al., 2008) for example for cultivation.

As primary producers, coastal plants play a vital role in coastal ecology (Pankhurst, 2005). These include:

- Maintaining water quality by filtering out nutrients and trapping sediments – thereby helping ecosystems to protect water resources;
- Regulating and establishing run off, and acting as a buffer against floods and droughts;
- Providing food, shelter and breeding habitats for both aquatic and terrestrial fauna and
- Preventing erosion.

In addition, many native coastal plant species play a major role in the formation and stabilization of sand dunes as well as to protect the shoreline from erosion. The foliage and deep root systems of these plants assist in the formation of the dune through reduction of site-specific wind velocity, facilitating wind-blown sand deposition, and direct stabilization of the dunes by the deep root systems. For example, as sand builds up around dune plants, new roots develop on the buried stems and new shoots emerge from the surface of the sand. The result is a dense mat of vegetation that anchors the dune below its surface and traps more windblown sand thus building and stabilizing the dunes (USDA-NRCS Jamie L. Whitten Plant Materials Center, 2007).

1.1 Description of the coastal zone in Mozambique

According to Tinley (1971), the Mozambican coast is a compound shoreline produced by successions of emergence and submergence. It can be divided into three main natural regions:

- Coral coast with fringing coral and coral rock cliffs occurring in the north;
- Parabolic dune coast with high dunes from Bazaruto to Ponta de Ouro; and
- Swamp coast between Pebane and the Zambezi river mouth that includes the delta coast comprising mostly mangroves.

The coastal area in Mozambique lies in what White (1983) called the Zanzibar-Inhambane Regional Mosaic – a phytochorion he described as stretching along the East African coast from Somalia to South Africa (Figure 1). In Mozambique this zone is considered to extend from the north up to the Limpopo River in the Gaza Province. South of the Limpopo River the coastal zone forms part of the Maputaland-Tongoland Center of Endemism (Van Wyk & Smith, 2001). The coastal belt therefore has two distinct biogeographic units, namely the Zanzibar-Inhambane and Maputaland-Tongoland bioregions.

According to Younge et al. (2002) “the eastern African coastal forest ecoregion is recognized as one of Africa’s centres of species endemism and is distributed over six countries”: with these being Somalia, Kenya, Tanzania, Mozambique, Zimbabwe and Malawi. The coastal belt of Mozambique is estimated to comprise 4 750 km^2 and is largely vegetated with coastal forest.

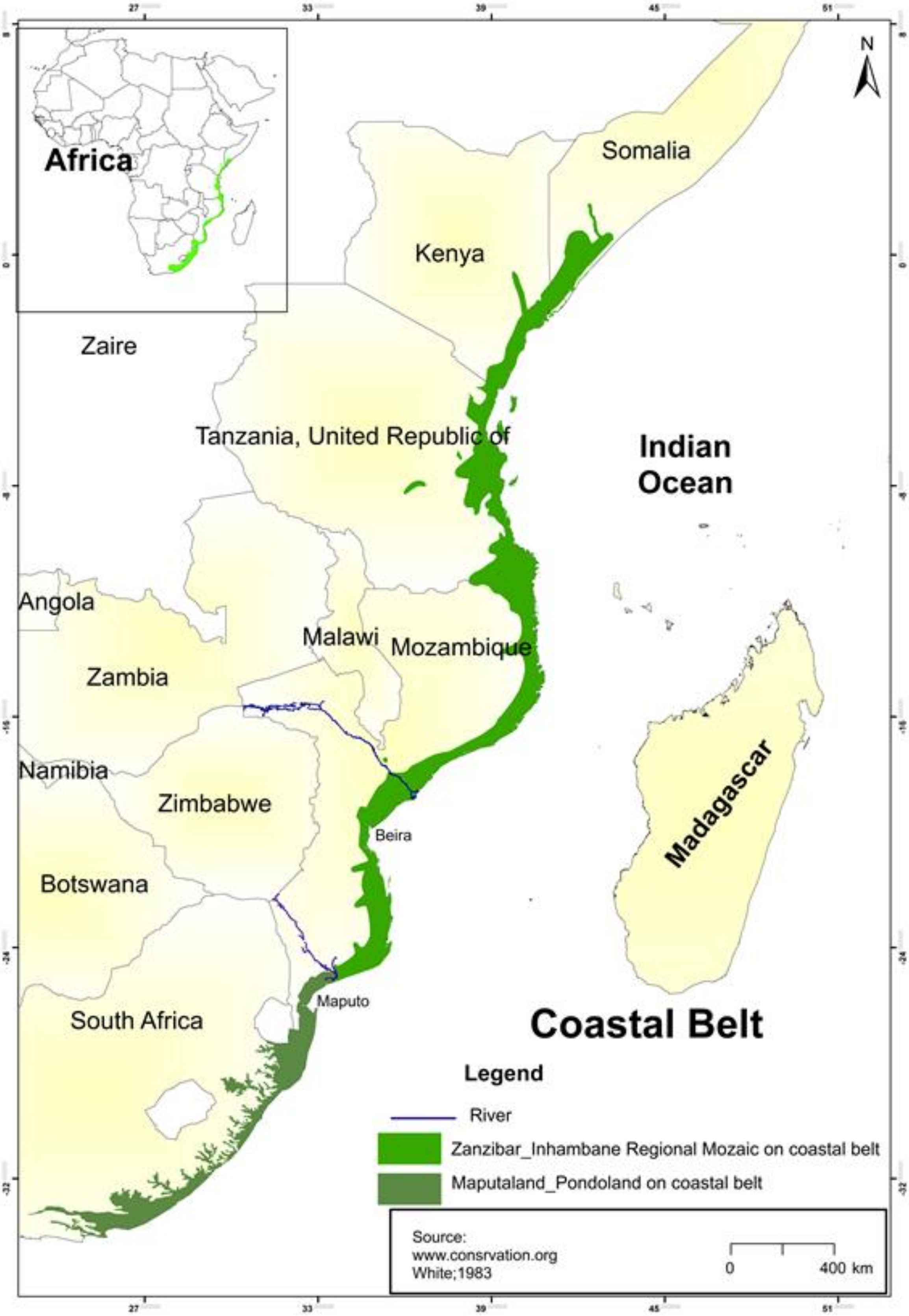

Figure 1. The Indian Ocean Coastal Belt according to White (1983).

Mozambique consists of a central plateau that steps down to extensive coastal plains representing 44% of the country. The remainder of the country is made up of plateau (43%), and mountain regions (13%). Mozambique has an Indian Ocean coastal plain of more than 2 700 km^2 (Halim, 1984). Some 62 million hectares (about 80% of the national territory) are vegetated with natural vegetation including forests of different heights and densities, savannas, bushveld and prairies (Kanji et al., 1998).

1.1.1 Geography and climate

The major part of the Mozambique coast has a tropical humid to sub-humid climate, with little rain in the dry winter season. The coastal seaboard in southern Mozambique is characterized by a low coastal plain – largely below 100 m above sea level (masl). It is composed predominately of Quaternary sands, with the forest dune cordon enclosing a chain of barrier lakes. The coastline has an alternating zigzag pattern of a linear coastline, cut in unconsolidated Quaternary to recent sand, with dune-rock forming reefs (Tinley, 1985).

1.1.2 The Zanzibar-Inhambane Regional Mosaic (sensu lato)

According to Burgess et al. (2004) the Zanzibar-Inhambane region comprises about 259 900 km^2 in total. In Mozambique this region extends from the Rovuma River (the border with Tanzania: 10º28'6"S : 40º28'8"E) to the Limpopo River (25º12'5"S : 33º31'21"E) and comprises about 147 000 km^2. The climate is tropical, the elevation is about 200 masl, and the rainfall is between 800 and 1200 mm per year (White, 1983).

1.1.3 Maputaland

Maputaland is in the south-east of Mozambique from the Limpopo River Mouth at Xai-Xai, the capital of Gaza Province (Van Wyk & Smith, 2001; 25º12'5"S : 33º31'21"E) to Ponta de Ouro (the border with South Africa; 26º51'54"S : 32º51'24"E), occupying about 30 200 km^2 (Burgess et al., 2004). Morphologically it has two major physiogeographic units: the Lebombo Mountains in the west and a low topographic coastal plain along the Indian Ocean seaboard in the east (Momade & Achimo, unpublished). Average humidity is relatively high along the coastal plain, even in drier inland parts. Winters are drier than summers (SABONET, 2002).

The climate is tropical to subtropical and the elevation in the coastal zone of Maputaland is about 150 m near the coast to about 600 m in the Lebombo Mountains. The annual rainfall averages about 1 100 mm along the coast but declines progressively inland to about 500 mm (Van Wyk & Smith, 2001; Momade & Achimo, unpublished).

1.2 Geology and soil

Most of the land in the Zanzibar-Inhambane Regional Mosaic (including the Inhambane Province) lies below 200 masl. The coastal plain is underlain by marine sediment of various ages from Cretaceous to recent (White, 1983). According to Van Wyk (1996) and Momade and Achimo (unpublished) the geology of Maputaland consists of volcanic rocks of Karoo origin (basalts, rhyolites, tuffs, vitreous material and dolerites) in the Lebombo Mountains.

The soils in most of Maputaland are infertile. The potential agriculture capacity is low due to the abundance of geologically recent fine-grained, homogeneous, grey, siliceous and aeolian sands. This has resulted in a shifting form of cultivation practiced by the local population, which involves clearing, burning, and planting for a few years. On the Lebombo Mountains and in some of larger river basins the soil is relatively fertile with high clay content (Bruton & Cooper, 1980).

1.3 Problem statement

Biodiversity conservation is one of the major concerns in biogeography and ecology. Species richness is distributed non-uniformly across the biosphere (Sechrest et al., 2002) and nature conservation is often based on the concept of biodiversity hotspots (Myers et al., 2000; Brooks et al., 2002; Roberts et al., 2002). Many studies have discussed the factors determining the spatial distribution of species at various spatial scales (Quist et al., 2004; Trivedi et al., 2008; Soberón, 2010). Species distribution models (SDMs) that use environmental factors and localities based on historical collections are increasingly being used to not only analyse species distributions, but also to predict the presence or absence of species based on their habitats in unrecorded areas (Elith & Leathwick, 2009). Notably, SDMs have been used to predict potentially suitable areas for the preservation of endangered and rare species (Solano & Feria, 2007; Thorn et al., 2009), for the identification of potential sites for reintroduction or restoration of populations (Kumar & Stohlgren, 2009) and for assessing potential effects of future climate change on species distributions as well as on local species diversity (Pearson & Dawson, 2003; Hole et al., 2009). To enable the analysis of the impacts of climate change on species, it is essential to quantify the relative importance of climate relative to other descriptors of the environment (Newbold, 2010).

Coastal vegetation is as an important resource as it provides habitat and food while providing and important ecological function. Most coastal areas of the world are under threat, and coastal vegetation has often been destroyed by development, e.g. for the tourism industry. Many parts of the coastal area of southern Mozambique have been completely destroyed due to anthropogenic activities such as rapidly increasing human habitations, harvesting of firewood, and emigration of able-bodied workers (Werger, 1978; Bruton & Cooper, 1980). Where the vegetation has not been destroyed, it consists of a complex forest mosaic, scrub forest, evergreen and semi-evergreen bushland, thicket, grassland (White, 1983; Tinley, 1985) or wooded grassland (Matthews et al., 1999). In Maputaland at least 15 vegetation types have been described, of which two are remarkable – sand forest and wood grassland (Moll, 1980) – both endemic to Maputaland Centre of Endemism (SABONET, 2002). In addition, Burgess et al. (2004) classify both southern Zanzibar-Inhambane coastal forest mosaic and Maputaland coastal forest mosaic as being critically threatened.

Destruction of coastal vegetation has several impacts, both socially and economically. The most important include increased impacts of floods and drought, as well as loss of species diversity.

This project endeavours to propose a possible way to prevent destruction of coastal vegetation through informing managers of the importance of this ecosystem. It is also hoped that this information will be used by the people to provide knowledge on how to use coastal ecosystem resources that are vital for human beings, giving recommendations for the next generation. Mozambique, as a signatory of the United Nations (UN) Convention on Biological Diversity (CBD), has obligations towards avoiding biodiversity loss.

1.4 Rationale and motivation

Before biodiversity can be monitored, an inventory of the natural resources of an area must be compiled. These include species, ecosystems and environmental features of a region. Such an inventory is essential to develop future monitoring strategies and management plans of large natural areas. Knowledge of a region's plant diversity forms the basis for understanding and managing its plant resources and environment. Concern for the survival of plant species has driven conservation policies and actions for many centuries. One of the main problems facing plant conservation in Mozambique is the lack of sound information on which to base strategic conservation planning.

According to Sieben (2011), detailed vegetation descriptions, together with the correlation between vegetation types and environmental conditions are essential tools in the management of vegetation. An understanding and description of coastal vegetation across the country would be useful for conservation planning as well as for management decisions. Therefore, this study will contribute to understanding the type, and pattern of distribution of coastal vegetation, plant species richness and human impacts. It will help to identify biodiversity ‘‘hot spots’’ for conservation and wildlife habitat management and provide information on the ecological functions that are critically important when authorities attempt to manage the coastal zone.

One of the main problems facing plant conservation in Mozambique is the lack of sound information required for systematic conservation planning (Margules & Pressey, 2000). A baseline inventory of ecological data is essential to supply authorities with the necessary information required to designate areas for the most appropriate forms of land-uses and to formulate management plans for the protection and sustainable use of the region's native plant resources. Hence, the primary motivation for this study comes from the urgent need to determine which areas are of prime botanical importance, in particular those that are at risk of rapid loss and degradation of natural ecosystems due to unplanned and uncontrolled development. An adequate database of natural features is essential for effective land-use management and implementation of conservation initiatives.

Main objective: To develop a detailed knowledge of the plant species diversity and associations within the plant communities in southern Mozambique. This knowledge should be adequate to monitor and evaluate future activities for conservation, sustainable use and rehabilitation of natural vegetation – particularly in the face of specific developmental challenges in the region and in response to the International Convention on Biological Diversity.

Specifically:

- To classify the vegetation of the coastal zone of southern Mozambique and formally describe its plant communities;
- To assess the current conservation status of endemic and near-endemic species and to determine where such taxa are or are likely to be found and to evaluate how well their distributions are covered by the current protected area network.

- To investigate the most important environmental factors that might have an influence on vegetation and floristic diversity of the study area;
- To investigate the habitat diversity with specific emphasis on habitats containing taxa of conservation concern;
- To address the floristic status of the area and identify biogeographical patterns and floristic affinities between plant communities;
- To investigate and assess major threats to the region; and to make recommendations concerning sensitive plant species and floristic areas that should be conserved.

1.5 Study area

Mozambique is located in south east Africa, between 10°27'S and 26°52'S and 30°12'E and 40°51'E. The total area of the country is almost 800 000 km^2, which includes over 36 million hectares of arable land with a coastline of 2 740 km. It borders with Tanzania on the northern side, South Africa and Swaziland to the south and southwest, with Zimbabwe to the west, Zambia and Malawi to the northeast and the Indian Ocean on the east coast (FAO, 2011).

This study considered the coastal zone of southern Mozambique (Maputo, Gaza and Inhambane; Figure 2). Tinley (1985) characterized the coastal zone of southern Mozambique by the dominance of parabolic dunes. Topographically the study area is quite varied, consisting of beaches and low dunes along the Indian Ocean, and low undulating terrain on the coastal plains intersected by numerous drainage channels forming lagoons. It covers approximately 1 100 km of shoreline.

The thesis is divided onto six chapters (Figure 3):

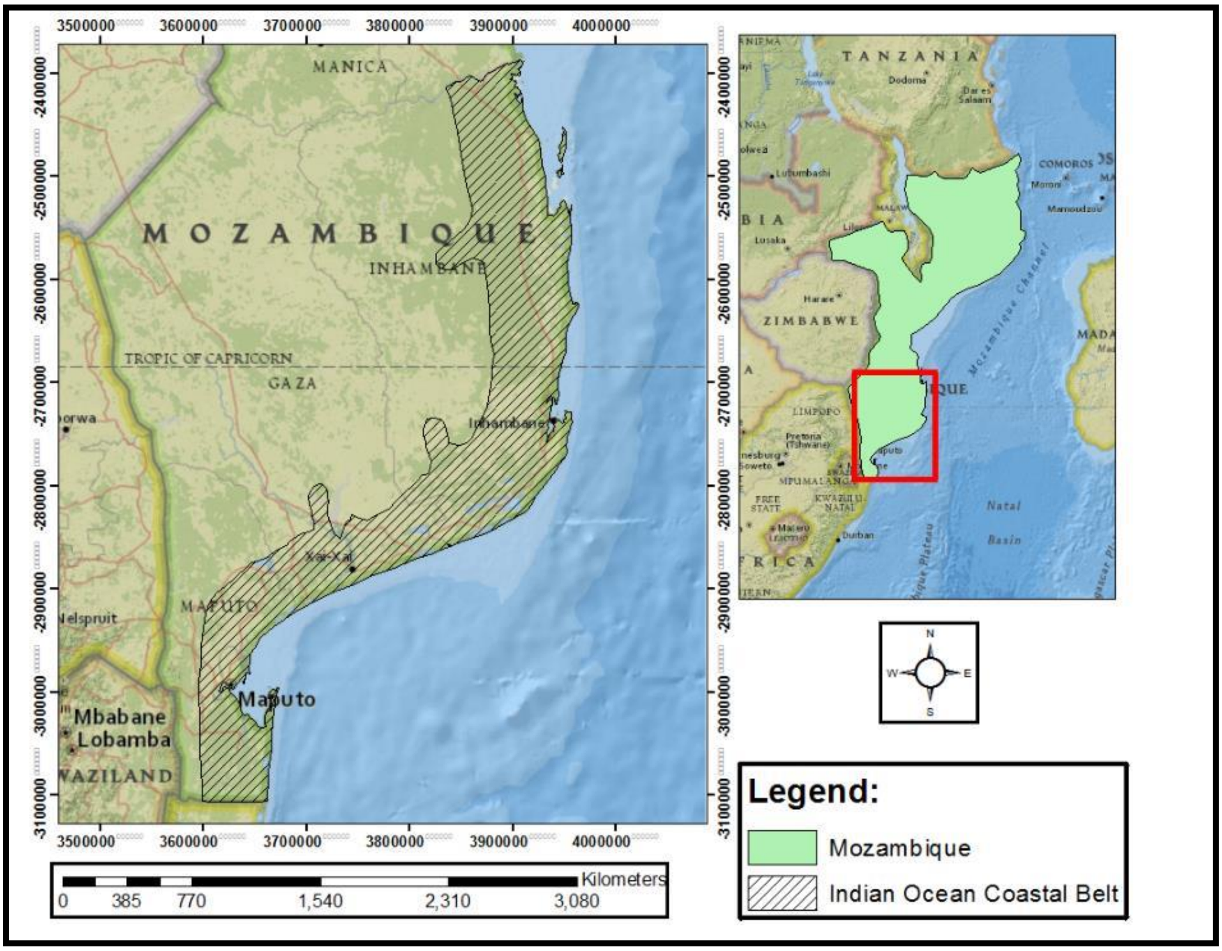

Figure 2. The study area comprising the coastal plain of southern Mozambique between the South African border in the south and the Save River in the north.

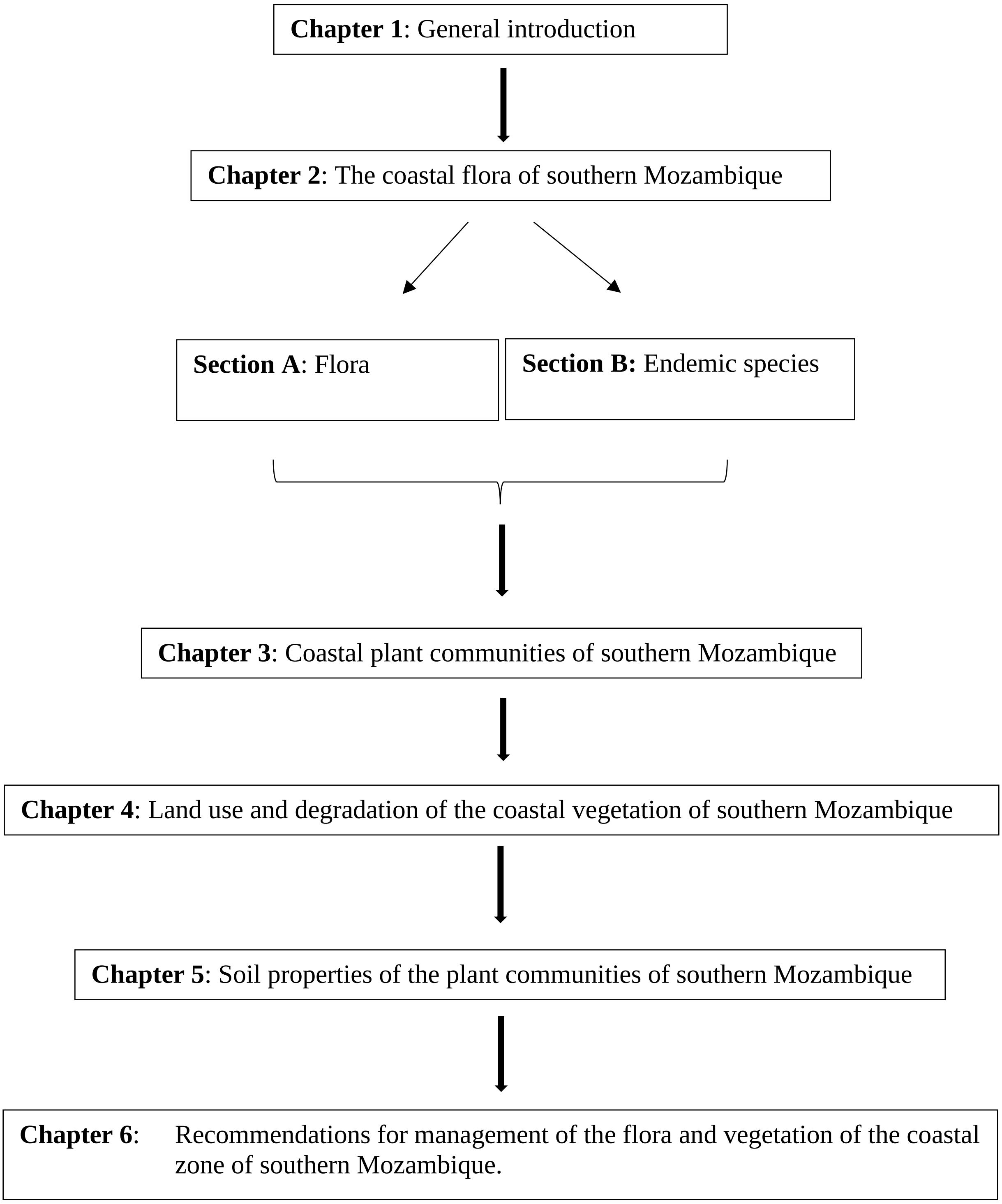

Figure 3. Flow diagram of the different chapters in this study.

2. The coastal flora of southern Mozambique

2.1 Introduction

There are still large gaps in the knowledge of the flora of Mozambique. According to a preliminary checklist of vascular plants, the flora of Mozambique comprises 3 932 indigenous plant taxa, of which 177 are endemic to the country (Da Silva et al., 2004). The current list of Mozambique taxa stands at 5 781 plant species (MICOA, 2014) following various collecting expeditions (e.g. Timberlake et al., 2009; Timberlake et al., 2011; Burrows et al., 2018).

Floristically, the coastal zone of Mozambique has been recognized as the Indian Ocean Coastal Belt (Figure 4) containing two phytochoria namely: the Zanzibar-Inhambane and the Tongaland-Pondoland Transitional Zone and Mosaic Regions (Moll & White, 1978). Later White (1983) named these the Zanzibar-Inhambane and the Tongaland-Pondoland Regional Mosaics (Figure 4). The Zanzibar-Inhambane Regional Mosaic occupies the East African coastal belt (between 50 and 200 km wide), from southern Somalia in the north to the mouth of the Limpopo River while the Tongaland-Pondoland Regional Mosaic extends to Port Elizabeth.

The Zanzibar-Inhambane phytochorion was split into two smaller floristic regions (we use the term Broad Habitat Unit here) by Clarke (1998): the Swahilian Regional Centre of Endemism along the Somalian, Kenyan, Tanzanian and northern Mozambique coasts; and the Swahilian/Maputaland Regional Transition Zone extending along the Mozambique coast and into southern Malawi and eastern Zimbabwe between the Swahilian Regional Centre of Endemism and White's (1983) Maputaland-Pondoland Regional Mosaic. The study area lies between the coastal zone from Save River to Ponta de Ouro and it includes two regions: the Swahilian/Maputaland Regional Transition Zone and the Maputaland-Pondoland Regional Mosaic that is part of the Maputaland Center of Endemism.

Wild & Barbosa (1967) classified nine vegetation types in the study area: Sideroxylon-Afzelia-Ficus-Balanites (their vegetation type 5); Mangroves (vegetation type 14a); Thicket and forest coastal dunes-*Mimusops caffra* (vegetation type 14b); *Brachystegia spiciformis* (vegetation type 20); Brachystegia-Afzelia-Sideroxylon (vegetation type 25); Albizia-Afzelia-Sclerocarya (vegetation type 34); Syzigium-Garcinia-Dialium (vegetation type 43);

Biogeographic Unit	**Name** ***Location***		
Biome	Indian Ocean Coastal Belt *Mozambique shoreline to ca. 100 km inland*		
Phytochorion	Zanzibar-Inhambane *Mozambique border (N) to Limpopo River*		Pondoland-Tongoland *Limpopo River to Mozambique border (S)*
Broad Habitat Unit	Swahilian Centre of Endemism *Rovuma River to Moma*	Swahilian-Maputaland Transition Zone *Moma to Limpopo River*	Maputaland-Pondoland Regional Mosaic *Limpopo River to Ponto de Ouro*

Note: Defining the precise limit of Swahilian centre of endemism is currently quite difficult as too few data are available from the vegetation. Timberlake et al. (2011) confirmed that the Cabo-Delgado region was in the Swahilian Centre. This region seems to end in somewhere in Moma (Nampula Province) (Clarke, 2000).

Figure 4. Vegetation of the coastal zone of Mozambique.

Hyphaene, Phoenix or Borassus (vegetation type 44), Commiphora-Combretum (vegetation type 46) and Formations on alluvium (vegetation type 54). White (1983) mapped the region as East African coastal mosaic (mapping unit 16a, b and c), which seem to better describe the floristically rich vegetation of the study area.

Although some plant exploration was undertaken in southern Mozambique between 1940 and 1980, according to information in the LMA and LMU herbaria, there is still a dearth of botanical information in Mozambique. The coastal region of Mozambique has long been recognized as "a probable area of high biological diversity and interest" (Wild & Barbosa, 1967). Huntley (1978), Moll & White (1978) and White (1983) agree: "This recognition was primarily based on the known high species diversity and high number of narrow-range endemics in the flora of coastal south-eastern Tanzania", a region that has no apparent geographical isolation from the adjacent Mozambique. Another reason is "because a significant number of Mozambique narrow-range endemics were confined to the northern coastal areas" (Timberlake et al., 2011). It is also based on the presence of the Maputaland Centre of Endemism in the south of Mozambique (Van Wyk, 1996; Van Wyk & Smith, 2001). It is also recognized that the climate along the coastal strip is moister and more humid than in the continental interior (Moll & White, 1978), and thus likely to be different ecologically.

During the civil war in Mozambique (1975-1994), botanical collecting came to a halt and has only taken place sporadically since then (Da Silva et al., 2004). Hitherto, most of the botanical inventories compiled in Mozambique have been done mainly in the south of the country (i.e. in the Maputaland Centre of Endemism – the southern Mozambique expedition of 2001: Izidine & Bandeira 2002; Izidine et al., 2003; Matimele, 2016). The southern Mozambique coastal vegetation is still poorly known in Gaza and Inhambane Provinces in particular.

According to Timberlake et al. (2011) the coastal forests of Eastern Africa have, over the last 20 or so years, been recognized as forming the most important part of a distinct ecoregion – the Eastern Africa Coastal Forests Ecoregion. It has particularly high levels of endemism. "Although small, this ecoregion is often regarded as a globally important conservation priority area" (Burgess & Clarke, 2000).

2.2 Flora

Mozambique has 5 781 listed plants species (MICOA, 2014). No studies show the numbers of coastal plant species and their distributions.

In this thesis three biogeographic units are used to refer to the coastal vegetation of Mozambique (Figure 4). These are based on the literature presented in section 2.1:

- The Swahilian regional centre of endemism is limited to Cabo Delgado and Nampula (outside this study area);
- The Swahilian/Maputaland Regional Transition Zone (Nampula south of Moçambique Island, Zambezia, Sofala and (relevant to this study) Inhambane and Gaza north of the Limpopo River; and
- The Maputaland-Pondoland Regional Mosaic (in Gaza south of the Limpopo as well as the Maputo Province) – also known as the Maputaland Center of Endemism.

These phytogeographic areas comprise a mosaic of unique types of forest, thicket, woodland, bushland and grassland.

2.3 Mozambique Endemics

Endemic species are those confined to a restricted geographic area, and may have a small population size and an associated relatively high extinction risk (Broennimann et al., 2005)

2.3.1 Swahilian-Maputaland Regional Transition Zone

This area lies from South of Moçambique Island to the mouth of Limpopo River, including islands (Schipper & Burgess, 2004). According to Clarke (1998) this transitional zone contains about 3 300 vascular plants of which about 100 are endemic – some of them occur in the Maputaland Center of Endemism. It is not known how many plant species occur in the south of this biogeographic unit.

2.3.2 Maputaland-Pondoland Regional Mosaic (Maputaland Centre of Endemism)

The boundaries of the Maputaland Centre of Endemism (Maputaland Centre of Endemism) were defined by Van Wyk (1996) to stretch from northern KwaZulu-Natal in South Africa to the Limpopo River in southern Mozambique. Maputaland is known for its rich fauna and flora with high levels of endemism (Van Wyk 1996). It has a high number of native plant species

(>2 500) with more than 230 being of restricted range distribution (Van Wyk 1996; Van Wyk & Smith 2001).

Izidine et al. (2003) recognized that the plant families Asclepidaceae, Rubiaceae, Acanthaceae, Liliaceae, Euphorbiaceae and Asteraceae contribute the largest number of endemics in this region. Matimele (2016) considered 13 species to be of conservation concern.

2.4 Methods and data analysis

2.4.1 Description of the flora

"The description of plant vegetation usually means that individual species within the community being studied have to be identified" (Kent, 2012). Such a description should include vegetation patterns and the measurement of species abundance.

In this study, the vegetation was sampled for floristic composition using quadrats. Quadrat size is important, and this should vary from one type of vegetation to another (Magurran, 2004; Birnie et al., 2005; Kent, 2012). The study area (Figure 2) is highly heterogeneous with many habitats and vegetation communities. Although various quadrat sizes have been recommended by Birnie et al. (2005) and Kent (2012) for certain types of vegetation, in this study, quadrat size was based on minimal area and species-area curves were used to determine this (Kent, 2012).

Species accumulation curves were determined by measuring the number of species in nested quadrats of increasing area. This was done for representative areas of grassland, woodland and savanna during an exploration visit in April 2013 (Figure 5, Plate 1). Using these species-area curves, phytosociological studies used 15 m x 15 m quadrats in woodland and forest, 30 m x 30 m for savanna and 2 m x 2 m for grassland (Figure 5). Square sample plots were used for operational simplicity, although Newton (2007) lists the limitations of these. Square plots are commonly used in sampling of tropical vegetation (Davidar et al., 2007).

In each plot, all plant species were identified, all shrubs and trees counted to give an indication of woody plant density (Shimwell, 1971) and the percentage cover measured for herbaceous plants (Mueller-Dombois & Ellenberg, 1974).

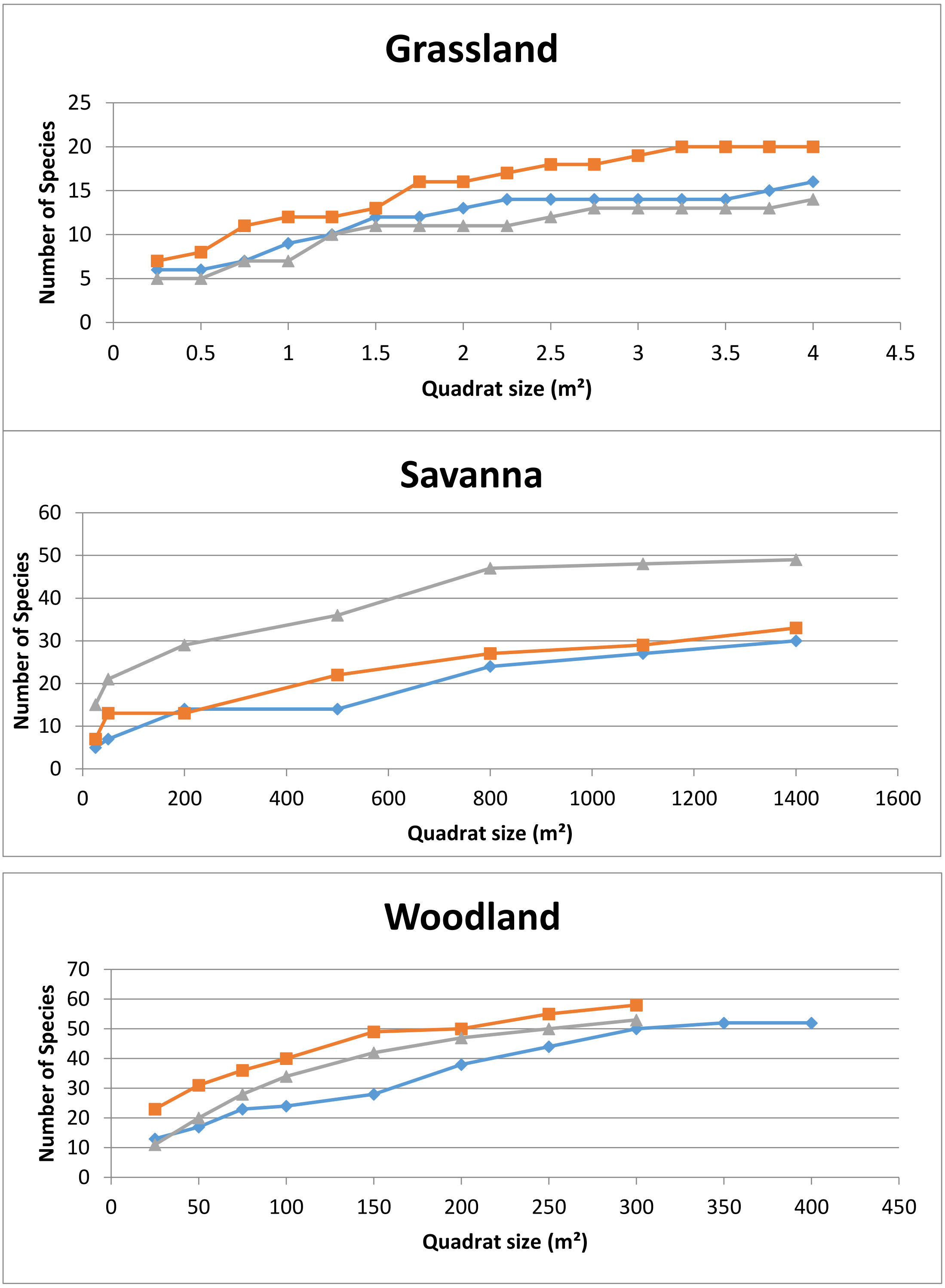

Figure 5. The species accumulation curves for grassland, savanna and woodland vegetation of the coastal plain of southern Mozambique. Three different areas were measured for each vegetation type.

Plate 1. A nested quadrat layout used to determine a species-area relationship of grassland quadrats.

According Birnie et al. (2005) there is no simple rule for calculating optimal quadrat size. It is therefore probably more honest to use a rule of thumb based upon the characteristics of the community to be sampled and the size of individual plants (Gauch, 1982). Because of the obvious relationship of species to the area, various investigators have attempted to standardize the size of quadrats (Shimwell, 1971; Kent, 2012). Birnie et al. (2005) suggested 1 m x 1 m or 2 m x 2 m quadrats for grasslands; between 20 m x 20 m and 50 m x 50 m quadrats for scrub, woodland shrub, and small tree woodland canopies or 1 to 2 m² for herb, 4 m² for tall herb and low shrub and 10 m² for tall shrub and low tree communities. The minimum areas calculated in this study (Fig. 5) fall within these recommendations.

To select sampling sites, homogeneous areas were delineated on satellite imagery. These were based on vegetation cover and density, topography, colour and texture. The homogeneous units provided a first level of stratification for selecting sample sites based on major gradients in the study area.

Data were collected in all types of vegetation, avoiding only wetlands (even though they represent an important habitat, the study was focused on terrestrial habitats). Field work was conducted from November 2013 to December 2015. In total, 242 sampling sites were measured. An assessment of habitat features (topography, aspect, slope, degree of erosion, stone/rock cover, clay content of the soil, drainage) were made at each quadrat. Information on grazing, burning and other human impacts was recorded as were GPS points (Figure 6). Sampling was limited to the areas adjacent to the road network due to the lack of vehicle accessibility and safety concerns related to off road driving.

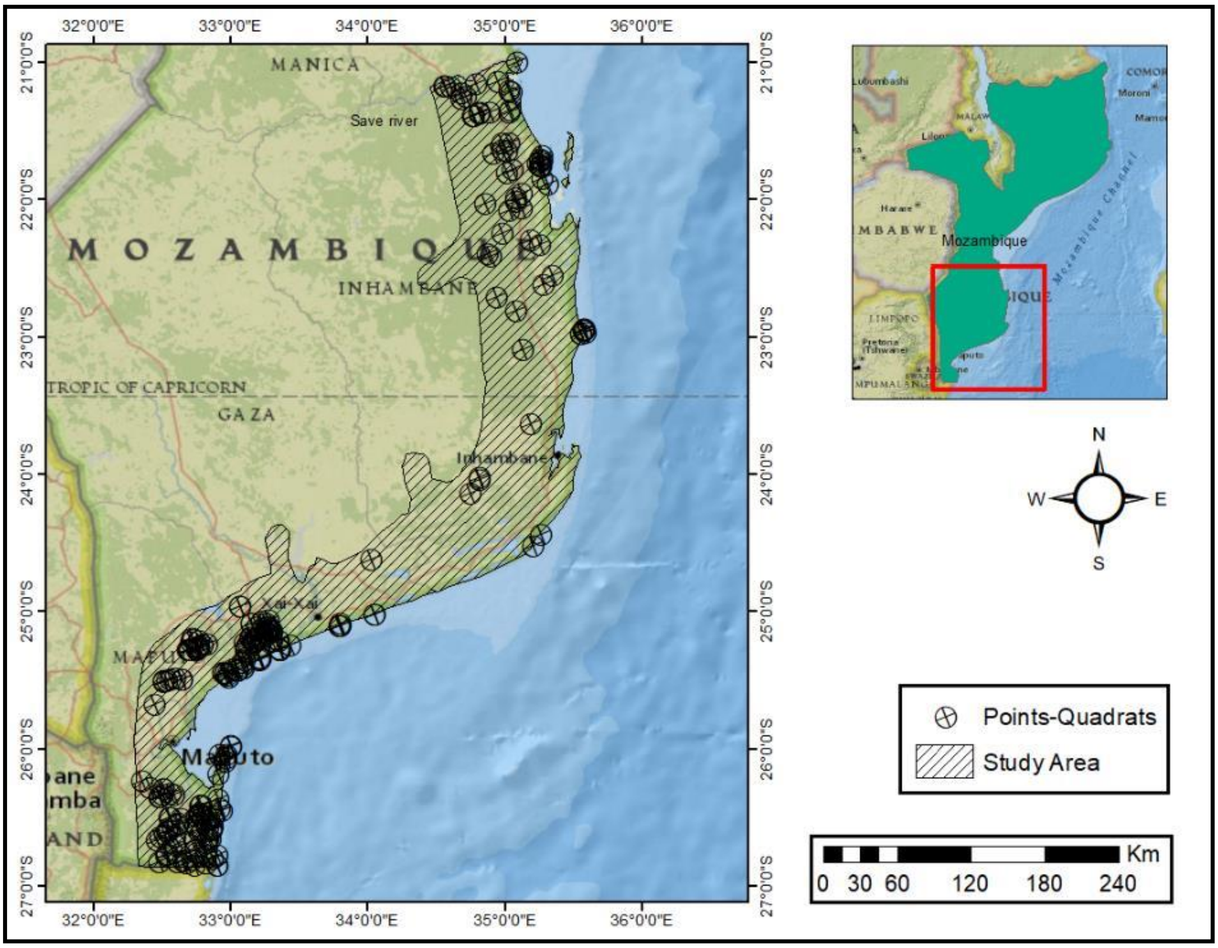

Figure 6. The locality of the sampling sites (quadrats) analysed this study.

2.4.2 Plant identification

Plant specimens collected were taken to the LMU herbarium at Eduardo Mondlane University in Maputo for drying and processing. Pre-identification was done during the field work. Later at LMU and LMA in Maputo, the specimens were identified to family and species level by following taxonomic keys and by comparison with older material stored in these herbaria. Confirmation of identifications was done at the South African National Herbarium in Pretoria (PRE) and the Buffelskloof Nature Reserve Herbarium (BNRH). The latter housed most of the material used for confirmation.

All species authorities are provided in Appendix A and not repeated in the text.

2.4.3 Plant community metrics

Functional diversity is a component that influences how ecosystems operate (Tilman, 2001). Magurran (2004) provided valuable reviews of concepts of diversity for ecologists, that focus on species richness (number of plant species in a quadrat, area or community) and relative abundance (species within the sample or community), diversity is thus measured by recording the number of species and their relative abundance. There are three types of diversity namely:

- alpha diversity – this refers to the number of species recorded in each quadrat;
- beta diversity – this refers to the differential species recorded in replicate quadrats (of the same vegetation type); and
- gamma diversity – represents difference in species composition between different areas or environments (Kent, 2012; also called habitat diversity).

The **alpha diversity** of each group in this study was assessed by calculating the Shannon-Wiener (H’) index that was calculated as follows:

$$H' = -\sum_{\mathrm{i=1}}^{\mathrm{S}} P_i \ln(P_i)$$

Where S is the number of species, P$_i$ is the abundance of the ith species, and ln = log base$_{\mathrm{n}}$ (Magurran, 2004; Jost, 2006; Kent, 2012). The value of the index usually lies between 1.5 and 3.5 although in exceptional cases it can exceeded 4.5 (Kent, 2012).

Exponent H´ was used to convert H´ to the effective number of species. This conversion provides a measure of “true” diversity indicating the number of equally-common species required to give the value of H´ (Jost, 2006);

The **Equitability of Evenness** index (E) is calculated as the Shannon Wiener index divided by the logarithm (ln) of the number of taxa (S);

Simpson index according to Magurran (2004) is calculated as:

$$D = \sum(\frac{n_i(n_i - 1)}{N(N - 1)}$$

where n_i = the total number of individuals of a particular species; N = the total number of individuals of all species. The Simpson index is the one of the most meaningful and robust diversity measures available, because it captures the variance of the species abundance distribution (Magurran, 2004).

The dissimilarity between the groups was computed through the **Bray-Curtis distance** index (Ricotta and Podani, 2017). The Bray–Curtis index is a rank-order index that is semi-symmetric.

Indicator Species Analysis (ISA) is a non-parametric method for identifying those individuals (in an individual-attribute matrix) that show significantly preferential distribution (frequency and abundance) compared to an *a priori* treatment group. An indicator value is calculated by multiplying the relative abundance of each individual in a particular group and its relative frequency of occurrence in the sample of that group (Dufrêne & Legendre 1997). The number of randomized indicator values higher than the observed ones is used to calculate the probability value (McCune & Grace 2002).

2.4.4 Assessment of endemic and near-endemic species

It is important to understanding why some regions have higher levels of diversity and which factors are driving the occurrence of species in a particular area. This is particularly true for endemic/near-endemic species. Knowledge of their distributions is crucial for environmental management and for the development of species conservation strategies. All records of endemic and near-endemics species were mapped to determine where these species of conservation importance are more concentrated. Individual species maps were also plotted.

Maximum Entropy Distribution or *Maxent* is a general-purpose method for characterizing probable distributions from incomplete information (Phillips et al., 2006). This model is a good alternative to those requiring both presence and absence records because reliable absence data are rarely available in poorly sampled regions (Engler et al., 2004). *Maxent* has been found to perform best among many different modelling methods (Elith et al., 2006; Ortega-Huerta & Peterson, 2008) and may remain effective despite small sample sizes (Hernandez et al., 2006; Pearson et al., 2007; Papes & Gaubert, 2007; Wisz et al., 2008). *Maxent* v. 3.2.2 (http://www.cs.pricenton.edu) was used to construct separate models for each endemic/near-endemic species using only presence data (Phillips et al., 2006; Elith et al., 2010).

The bioclimatic variables needed for *Maxent* represent annual trends (e.g. mean annual temperature and annual precipitation), seasonality (e.g. annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g. temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). Data for modelling was taken from the *WorldClim* database (http://www.worldclim.org/).

2.5 Results

2.5.1 The coastal zone of southern Mozambique

The coastal zone of southern Mozambique comprises a variety of ecosystems from marine to terrestrial. The study area extended from the Save River in the north to Ponta de Ouro in the south (1 100 km of shoreline). There are many types of habitat along the coast, including terrestrial and marine systems such as mangroves, littoral dunes, wetlands, rivers and lagoons.

The most important **rivers** in the coastal zone of southern Mozambique are the Save River, Limpopo River and the Incomati River that drain into the Indian Ocean.

There are also large natural **lagoons** in southern Mozambique from Ponta de Ouro to Inharrime – the largest are found between Manhiça (Maputo) and Inharrime (Inhambane). Some of these have fresh water and others are saline. Peatlands are also common, with one peatland having a large population of *Raphia australis*, a near-endemic palm species that occurs only in the coastal zone of southern Mozambique and the north of KwaZulu-Natal. Most of small rivers in this region drain into these lagoons, for example, seven small rivers flow into the lagoon at Bilene. The water level in some of the lagoons depends on the amount of rain received in that season (e.g. Matutuine and Inhambane from Jangamo to Inhassoro) while others do not depend on the rainy season (those between Manhica and Inharrime).

Littoral dune vegetation (Plate 2a) forms the most important habitat that protects terrestrial ecosystems from excessive marine influences. Coastal dune vegetation in southern Mozambique can be found from Inhassoro to Ponta de Ouro including the Bazaruto archipelago and Inhaca Island and they are most commonly vegetated parabolic dunes (Tinley, 1971). Small chains of dunes without vegetation can also be found (e.g. in Bilene and Kalanga; Plate 2b). From Inhassoro to Massinga the dunes are vegetated by miombo woodland, while savanna is the primary dune vegetation between Manhiça and Chideguele (Plate 2c). In Mambone, small patches of forest dominated by *Afzelia quanzensis* were found near mangrove forests. Inland, miombo forest occurs as patches in a *Senegalia nigrescens* (acacia) woodland. Inland acacia woodland has tall trees that can be between 7 and 12 m, although near the coast, trees did not often exceed 8 m.

Forest dominated by *Afzelia quanzensis* or *Syzygium cordatum* subsp. *cordatum* are the most common species observed along the lagoons both with saline or fresh water. *Afzelia quanzensis* were recorded in most lagoons in the coastal zone but is most common from Xai-Xai to Maputo. Inland areas of the Inhambane and northern Gaza coastal zones are dominated by miombo woodland (although miombo forest is also found) and savanna dominated by *Hyphaene coriacea*.

2.5.2 Floristic composition analysis

A total of 673 plant species were identified in this study (Appendix A), corresponding to 11.6% of the flora of Mozambique. These represented 104 families and 410 genera with the most important families being Fabaceae, Rubiaceae, Poaceae, Apocynaceae, Euphorbiaceae and Asteraceae (Figure 7). Flowering plants comprised 98% of all the species found, and trees and woody shrubs were dominant. The ferns are the most common non-flowering vascular plants. Six species of ferns were found in this study and the most common was *Pellaea viridis*.

a

b

c

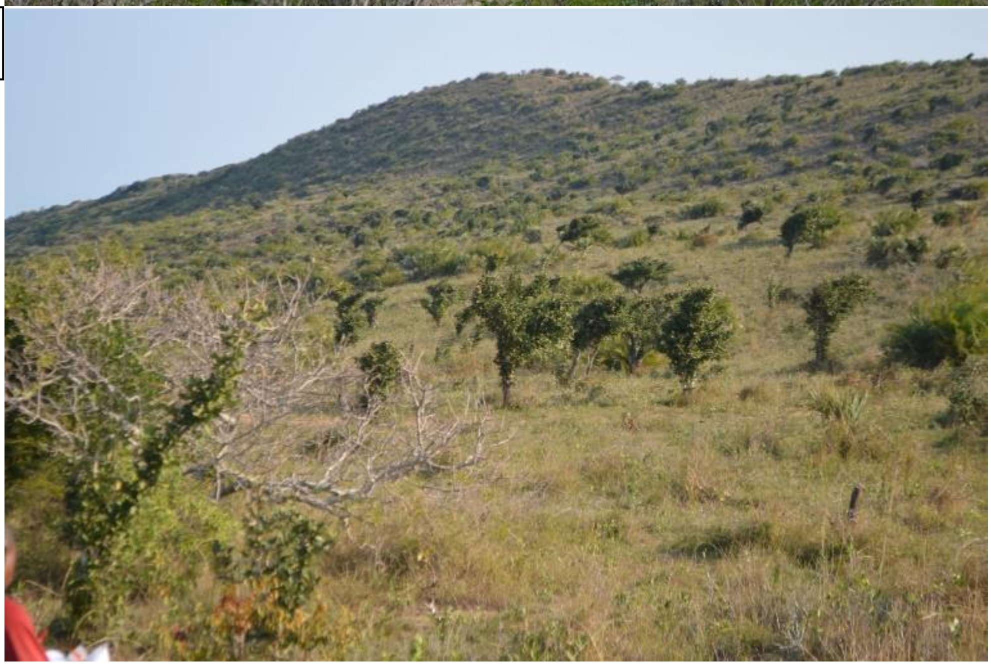

Plate 2. Littoral dune vegetation (a; primary); littoral dune backed by a lagoon (b); and dune savanna (c).

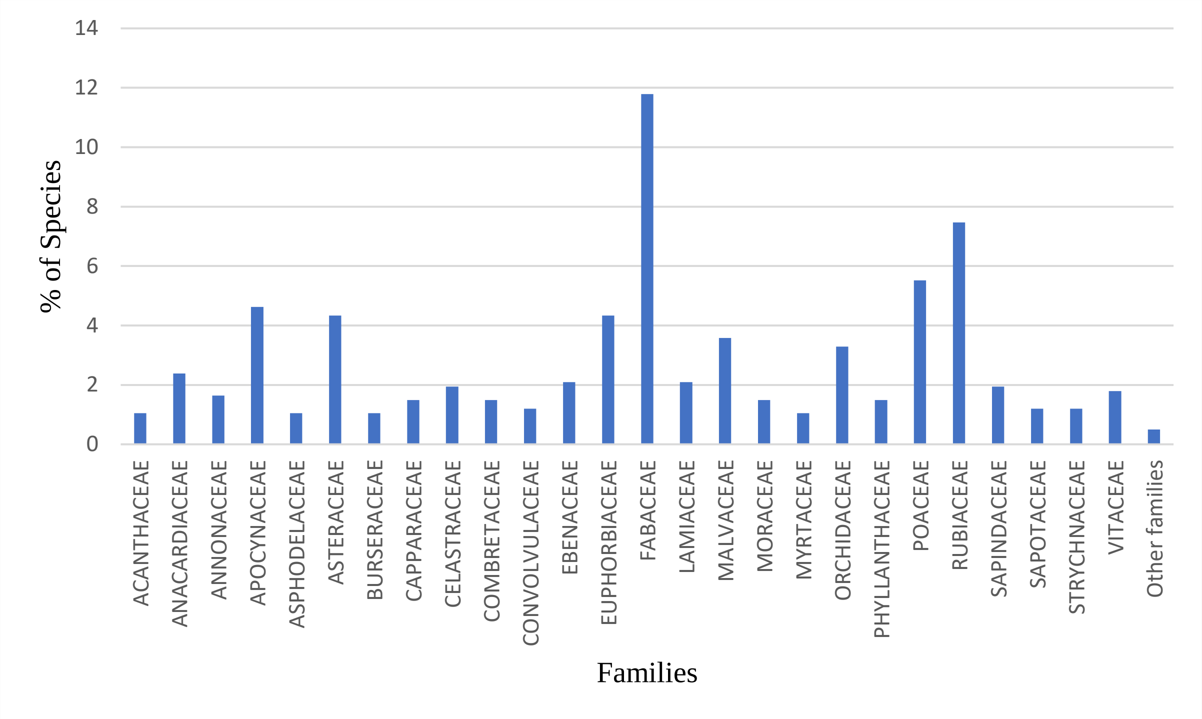

Figure 7. The major families of the flora of the coastal zone of southern Mozambique.

Only 3 gymnosperms were found:

- *Encephalartos ferox* subsp. *ferox* was found over the whole study area, but most commonly observed in Marracuene (Maputo) and Massinga (Inhambane);
- *Encephalartos ferox* subsp. *emersus* was found in Vilanculos and Jangamo in Inhambane where it was rare;
- the third is *Podocarpus falcatus* reported from the Txilitxili River in Ponta de Ouro.

2.5.3 Diversity

The diversity indices for all types of vegetation found in this study were high for the woody elements and for the herbaceous groups, apart from the grasslands (Tables 1 & 2).

In this study, species area curves were used to test the fidelity of the diversity index (Figures 8 & 9). These indicate that the sampling effort for forest, savanna and woodland was effective, while a few more samples would benefit the analysis of dune and miombo vegetation. Grasslands were found to be understampled (due to limited site availability).

Table 1. The Shannon-Wiener and Gini-Simpson diversity indices for woody elements in the vegetation types of the coastal zone of southern Mozambique.

Vegetation Types	**Shannon**	**Simpson**
Dune	3.932	0.952
Forest	4.364	0.977
Grassland	1.879	0.810
Miombo	4.212	0.958
Savanna	3.584	0.941
Woodland	4.107	0.963

Table 2. The Shannon-Wiener and Gini-Simpson diversity indices for herbaceous elements in the vegetation types of the coastal zone of southern Mozambique.

Groups	**Shannon**	**Simpson**
Dune	2.182	0.821
Forest	1.916	0.824
Grassland	1.224	0.569
Miombo	2.208	0.852
Savanna	2.864	0.921
Woodland	3.039	0.944

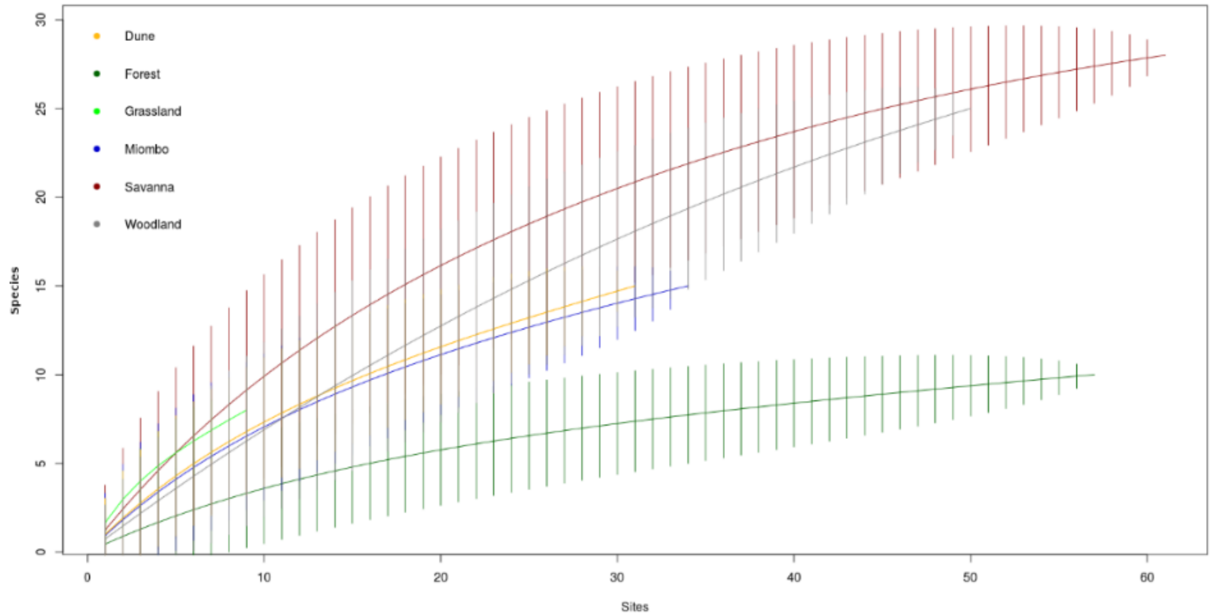

Figure 8. The species-area curve for woody elements in the vegetation types of the coastal zone of southern Mozambique.

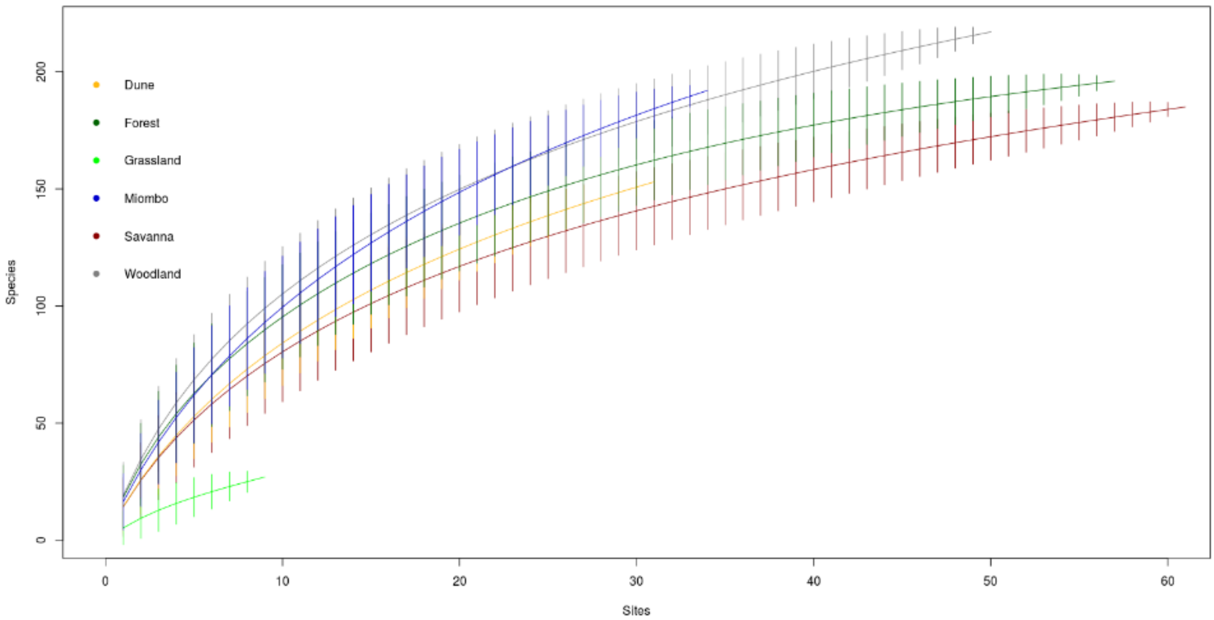

Figure 9. The species-area curve for herbaceous elements in the vegetation types of the coastal zone of southern Mozambique. The vertical bars are 95% confidence limits.

2.5.4 Endemics and near-endemics

A total of 45 endemic and near-endemic plant species was recorded in the coastal zone of southern Mozambique (Figure 10). Forest was the most prolific habitat for such taxa – representing 6.6% of all the species and 21.2% of all the families recorded. Most endemics and near-endemics were in the Fabaceae and Rubiaceae (Figure 10).

Maputo and Inhambane coastal zones contributed most species (Figure 11), and Gaza had only 2% endemism (Figure 11).

A species of *Cissus* was found in the Matutuine forest (Plate 3) that differs from the *Cissus rotundifolia* recorded elsewhere. This is likely to be a new species. If confirmed that it is a new, this *Cissus* sp. nov. will be endemic to the Matutuine forest in Maputo Province.

Plate 3. *Cissus* sp. nov. – a possible endemic to the Matutuine forest.

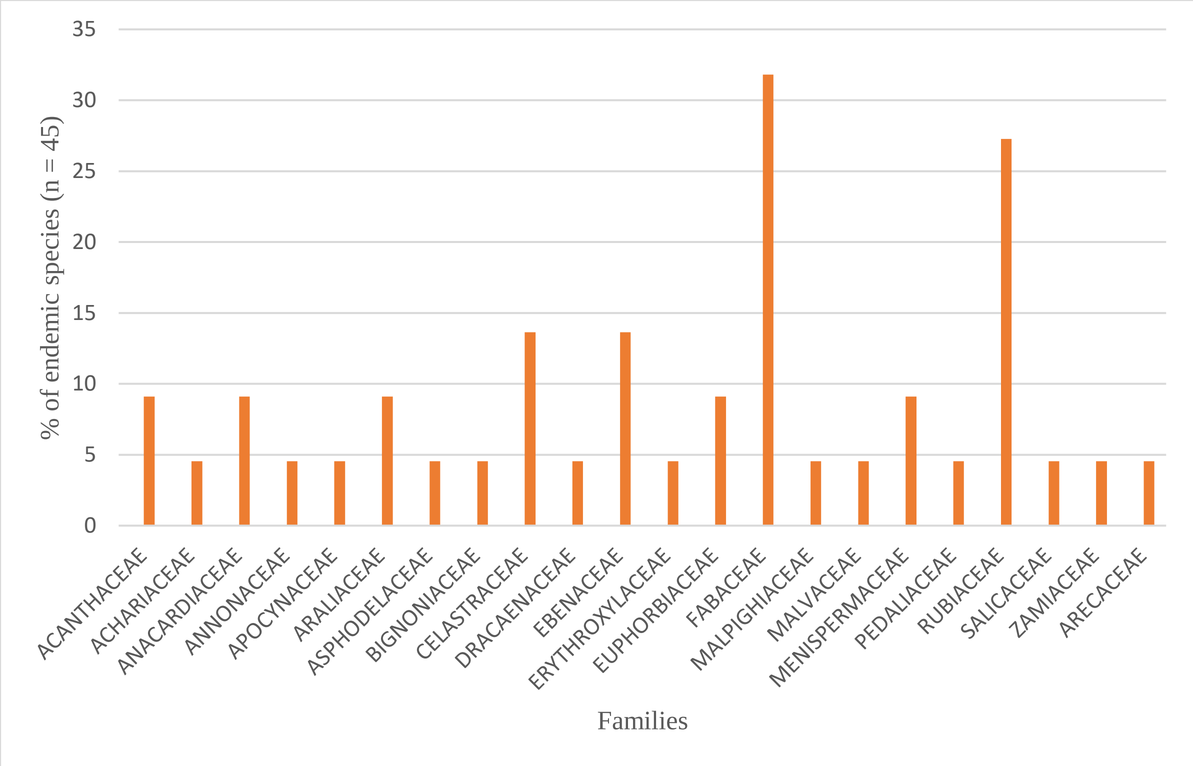

Figure 10. The families of the endemic and near-endemic plant species recorded in the coastal zone of southern Mozambique.

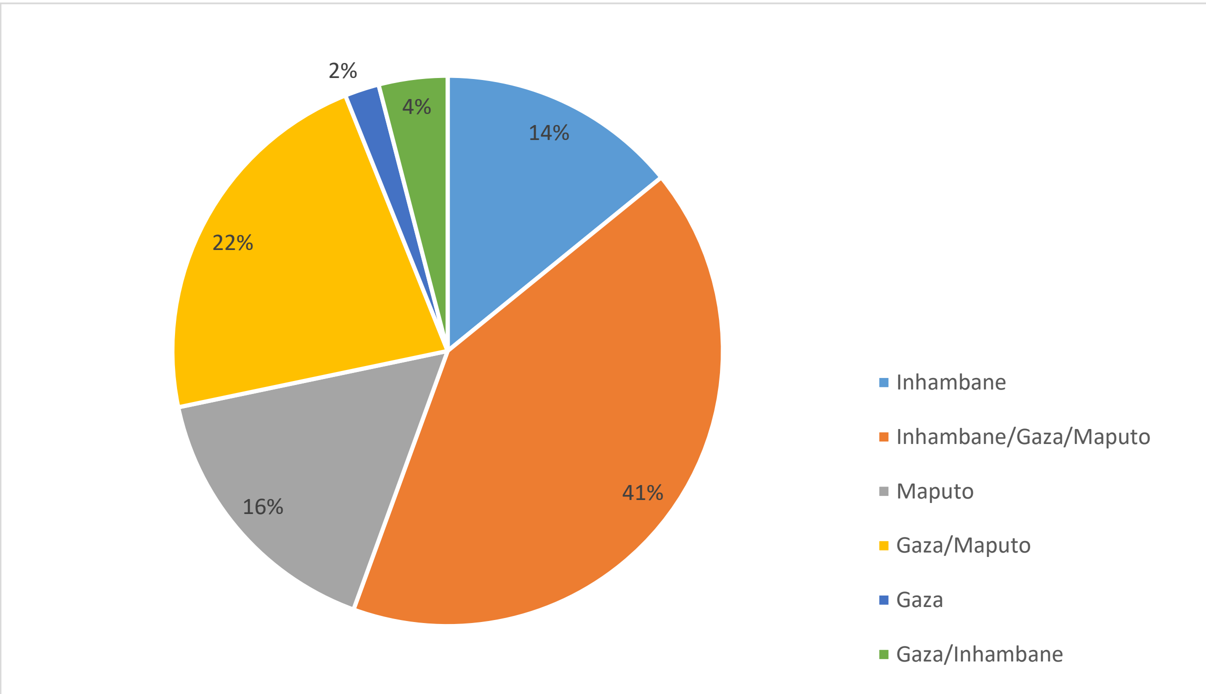

Figure 11. The percentage of endemic and near-endemic plant species in each province in the coastal zone of southern Mozambique.

Endemic species were mapped using locality data collected during field work as well as records of occurrence from LMU and LMA herbarium specimens. Figure 12 shows the localities where samples were collected during this study. There are four areas where most endemic and near-endemic species were found: three in the south (Maputo and Gaza Provinces) and one in north Inhambane Province. This confirms that the coastal zone of southern Mozambique lies in the Maputaland Centre of Endemism and these three areas could be combined (Figure 13) for purposes of management and conservation planning. However, a new area of endemism lies in Inhambane Province. It is split from the Maputaland Centre of Endemism by a zone (north Gaza-south Inhambane Province) with low levels of endemism. These two areas (the Maputaland Centre of Endemism and the Inhambane Centre of Endemism) confirm that the Indian Ocean Coastal Belt is a region with high levels of endemism.

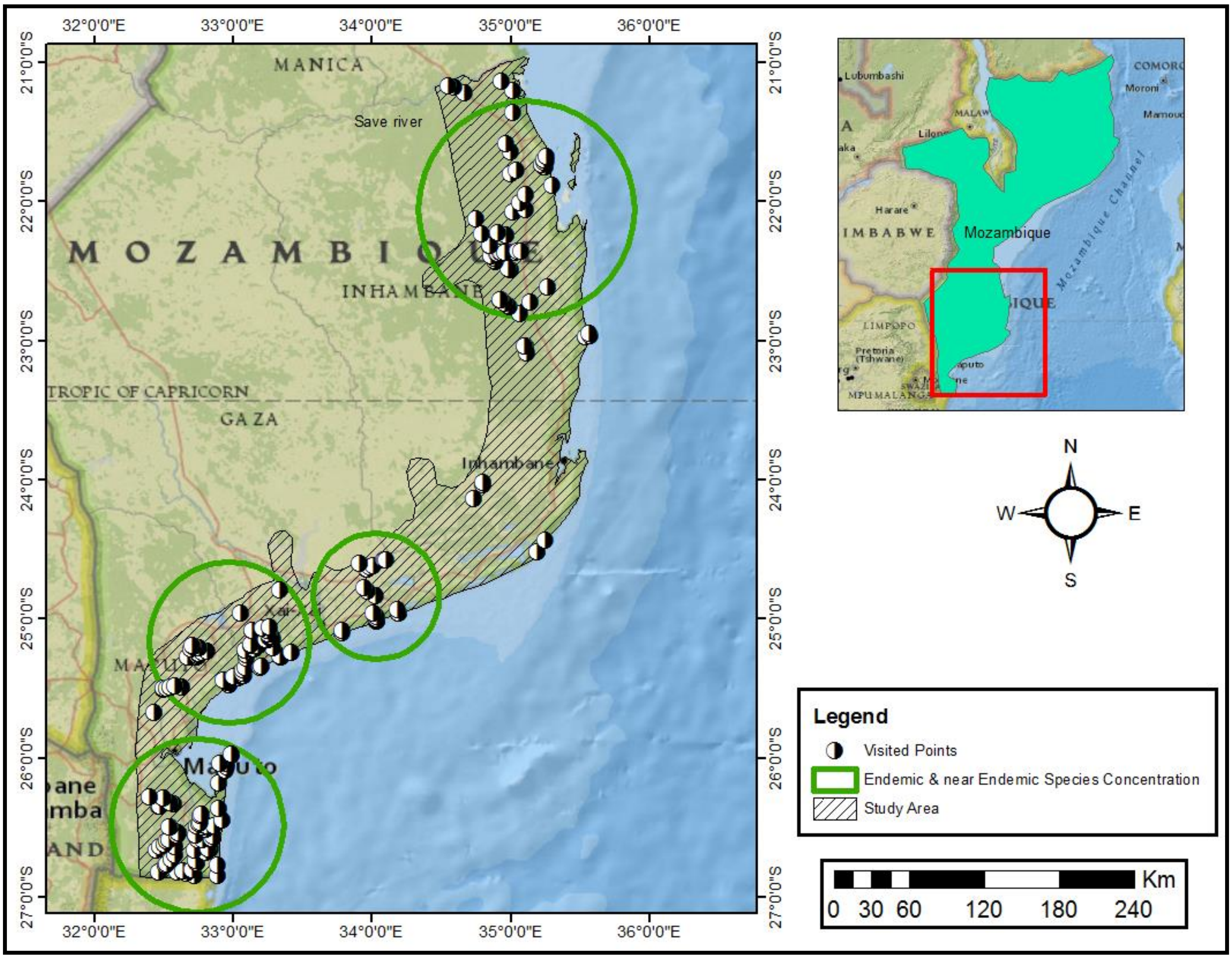

Figure 12. Localities of endemic and near-endemic species collected in this study in the coastal zone of southern Mozambique.

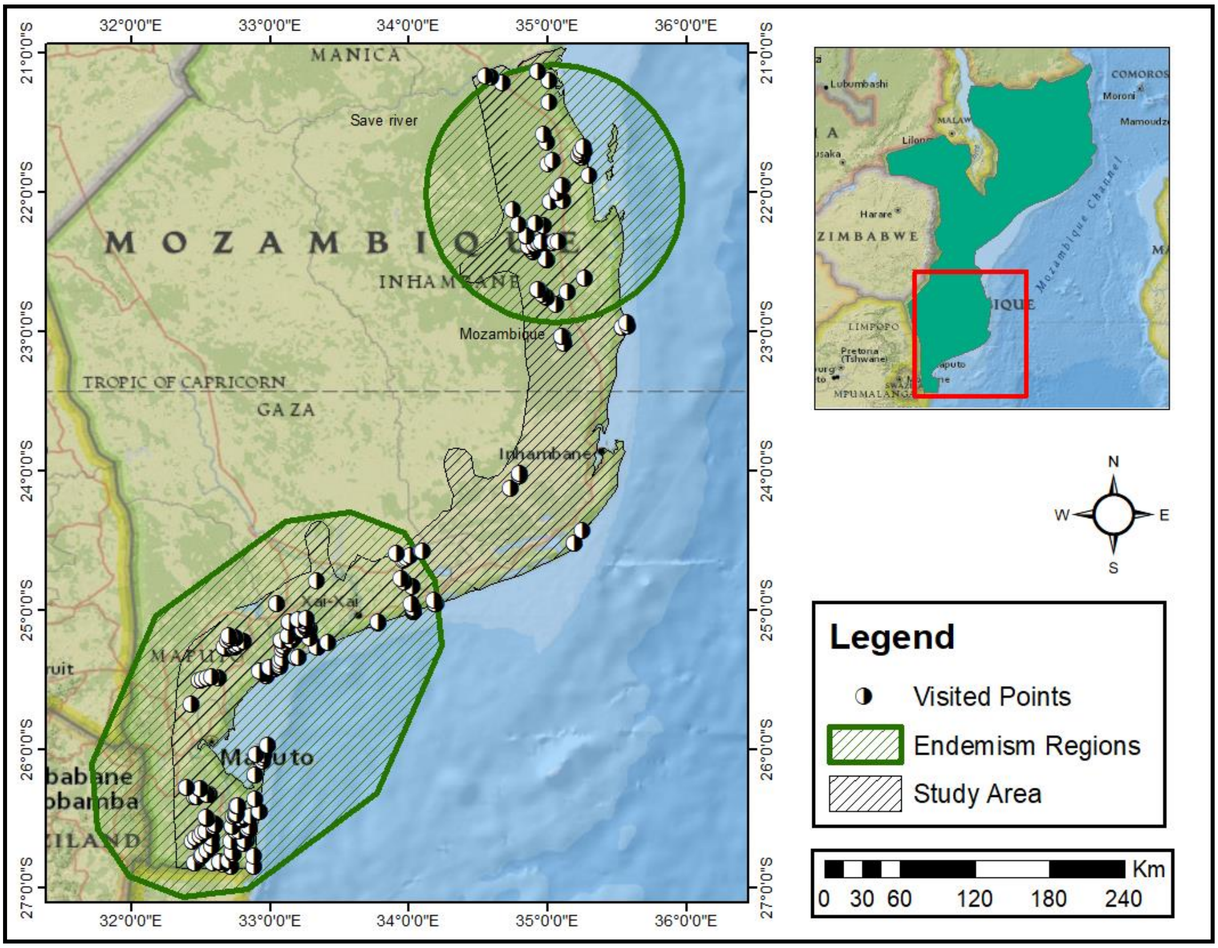

Figure 13. The two Centres of Endemism found in coastal zone of southern Mozambique.

Most of endemic species were found in forest and grassland vegetation types. During the field work the main threats operating at each locality for all the endemic and near-endemic species were assessed and summarized (Table 3). In this table eleven of the species are presented – eight from Inhambane Province and three from Maputaland: *Baphia ovata*, *Bauhinia burrowsii*, *Carissa praetermissa*, *Croton aceroides*, *Croton inhambanensis*, *Chamaecrista paralias*, *Cussonia arenicola*, *Dialium schlechteri*, *Eugenia albanensis*, *Ozoroa gomesiana* and *Xylia mendocae*. Although the threats differ between species, the loss and degradation of suitable habitat are the most important. Habitat loss occurs due to expansion of the tourism industry and human settlements as well as from subsistence agriculture (see Chapter 4).

Table 3. Summary of the main threats for each endemic and near-endemic plant species investigated in this study.

Location	**Species**	**Main threats**
Gaza and Inhambane	*Baphia ovata*	Habitat degradation due to the human settlement
Inhambane	*Bauhinia burrowsii*	Habitat degradation due to the subsistence agriculture and human settlement
Inhambane	*Carissa praetermissa*	Habitat degradation due to the charcoal production, fire wood collection and human settlement
Inhambane	*Croton aceroides*	Habitat degradation due to the charcoal production, fire wood collection and human settlement
Inhambane	*Croton inhambanensis*	Habitat degradation due to the charcoal production, fire wood collection and human settlement
Inhambane	*Chamaecrista paralias*	Habitat degradation due to the charcoal production, fire wood collection and human settlement
Maputaland	*Cussonia arenicola*	Habitat degradation due to the charcoal production, fire wood collection, human settlement and subsistence agriculture.
Maputaland	*Dialium schlechteri*	Removal of habitat due to human settlements, subsistence agriculture and tourism industry.
Maputaland	*Eugenia albanensis*	Removal of habitat due to large scale human settlements and fire. A new road was constructed, and more are planned due to rapidly growing tourism and urbanization.
Gaza and Inhambane	*Ozoroa gomesiana*	Removal of habitat due to the human settlements and subsistence agriculture
Inhambane	*Xylia mendocae*	Removal of habitat due to the large scale of tourism, human settlements and subsistence agriculture.

2.5.5 The current and predicted future species distribution

Only seven species (Table 4) had enough presence records for *Maxent* modelling. There is a dearth of information on the species from Inhambane – this centre of endemism has only been discovered recently, and this is the first study in which plant collection provided information on this region.

The seven species analysed, and their likely suitable habitats as estimated by *Maxent* are distributed across the southern Mozambique coastal zone (Figure 15 to 21). Models for all species had reasonable discriminatory power with AUC values ranging from 0.65 to 0.99 (Table 4) indicating average to excellent models. The best models were obtained for *Cussonia arenicola*, *Dialium schlechteri* and *Xylia mendocae*.

The modelled distribution map for *Baphia ovata* (Figure 15) and *Ozoroa gomesiana* (Figure 20) shows suitable habitat in the north of Inhambane, although in the field these species also occur in the north of Gaza Province (Chibuto). Suitable areas for *Bauhinia burrowsii* (Figure 16) lie only in the north of Inhambane Province. The predictive map for *Cussonia arenicola* (Figure 18) and *Dialium schlechteri* (Figure 17) showed habitat suitability in the Maputaland Centre of Endemism. *Xylia mendocae* (Figure 21) has high habitat suitability over the whole study area.

Table 4. Area under the curve (AUC) statistics obtained from the *Maxent* model of seven species endemic to coastal zone of southern Mozambique. 75% of the records were used as training data, and 25% as testing data. AUC values are all average to excellent.

Species	**Training data**	**Testing data**
Baphia ovata	0.93	0.65
Bauhinia burrowsii	0.87	0.95
Croton inhambanensis	0.82	0.85
Cussonia arenicola	0.99	0.99
Dialium schlechteri	0.97	0.86
Ozoroa gomesiana	0.99	0.74
Xylia mendocae	0.95	0.91

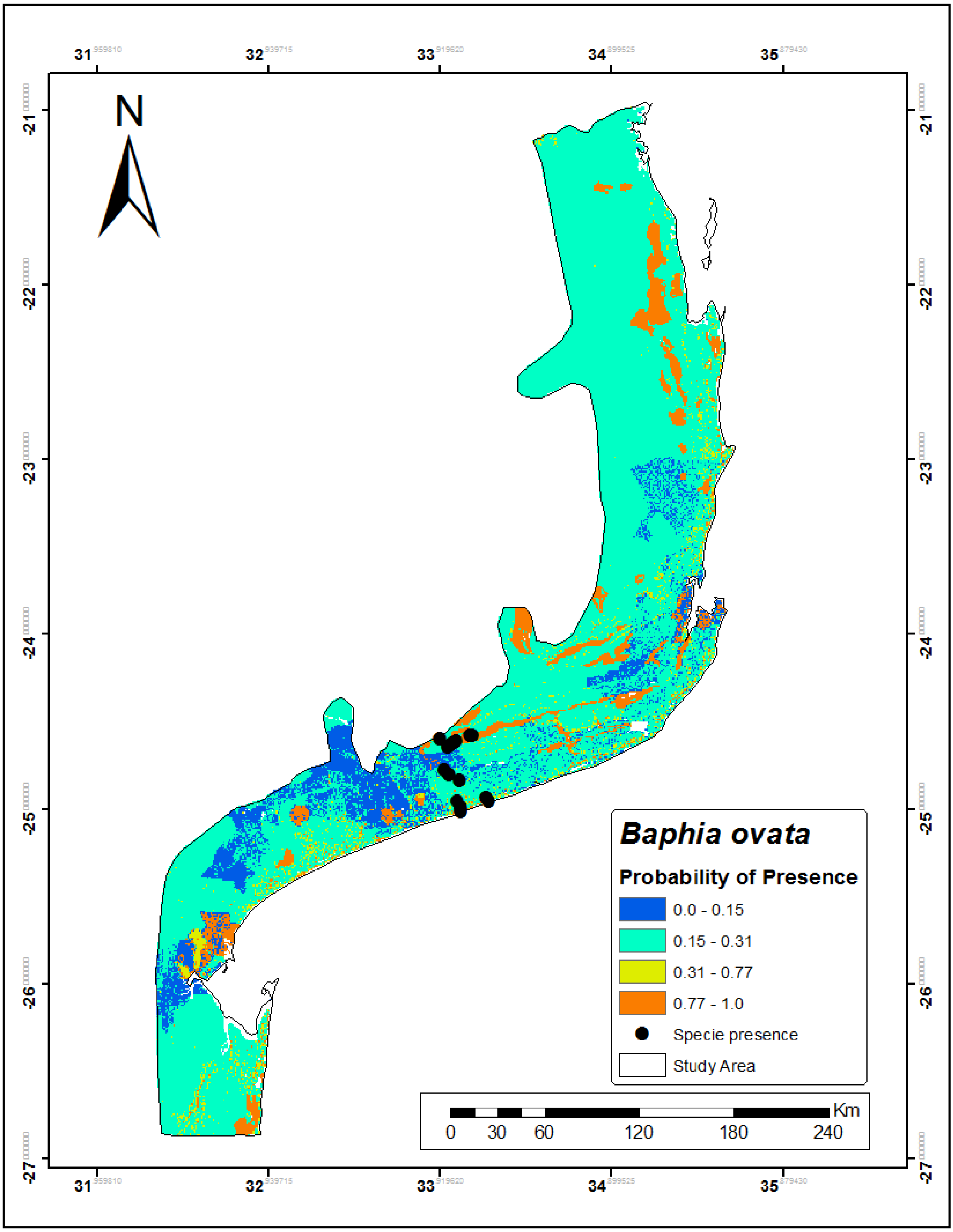

Figure 14. The *Maxent* species distribution model for *Baphia ovata* Sim.

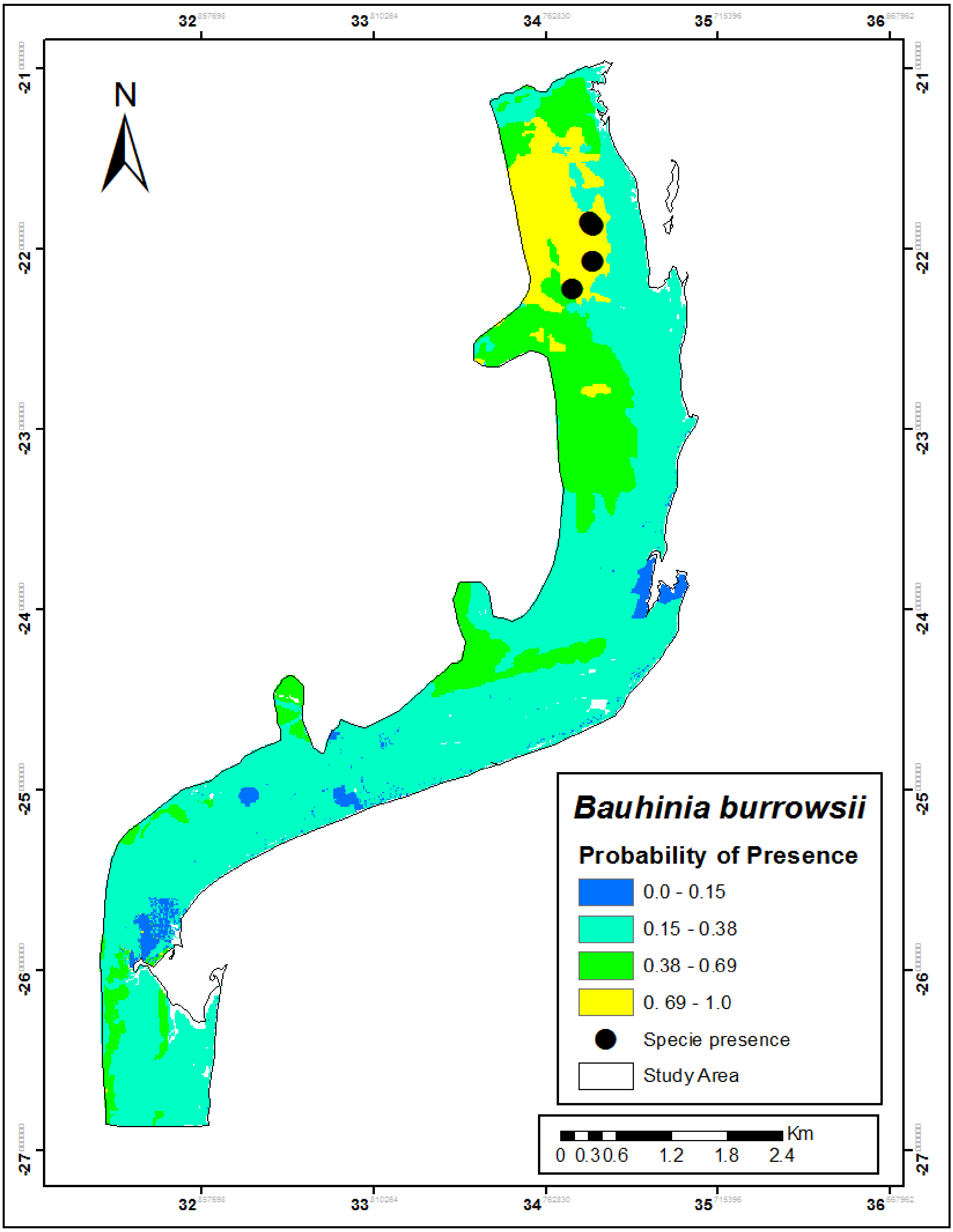

Figure 15. The *Maxent* species distribution model for *Bauhinia burrowsii* E.J.D. Schmidt.

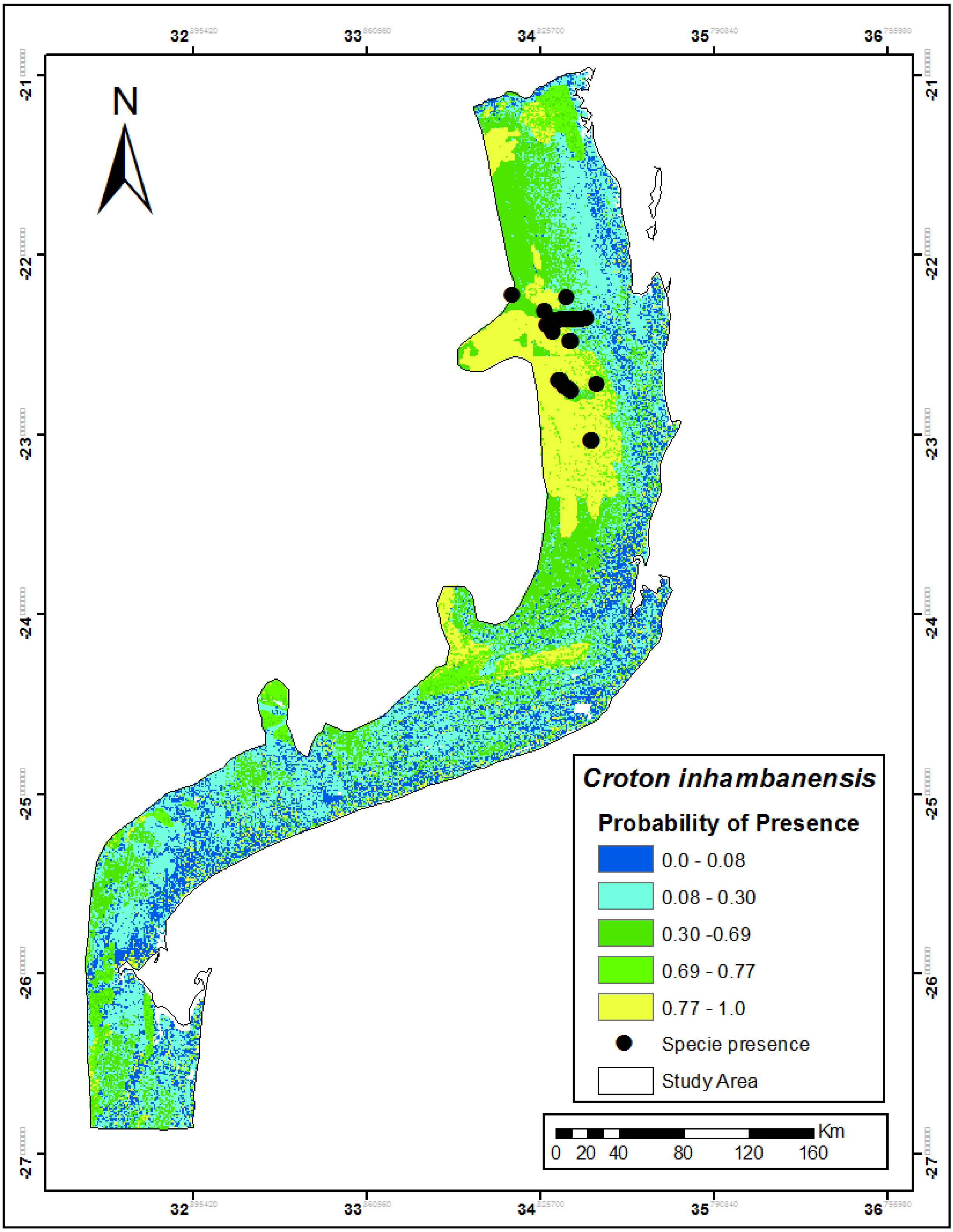

Figure 16. The *Maxent* species distribution model for *Croton inhambanensis* Radcl.-Sm.

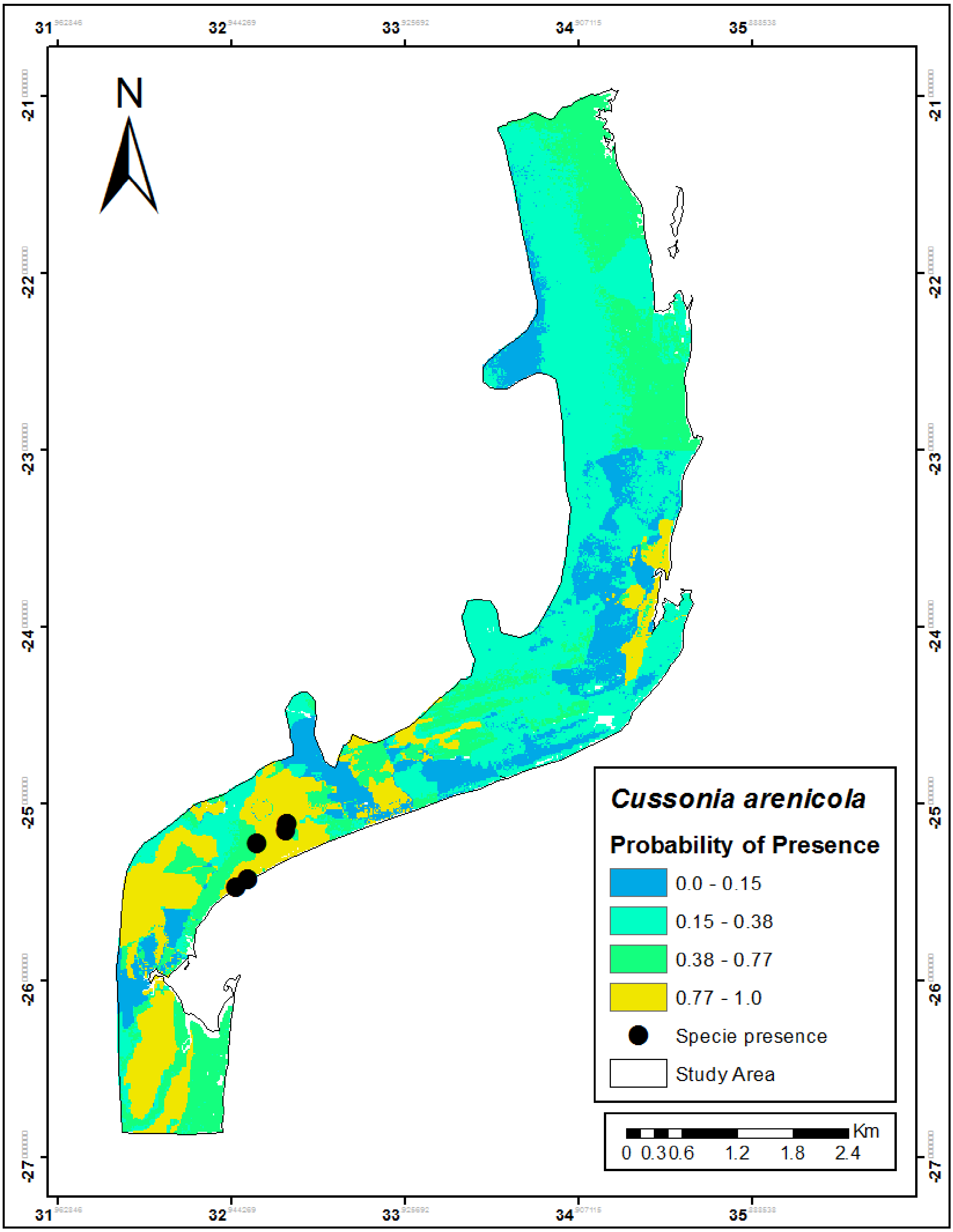

Figure 17. The *Maxent* species distribution model for *Cussonia arenicola* Strey.

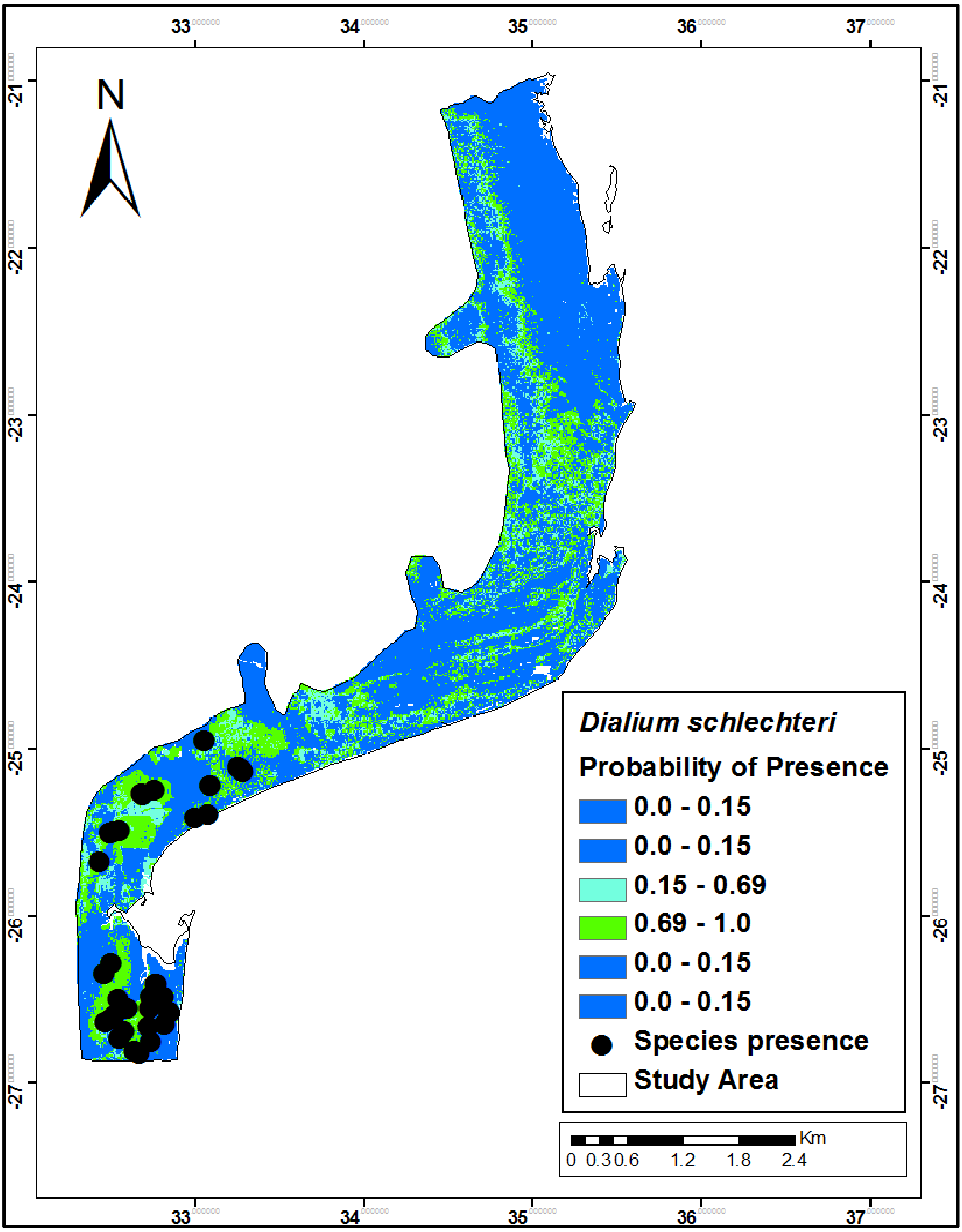

Figure 18. The *Maxent* species distribution model for *Dialium schlechteri* Harms.

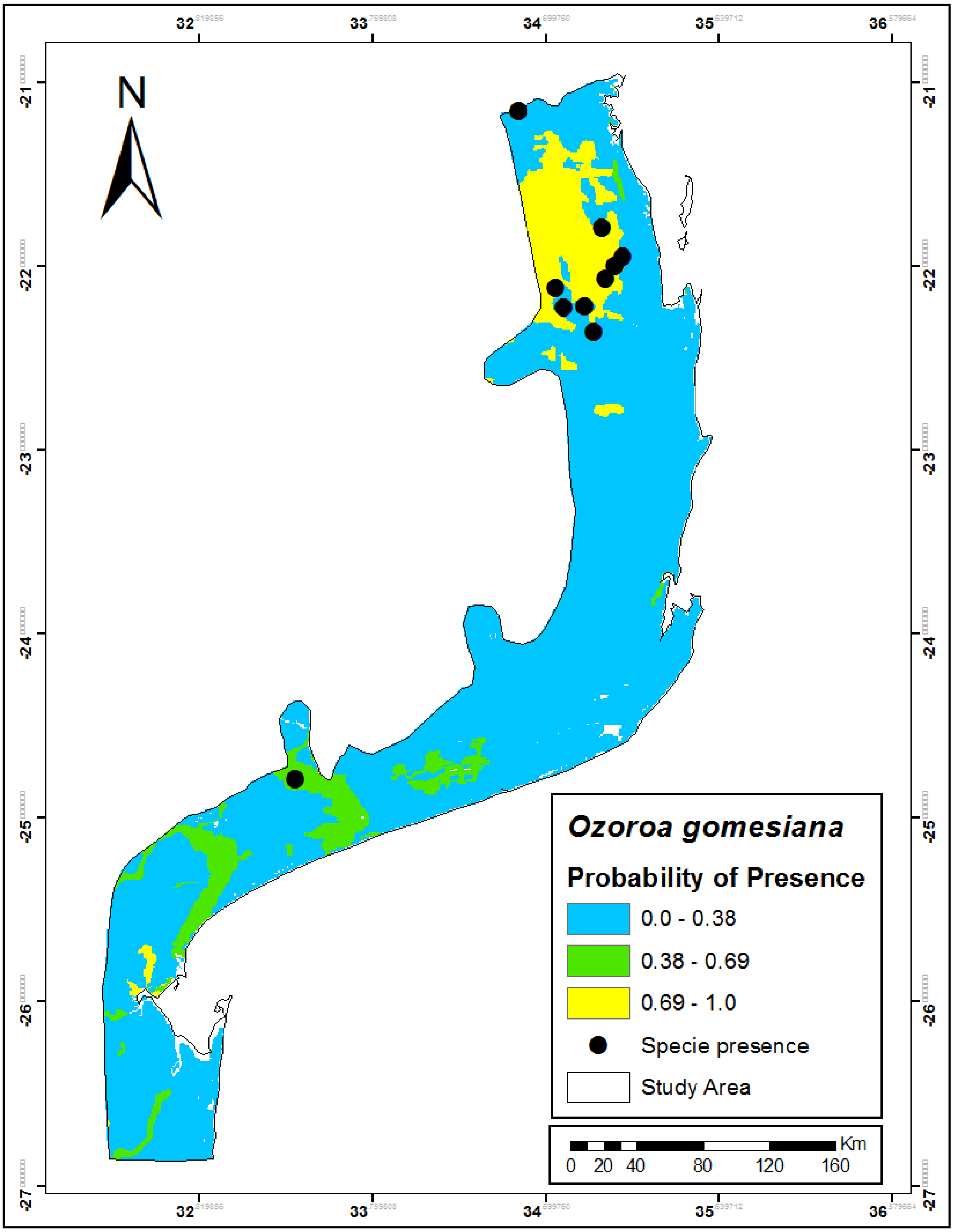

Figure 19. The *Maxent* species distribution model for *Ozoroa gomesiana* R. & A.Fernandes.

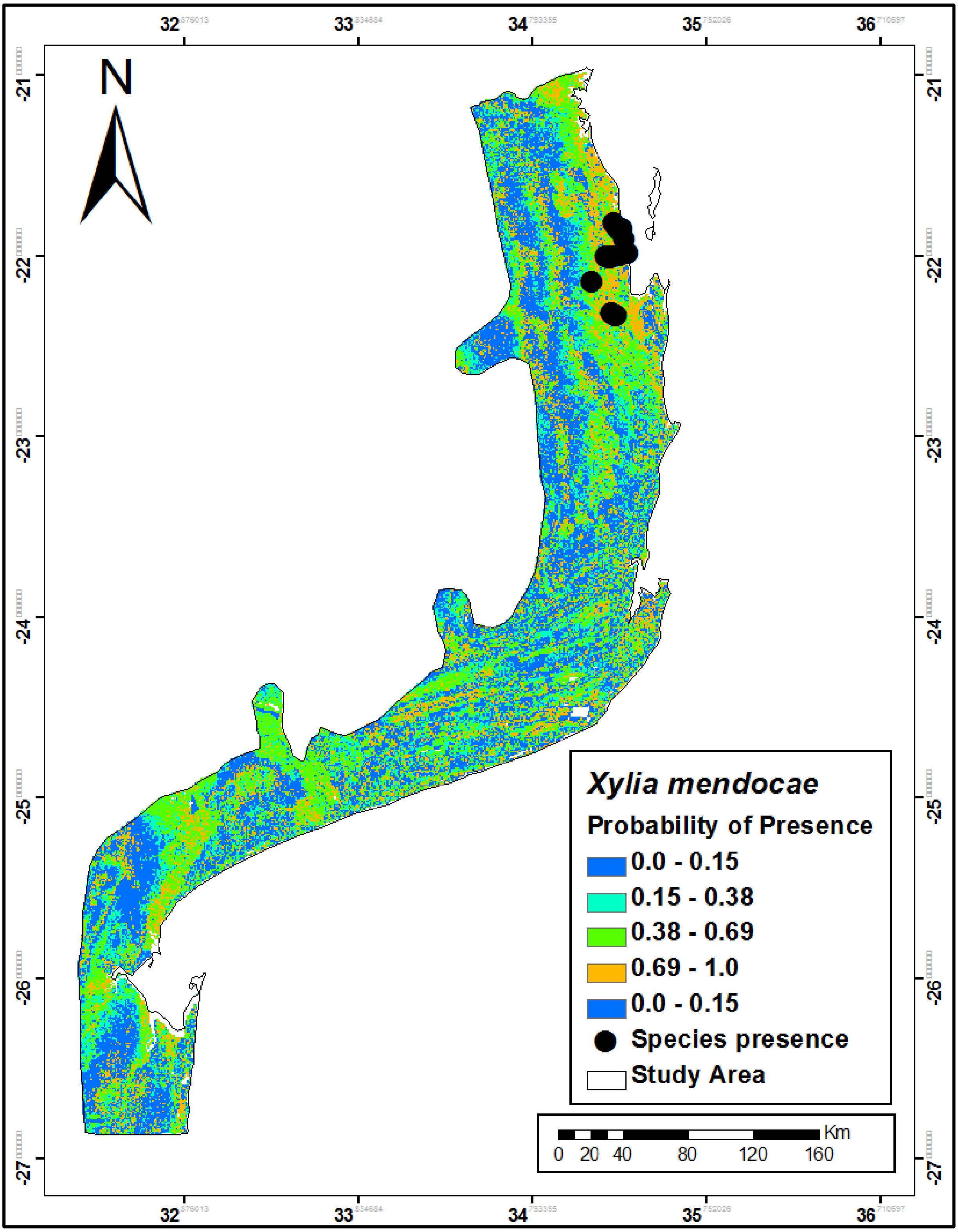

Figure 20. The *Maxent* species distribution model for *Xylia mendocae* Torre.

2.5.6 Overlap of modelled distributions with existing protected areas

A combined map of potential distributions of the seven endemic species indicated that suitable areas are clustered in Maputaland Centre of Endemism (Figure 14). Suitable areas for the endemic species are very poorly covered by the existing protected areas in the coastal zone of southern Mozambique. Currently, 22 national parks and reserves in Mozambique cover an area of 216 278 km^2 representing about 25% of total area of the country. The endemic species analysed here occur in an area of about 900 km^2, of which less than 500 km^2 are situated inside two reserves: Reserva Especial de Maputo in district of Matutuine. Very few endemics were found in Reserva Nacional de Pomene in Inhambane – most of the endemic species from that area of high endemism occur from Inhassoro to Vilanculos. Good specimens of endemic species were collected within the Reserva Especial de Maputo. This confirms that large areas with significant populations of endemic species lie outside of protected areas.

2.5.7 Factors determining distribution of assessed endemic and near-endemic species

The best environmental predictors of the distribution of the seven assessed endemic species were soil type, altitude, slope and human population (Table 5).

Table 5. Contribution (%) of the environmental predictor variables to the Maxent distribution model for the seven endemic species of the coastal zone of southern Mozambique. The dash symbol (-) indicates that the variable does not have any effect on the species distribution. TS = Temperature Seasonality; PW = Precipitation of Wettest Quarter; PS = Precipitation Seasonality; AP = Annual Precipitation; HI = Human Influence Index; HP = Human Population.

Variables	Bap_ovat	Bau_burr	Crot_inha	Cus_aren	Dia_schl	Ozo_gome	Xyl_mend
TS	0.1	-	-	-	-	-	-
PW	0.1	-	-	-	-	-	-
PS	-	-	-	0.3	-	-	-
AP	-	-	-	0.3	-	-	-
HI	-	-	0.2	-	1.5	-	-
HP	4.2	2.6	0.1	25.8	4.9	0.1	0.7
Slope	19.6	0.1	10.4	-	1.2	-	7.8
Altitude	-	-	12.2	1.6	11.6	-	68.3
Soil Type	76	97.3	77	72	80.8	99.9	23.2

Bap_ovat = *Baphia ovata*; Bau_burr = *Bauhinia burrowsii*; Crot_inha = *Croton inhambanensis*; Cus_aren = *Cussonia arenicola*; Dia_schl = *Dialium schlechteri*; Ozo_gome = *Ozoroa gomesiana* and Xyl_mend = *Xylia mendocae*.

2.6 Discussion

Diversity in the all vegetation types of the coastal zone of southern Mozambique was high, although notably lower in grassland. A diversity metric test of fidelity indicated that more sampling should be done in grasslands, but also for miombo and dune vegetation types – both for woody and herbaceous groups. It is recognized that diversity parameters are difficult to compare if plot sizes are not equal for all samples and the values calculated in Tables 1 and 2 should therefore only serve to indicate broad trends for each vegetation type of vegetation.

Apart from a new understanding of diversity in the coastal zone of southern Mozambique, this study has delivered range extensions of known species distributions. For example, *Mussaenda arcuata*, a species known only from the north of Mozambique was found in a small river in Bilene. *Cassipourea malosana*, known from South Africa (http://newposa.sanbi.org/sanbi) was recorded on Inhaca Island.

The coastal zone of southern Mozambique has high level of endemism. This study confirms the extent and definition of the Maputaland Centre of Endemism in the coastal zone of southern Mozambique as one of the most important (Van Wyk 1996; Van Wyk & Smith 2001). Matimele (2016) also reported high levels of endemism in the Licuati Forest. This study suggests that Maputaland Centre of Endemism in Mozambique extends from Ponta de Ouro and ends at Xai-Xai, close to the Limpopo River. However most endemic species are concentrated in Maputo (Matutuine and Manhica districts). In the Gaza Province, endemic species in the coastal zone are concentrated in Bilene district.

The Shannon-Wiener indices of 3.34 to 4.14 for forest in the Kouilou Département of the Congo (Van Rooyen et al., 2016) and of 5.24 to 5.46 in mixed forests of the Dja forest, Cameroon (Senterre & Lejoly 2001) compare favourably with those measured in this study (4.362 for woody elements). Generally, the diversity indices coincide with the range reported for other tropical forests, even though these forests are in the coastal zone. In this study, forests had the same dominant families (Fabaceae and Rubiaceae) as found by both Timberlake et al. (2011) for the coastal forests of north Mozambique, and Ndayishimiye et al. (2012) found in Central African forests. The single richest community in terms of plant endemics is in the forests of Matutuine (Maputo) to Bilene in Gaza. The microclimatic environments within these forests make them unique and they contain unique species.

This study included a small part of the Zanzibar-Inhambane regional mosaic (sensu lato) (Inhambane Province and north of Gaza). Another area of concentration of endemic species was found from Panda to Guvuro between the Vilaculos and Inhassoro districts. This was predicted by Clarke (1998) and confirmed here. Further research will be required to determine whether this represents an extension of the Maputaland Centre of Endemism proposed by Van Wyk (1996; all southern Mozambique) or forms part of a separate Centre. However, several species distributions extend from the Maputaland Centre of Endemism to the area in the north. It should also be noted that this study is limited only to the coastal zone.

Gaza Province is the coastal area with a low number of endemic species. However, this province has small patches of forest that have high conservation value due to their unique characteristics. The forest patch in Chiacho, Bilene, contains a unique endemic, *Memecylon incisilobum*, a species that has been assessed to be Critically Endangered by Matimele (2016). This patch was sampled in this study and confirmed to be unique but shares a phytosociology with other patches of forest sampled in the study (see Chapter 3). In this study, these coastal forest patches were taller (around 20 m) then those in the Maputo National Reserve (one of the protected areas located in the study area) where trees were between 10 and 15 m tall (Matos, 2017; Chavana, 2018). This highlights the different conditions in these forest patches that may provide unique habitats for endemic species.

In this area, information provided by elderly local people confirm that this is a sacred forest called 'Kuati la ka Massingue'- meaning Massingue sacred forest, although the younger people do not value this culture any more. This is clearly shown by the depletion of the sacred forests for agriculture and collection of wood for charcoal and fire wood. Sacred sites, including sacred forests or sacred groves, are sites that have local cultural or spiritual significance. These have been protected around the world for a variety of reasons, including for religious practices and ceremonies or for burial grounds (Daniel et al., 2015). Sacred forests have high conservation value and should be protected by local communities to serve their unique cultural beliefs and special spiritual significance. These should be promoted to have the highest priority to be added to an *in situ* biodiversity conservation system.

Mozambique is exceptional in the number and age of sacred natural sites. While sampling for this study, many locations were reported by elderly people that were sacred forests but were abandoned by the younger generation. However, the Chiacho forest (Kuati la ka Massingue) is intact and still in a good condition. Few people know about it and respect its history. Local people reported that people from other regions travel to this forest to collect resources. The peculiar characteristics of this small patch of sacred forest indicates that they should form the core of natural conservation areas. This approach was recommended by for example, Daniel et al. (2016) who studied 8 sacred forests in Nigeria, but also in Mozambique in a study of the Chirindzene forest in the Gaza Province – the best-known example of sacred forest conservation in the country (Simbine, 2013).

During this study, the Chirindzene forest was also sampled and the importance of conservation of sacred forests is highlighted in that, despite current resource utilization, trees taller than 25 m were measured. The people who use the resources provided by the sacred forest only collect what is necessary and important for their lives such as medicinal plants. Of concern is that if the cultures and beliefs are lost, the importance of the sacred forests will be lost, and the sacred locations will become degraded. This loss of cultural value is the case for the Kuati la ka Massingue forest in Chiacho and the concern is that this forest will become degraded.

There were however, intact sacred forests that were sampled during the field work for this study. In Matutuine, a sacred forest was found to be in better condition than some patches of forest within Reserva Especial de Maputo, supporting the idea that sacred forests can be used to conserve endemic species (Anderson et al., 2005; Khan et al., 2008). According to Schaaf & Lee (2006), traditional respect for the environment and access restriction to sacred sites has led to well conserved areas with high biological diversity within otherwise degraded environments.

This study demonstrates how Species Distribution Modelling Results can be used to predict potential species distribution in areas for which little biodiversity data is available. The models provide good discriminatory ability, at the level of average to excellent (Thuiller et al., 2003). Even the species with the lowest discriminatory (*Baphia ovata*, with a score of 0.65) was sufficient to provide areas of importance for future collection effort. AUC values below 0.5 are considered to have no value and indicate performance weaker than random guessing (Hawk, 2017). The maps of the potential distributions (Figure 15 to 21) suggest that their distributions may range somewhat beyond the localities where the species were collected. Among the seven endemic species considered in this study, three had the highest probability of occurrence in the Maputaland Centre of Endemism and the other four in Inhambane Province. This small area in Inhambane can be considered an Important Plant Area (IPA) at the very least, due to the concentration of endemic species that only occur in this region.

Environmental variables associated with the distribution of the seven endemic species suggest that their ecological requirements differ. A mix of climatic and non-climatic variables best explain endemic species distributions in the coastal zone of southern Mozambique. Soil type is the most important predictor (see Chapter 4 also). Annual temperature range and precipitation of the driest month were also important predictors. The results from *Maxent* are unsurprisingly, good predictors in the areas that they were collected in this study (preferential for the location where collected) although *Xylia mendocae* appears to be predicted to occur in the whole study area. This species is associated with elevation rather than soils as the most important determinant of distribution.

Comparing collection localities to the potential distribution shows that the latter extends beyond the limits of the historical collections. Notably, potential distributions of *Xylia mendocae*, suggest that the species has been undercollected, and it may reach the extremes of the Maputaland Centre of Endemism. However, the potential distributions of *Bauhinia burrowsii*, *Croton inhambanensis* and *Ozoroa gomesiana* confirm that these species are confined to a small geographical area along the Indian Ocean Coastal Belt of White (1983), specifically in the Zanzibar-Inhambane regional mosaic of Burgess et al. (2004).

The models presented in this study have some limitations. Most notably they are affected by sampling intensity and the overrepresentation of records from easily accessible areas (Koffi et al., 2008; Phillips & Elith, 2010). In this study, areas predicted to have high occurrence are also areas where most collections have occurred. In addition, the environmental variables used to model the species are not the only factors to influence their distribution. Other factors such as dispersal and biotic interactions may also determine species distributions (Roura-Pascual & Suarez, 2008; Kearney & Porter, 2009; Blach-Overgaard et al., 2010; Morueta-Holme et al., 2010).

The results of this study have implications for the conservation of species restricted to a single phytogeographical region. Endemic species are, by definition, confined to small geographical areas, but may also be associated with particular habitats, have small population sizes, and may have restricted dispersal potential (Rabinowitz, 1981; Ceballos et al., 1998). Endemic species may also be threatened by the destruction of their habitats and by climate change (Brooks et al., 2002; Morueta-Holme et al., 2010). Areas that potentially could contain many endemic species in the coastal zone of southern Mozambique are in forested landscapes, which are largely unrepresented in the current protected area system.

Importantly, only a few small protected areas overlap with areas of a high probability of occurrence of endemic species. On the scale of this study, deforestation for agriculture, charcoal and fire wood production; fragmentation and the tourism industry and change of landscape structure are three major determinants of biodiversity loss (Bogaert et al., 2008; Bamba et al., 2010), including the studied endemic species. Preserving the areas with a high concentration of endemic species becomes a high priority for Mozambique. Special conservation effort is recommended for *Xylia mendocae*, *Bauhinia burrowsii*, *Croton inhambanensis* and *Ozoroa gomesiana* as their potential distributions are limited to a small region.

In conclusion, this study shows that most areas with endemic species are outside of protected areas (only two areas protect them). For the most important endemic species identified in Inhambane Province, no plants could be found in the Pomene National Reserve. This means that the proclamation of additional reserves must take priority in order to improve the protection of these species in Inhambane to safeguard the endemic biodiversity of Inhambane. Degradation of the main habitat of the Inhambane endemics was evident across the study area indicating the importance of conservation action before these habitats are destroyed.

3. Coastal plant communities of southern Mozambique

3.1 Introduction

Vegetation is often used as a surrogate or building block for the definition of habitats (Timberlake et al., 1993). The use of broad habitat units defined by a combination of environmental factors and vegetation would probably represent the most useful input for the drafting of the management plan (Stalmans & Peel, 2010).

Community ecology considers assemblages of plants and animals living together and, with the environmental factors with which they interact form ecosystems (Gauch, 1982). Thus, according to Kent (2012), a “plant community is a characteristic group of plants that grow naturally together in a particular environment. The composition of a plant community is determined by a complex interaction of several factors including climate, soil type, position in the landscape and competition between plant species”.

The coast is a particularly dynamic environment in which disturbance is a major and natural phenomenon to which the plants are well adapted. The strong patterning and zonation of coastal plant communities, with respect to environmental gradients such as exposure to salt spray, tidal impacts and sand movement, is a demonstration of the interaction between plants and their environment. “One of the particularly significant interactions is the relationship between beach grasses and dune formation” (Rudman et al., 2008).

Coastal vegetation communities are diverse in composition and structure. White (1983) gives a general description of the main coastal vegetation communities of Mozambique and Tinley (1971) relates these to coastal geomorphology.

The vegetation of the Indian Ocean Coastal Belt in Mozambique lies between the mouth of the Rovuma and Ponta de Ouro. The complexity of this belt makes it comparable to the Afromontane region, thus making it an interesting and an important area scientifically. According to Moll & White (1978) and Moll (1980), this complex mosaic of different vegetation types, including forest, thicket, woodland, bushland, wooded grassland and aquatic and semi-aquatic communities has led to a variety of ecological interpretations.

According to Williams and Margules (2004) biogeography can be seen as the study of the distribution patterns of species in time and space. Biogeographic information is important for decision support for the planning and management of resources through units that are used for analyses. Phytogeographic units are important in conservation management as they provide the framework with which to determine conservation priorities (Lovett & Taplin, 2004). The most common phytogeographic system used in Africa is that of White (1983). Phytogeographically the entire study area considered here, is part of the coastal zone with its rich diversity of flora, including endemic species (Werger, 1978; White, 1983; Clarke, 1998).

3.2 Methods and data analysis

Survey plots were selected randomly in sites that represented the vegetation types of the study area. To define the phytosociological relationships between the different groups, multivariate analysis was done. Multivariate analysis is crucial for community ecology because it allows us to discover structure and summarize data, thereby providing an understanding of the communities (Gauch, 1982, Catorci et al., 2014). Data were analysed through a combination of classification and ordination techniques.

The characterization of habitats by species assemblages or indicator species is one component of the structure-activity relationship analysis (Dufrêne & Legendre, 1997). Its results have predictive power at sites with habitats similar to those used to find the indicator species. The identification of characteristic or indicator species is a traditional activity in ecology and biogeography. Studies based on field work describing sites or habitats, usually mention one or several species characterizing each habitat or community (Dufrêne & Legendre, 1997). Species composition may be more informative of environments than any given set of measured environmental variables (Jongman et al., 1985). In order to investigate the species composition of the groups, the Indicator Species Analysis (ISA) was done, a non-parametric method for identifying those items (species/trait) that show significantly preferential distribution (frequency and abundance) compared to an a priori treatment group. An indicator value is calculated by multiplying the relative abundance of each item in a particular group and the relative frequency of the item occurrence in the sample of that group (Dufrêne & Legendre, 1997, Catorci et al., 2014).

Community analysis packages were used in *R* (version 2.14.0, R Core Team, 2012). For calculation of community metrics, Indicator Species Analysis and ordination using Detrended Correspondence Analysis or Redundancy Analysis, *Vegan* (Oksanen et al., 2018) with *FactoMineR* (Le Sebastien, 2008) was used (Jongman et al., 1985; Dufrêne & Legendre, 1997; Legendre and Gallagher, 2001). Detrended Correspondence Analysis is an indirect gradient analysis that uses only species data to infer communities. Redundancy Analysis is a direct gradient analysis used to deduce environmental factors that influence the groups. Bray-Curtis cluster analysis was used to demonstrate the relationships between the different vegetation types (Jongman et al., 1985) and TWINSPAN (Hill, 1979) was used to show heterogeneity in the vegetation types.

3.3 Results

Detrended Correspondence Analysis of the woody plants recorded in all the plots showed a separation between six different Vegetation Types along the coastal zone of southern Mozambique (Figure 21): Coastal Grasslands, Coastal Savanna, Coastal Woodland, and Coastal Miombo with different ordination domain centres (left to right in Figure 21). Dune Forest and Coastal Forests also separated, but their ordination domain centres were close to each other, indicating more similarity between these two types of forest (Figure 21). There were too few samples of Miombo Dune or Miombo Forest vegetation to provide a meaningful assessment of these as separate vegetation types, but their affinity to Coastal Miombo is confirmed. The separation of Dune Forest from Coastal Forest is confirmed by an 80% separation of these two vegetation types in ordination space in the absence of the polarising influence of the non-forest types (Figure 22).

The influence of environmental variables on the communities was considered (Figure 23). Dune Forest and Coastal Forest were associated with high levels of dry quarter and annual precipitation and, to a lesser extent, soil organic content (possibly both a cause and effect relationship). Coastal Miombo vegetation had a unique set of environmental factors with high wet quarter precipitation, warm temperatures and narrow valleys being defining. Dune Forest, Coastal Forest and Coastal Miombo soils had higher pH than the other vegetation types. The Coastal Savanna and Coastal Woodlands were found at high altitudes on gentle slopes. Clay content of these soils was greatest.

For future reference in coastal zone planning and management, descriptive statistics of these environmental variables are given for each vegetation type (Appendix B).

A Bray-Curtis cluster analysis confirms that Dune and Coastal Forests are closely grouped with high similarity based on the woody elements of the vegetation (Figure 24). Coastal Savanna and Woodland also grouped with slighty less similarity (Figure 24) while Coastal Grassland and Miombo clustered separately from the other vegetation types.

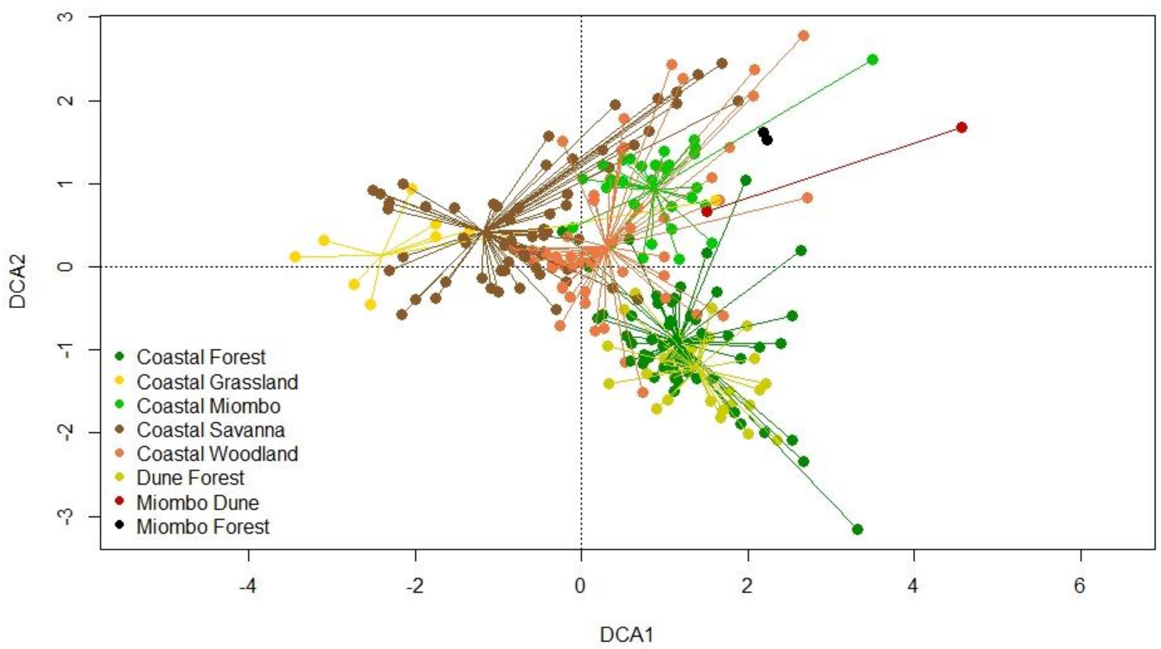

Figure 21. An *Ordispider* of the Detrended Correspondence Analysis of quadrats of all sites measured in this study. The eigenvalues for DCA1 = 0.739 and DCA2 = 0.588. The cumulative variance for the analysis is 4.57%.

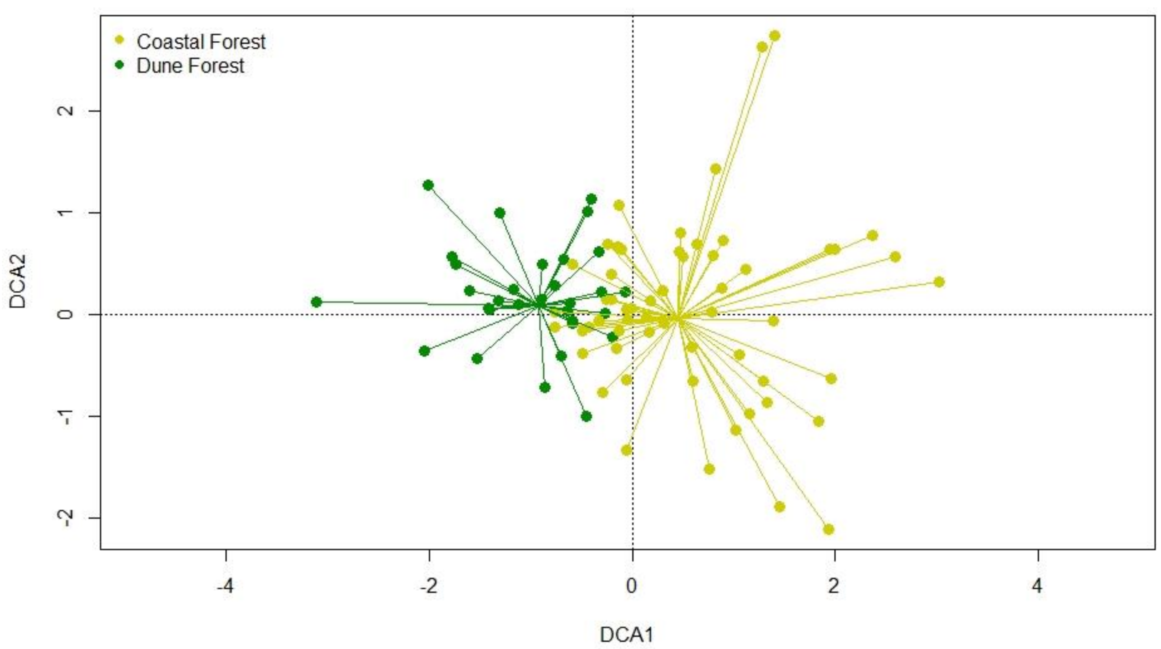

Figure 22. An *Ordispider* of the Detrended Correspondence Analysis of Forest quadrats measured in this study. The eigenvalues for DCA1 = 0.577 and DCA2 = 0.404. The cumulative variance for the analysis is 7.30%.

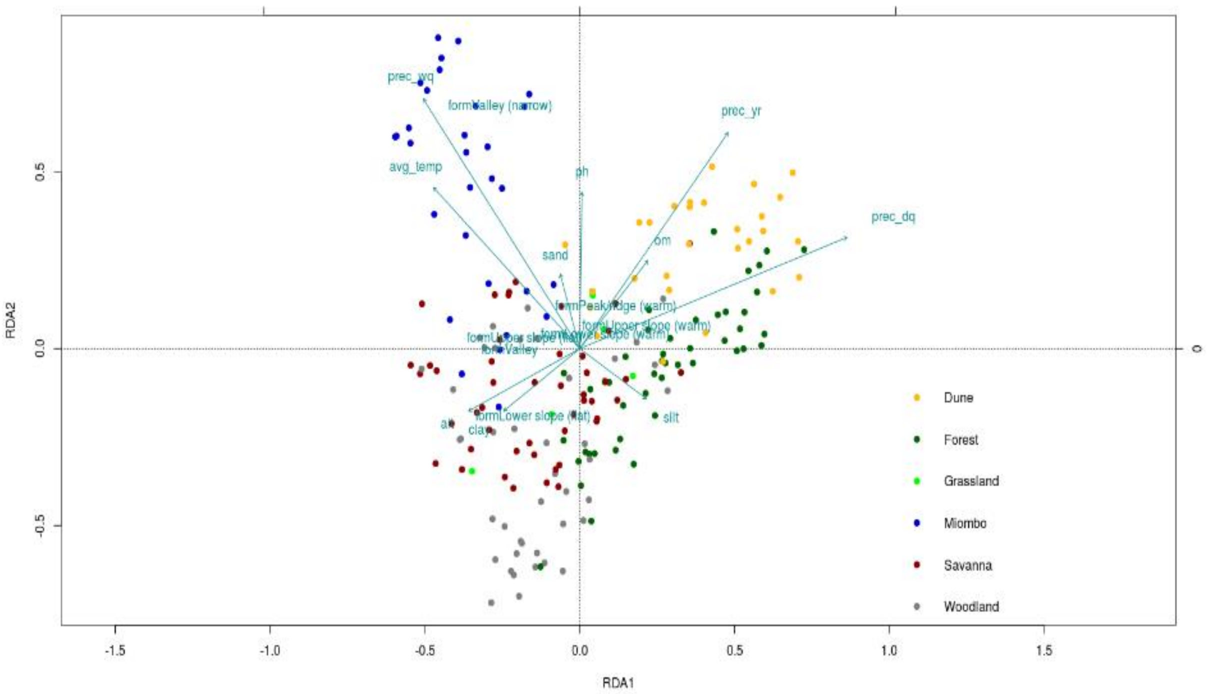

Figure 23. A Redundancy Analysis of quadrats of all sites measured in this study constrained by environmental variables.

Environmental variable abbreviations are:

alt = altitude (m)
avg_temp = annual average temperature (°C)
prec_dq = dry quarter precipitation
prec_wq = wet quarter precipitation
prec_yr = total annual precipitation

Several landscape morphology metrics are used (valley, slope, peak)

Several soil characteristics were also used:

om = organic matter (% of DM)
pH
sand (%)
silt (%)
clay (%)

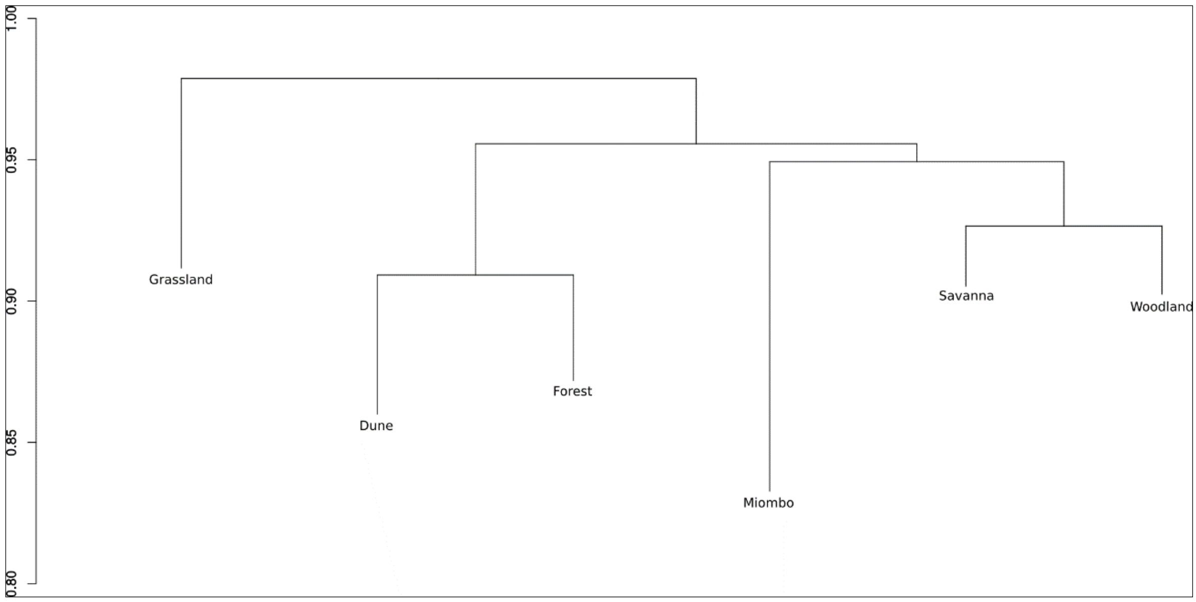

Figure 24. The phytosociological affiliations of the different vegetation types of the coastal zone of southern Mozambique based on woody species.

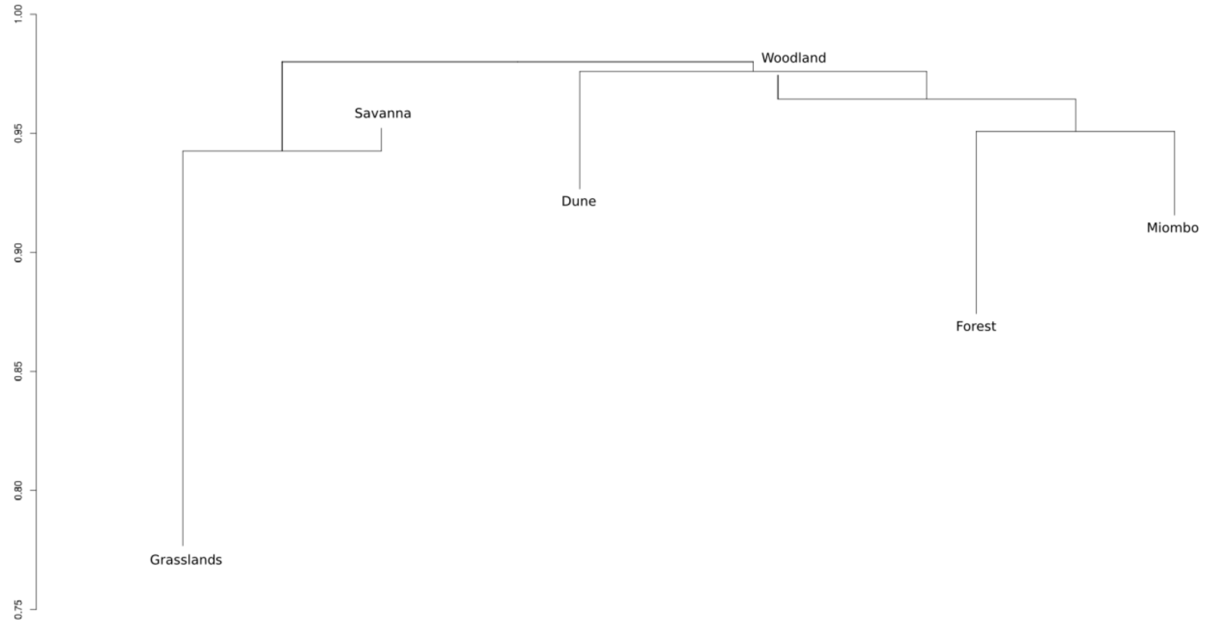

Figure 25. The phytosociological affiliations of the different vegetation types of the coastal zone of southern Mozambique based on herbaceous species.

For the herbaceous layers, the Bray-Curtis cluster analysis showed affinity between Coastal Forest and Miombo (Figure 25) with Coastal Grassland and Savanna unsurprisingly sharing a group (Figure 25). The herbaceous layers of the Dune Forest and Dune Woodland did not group with any of the other vegetation types (Figure 25).

TWINSPAN analyses of presence-absence data for both woody and herbaceous species (Table 6) indicates that Dune Forest forms a high-fidelity group (87%) as does Coastal Forest (79%). Coastal Savanna-Miombo (67%) and Coastal Woodland (59%) are heterogeneous groups but one area of Coastal Grasslands (5 plots) were different from the all groups (Table 6).

Table 6. The number of quadrats in each of the five major TWINSPAN groupings of presence-absence data of both woody and herbaceous species of plants in the different vegetation types of the coastal zone of southern Mozambique.

TWINSPAN Groups	**A**	**B**	**C**	**D**	**E**
Dune Forest	**27**	4			
Coastal Forest	5	**48**	5		
Coastal Savanna	1		**44**	12	
Coastal Woodland	1	6	24	**24**	
Coastal Miombo		3	**21**	5	
Coastal Grassland			3		**5**

The indicator species for each of the vegetation types as identified by *ISA* as well as their mean abundances are listed in Table 7 (woody species) and Table 8 (herbaceous species).

Table 7. Woody indicator species of the vegetation types as calculated by *Indicator Species Analysis*. Only significant indicator values above 30 are shown. Species are listed in decreasing order of indicator value.

Group	**Indicator species**	**Indicator value (%)**	**p**
Dune Forest	*Mimusops caffra*	81	0.0001
	Diospyros rotundifolia	64	0.0001
	Zanthoxylon delagoensis	55	0.0006
	Gymnosporia heterophylla	43	0.0160
	Apodytes dimidiata	42	0.0278
	Carissa bispinosa	39	0.0287
	Diospyros natalensis	37	0.0158
	Eugenia natalitia	36	0.0066
	Eugenia sp. JB2018	36	0.0065
	Tricalysia sonderana	36	0.0071
	Cissus quadrangularis	36	0.0396
	Erythroxylon emarginatum	32	0.0429
	Tephrosia purpurea subsp. *canescens*	31	0.0058
	Tricalysia delagoensis	31	0.0496
Coastal Forest	*Afzelia quanzensis*	61	0.0012
	Eugenia capensis	56	0.0032
	Hymenocardia ulmoides	53	0.0063
	Dialium schlechteri	52	0.0036
	Landolphia kirkii	43	0.0268
	Dalbergia obovata	42	0.0086
	Brachylaena discolor	39	0.0442
	Diospyros inhacaensis	33	0.0393
	Drypetes arguta	32	0.0171
Coastal Grassland	*Eugenia albanensis*	74	0.0001
	Eugenia mossambicensis	52	0.0011
	Chamaecrista mimosoides	47	0.0032
	Gymnosporia markwardii	46	0.0053
	Parinari capensis subsp. *incohata*	38	0.0196
	Pachycarpus appendiculatus	33	0.0354
	Vernonia poskeana	32	0.0369
Coastal Miombo	*Julbernardia globiflora*	82	0.0001
	Brachystegia spiciformis	74	0.0001
	Brachystegia torrei	48	0.0018
	Ancylobotrys petersiana	43	0.0051
	Ochna natalitia	40	0.0316
	Indigofera podophylla	38	0.0105
	Strychnos spinosa	37	0.0159
	Heinsia crinita subsp. *parviflora*	31	0.0282

Coastal Savanna	*Dichrostachys cinerea*	50	0.0210
	Albizia versicolor	47	0.0118
	Sclerocarya birrea	44	0.0176
	Hyphaene coriacea	43	0.0245
	Ozoroa obovata	41	0.0367
	Annona senegalensis	41	0.0162
	Dalbergia melanoxylon	37	0.0303
	Crotalaria monteiroi var. *monteiroi*	37	0.0457
	Bolusanthus speciosus	37	0.0198
	Ozoroa engleri	32	0.0390
	Combretum imberbe	31	0.0436
	Vernonia natalensis	31	0.0282
Coastal Woodland	*Margaritaria discoidea* var. *nitida*	54	0.0027
	Albertisia delagoensis	50	0.0069
	Xylotheca kraussiana	47	0.0217
	Clerodendrum glabrum	41	0.0283
	Artabotrys brachypetalus	36	0.0342
	Grewia caffra	40	0.0415
	Lantana rugosa	32	0.0129

Table 8. Herbaceous indicator species of the vegetation types as calculated by *Indicator Species Analysis*. Only significant indicator values above 30 are shown. Species are listed in decreasing order of indicator value.

Group	**Indicator species**	**Indicator value (%)**	**p**
Dune	*Carpobrotus dimidiatus*	53.5	0.0010
	Scaevola plumieri	45.9	0.0024
	Ipomoea pes-caprae	39.7	0.0208
	Sporobolus virginicus	39.7	0.0189
Forest	*Panicum heterostachyum*	50.6	0.0029
	Microcoelia exilis	38	0.0358
Grasslands	*Bulbostylis burchellii*	61.7	0.0001
	Dicerocaryum forbesii	52.7	0.0012
	Aristida stipitata subsp. stipitata	38.8	0.0193
Miombo	*Panicum maximum*	0.428	0.0147
	Digitaria eriantha	0.418	0.0173
	Schizachyrium sanguineum	0.371	0.0424
Savanna	*Gazania krebsiana*	0.435	0.0297
	Hyperthelia dissoluta	0.422	0.0176
Woodland	*Panicum maximum*	0.361	0.0273

3.3.1 Dune Forest

Dunes in southern Mozambique occur from Inhassoro in Inhambane Province to Ponta de Ouro in Maputo. The tallest dunes can be found between Bazaruto archipelago and Inhaca Island.

Littoral dunes are highly complex – there are interdunes depressions that may form lagoons (Plate 4) or be vegetated with grassland or savanna. Some of the lagoons have fresh water and others are brackish (with no linkage to the sea). These lagoons are common from Maputo to Gaza. In Matutuine district (Ponta de Ouro), the interdune depressions seem to have high groundwater levels as indicated by the presence of wetland species *Centella asiatica* and an assortment of Cyperaceae.

Plate 4. Dunes and a lagoon along the coastal zone of southern Mozambique.

Dune Forest was found from Inhassoro to Ponta de Ouro including the Bazaruto archipelago and Inhaca Island. Most of the dominant dune vegetation (called Dune Forest in this study) was similar occurring from Massinga to Ponta de Ouro. However, another type of dune vegetation was dominated by miombo (could be called Dune Miombo). This was only found in Inhassoro and Vilanculos (Plate 5).

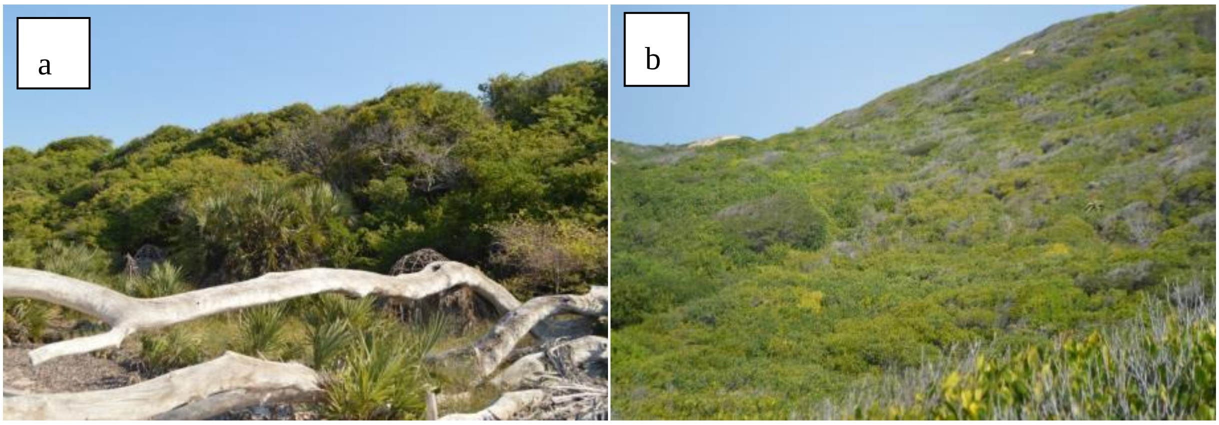

Plate 5. Dune Miombo in Inhassoro (a) and Dune Forest, the most dominant type in the study area (b).

The most important species for Dune Forest were: *Mimusops caffra*, *Diospyros rotundifolia* and *Zanthoxylon delagoensis*. The Dune Miombo could not be analysed statistically because too few quadrats could be measured. However, the most important species is *Julbernardia globiflora* (Plate 6).

Plate 6. *Julbernardia globiflora* trees growing on a dune.

Littoral dune plants can develop special characteristics, e.g. herbaceous plant species that occur just above the intertidal zone. As they would be affected by drought and, sometimes, by salt-water, almost all of them have xerophytic characteristics (e.g. pale colour, succulent habit). They may have halophytic properties, since they are exposed to salt water either directly from tidal movements or indirectly from wind-blown salt-spray (Sridith, 2002; Laongpol et al., 2005) In southern Mozambique, examples of this type of species include: *Ipomoea pes-caprae, Carpobrotus dimidiatus* and *Canavalia rosea*.

Common features of the trees and shrubs occurring behind this herbaceous zone are sclerophyllous leaves with thick cuticles and pale coloration. Plants further inland have the regular characteristics of mesophytes since they are not affected by tides, salt spray or strong winds (Plate 7). On the other hand, some tree species occur almost everywhere, e.g. *Mimusops caffra* and *Diospyros rotundifolia*, with those occurring next to the open sea being under a direct influence of strong wind from the sea and salt spray. These have a short, stunted canopy caused by the salt spray, whilst individuals further inland have a more regular canopy size.

Plate 7. The influence of strong wind on the vegetation of coastal dunes.

3.3.2 Forest

Two types of forest were identified along the coastal zone of southern Mozambique namely Coastal Forest (dry) and the Licuati Forest. The Licuati forest in this study is not described separately here, although it is recognized to be different from the Coastal (dry) Forest in that it is structurally relatively dense with different strata. It is a short forest, 5 to 12 m tall, with a closed canopy from which few large trees emerge. There is a noticeable lack of undergrowth and hence, a low abundance of herbs (Plate 8). The emergent trees in most places are covered by lichens and epiphytic plants such as orchids (Gaugris & Van Rooyen, 2007).

Coastal (dry) Forest in this study is dominated by *Afzelia quanzensis*, *Eugenia capensis*, *Hymenocardia ulmoides* and *Pteleopsis myrtifolia*. There are different types of shrubs in the understorey. Coastal Forest can become up to 25 m tall in places. This Forest type was found from Maputo Province (Matutuine district) to Gaza Province (Xai-Xai). In Matutuine, Coastal Forest appears as a small mosaic within Coastal Savanna. Small forest patches occur in Chibuto-Gaza as described by White (1983), and these were visited during the study and found to have almost completely degraded due to the settlements and agriculture. Nevertheless, indicator species could be found: mostly *Dialium schlechteri*, *Eugenia capensis* subsp. *capensis*, *Acridocarpus natalitius* var. *natalitius* and *Mimusops caffra*. Coastal Forest in southern Mozambique occupies some 800 ha (Figure 26).

Plate 8 shows the nature of Coastal Forest in the study area – species composition is similar, but some have no ground cover. Where there is ground cover, this is formed by ferns, or other understorey species (e.g. a massive area had *Zamioculcas zamiifolia*). Further inland, forests mostly comprise miombo, mopane, and other undifferentiated vegetation (Stalmans & Wishart, 2005; Stalmans & Peel, 2010).

Plate 8. Coastal Forest with or without an herbaceous layer of vegetation on the ground.

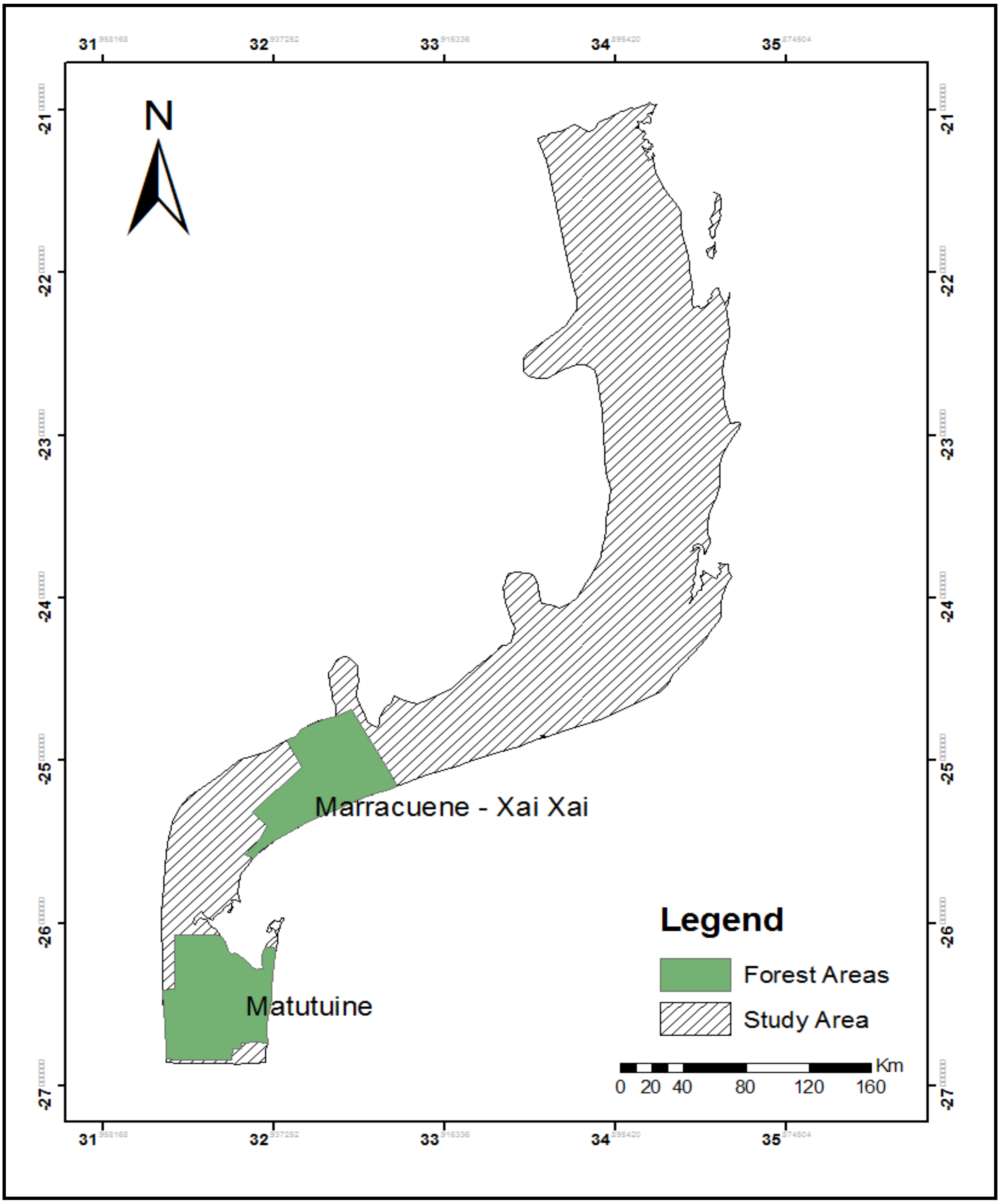

Figure 26. The areas of southern Mozambique that have Coastal Forest.

3.3.3 Coastal Grasslands

Grasslands are one of the dominant types of vegetation in Mozambique. Physiognomically, typical grasslands are areas where the vegetation is characterised by extreme dominance of grasses (Poaceae) – however, sedges (Cyperaceae) and rushes (Juncaceae) may also occur. For this study the definition of Matthews et al. (1999) is taken. In the coastal zone, this type of vegetation could also be called wooded grassland due to the abundance of geoxylic suffrutices (Matthews et al., 1999; Mucina et al., 2006). These Coastal Grasslands only occur in Maputo (Matutuine), from Bela Vista to Ponta de Ouro. Indicator species are: *Eugenia albanensis*, *Eugenia mossambicensis*, *Salacia kraussii*, *Parinari capensis* Harv. subsp. *incohata* and *Gymnosporia markwardii*. The latter three are also common in Coastal Savanna (as applied in this study). In places patches of forest were found in these wooded grasslands (Plate 9).

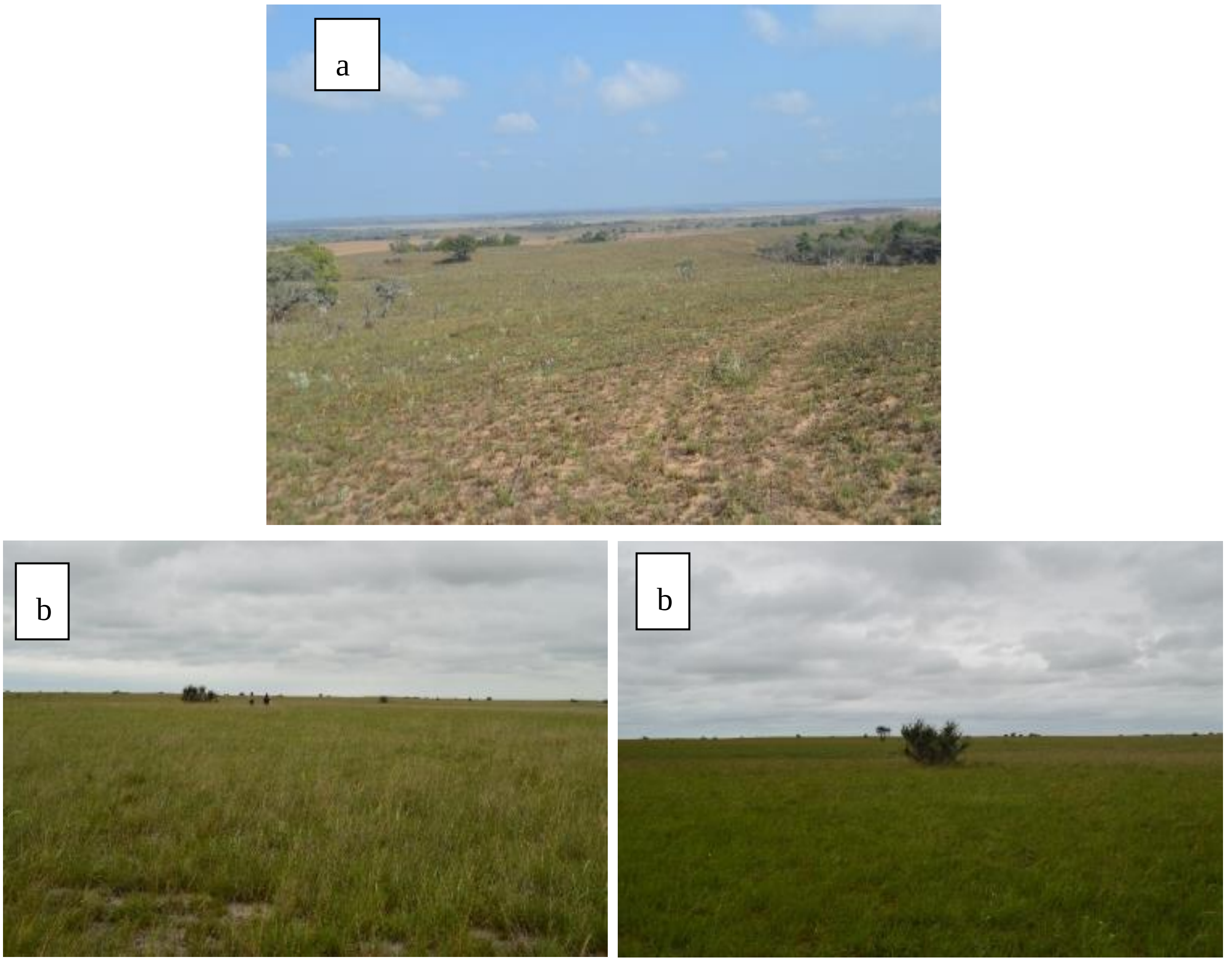

Plate 9. Coastal Grasslands with (a) and without (b) patches of forest.

3.3.4 Coastal Miombo

A vast portion of southern, central and eastern Africa is covered by miombo woodlands and in places these have been called forests (Millington et al., 1994). Miombo woodlands are the most extensive and common vegetation type in Mozambique (Campbell et al., 1996). They occur from the Limpopo River to the north of the country and occupy approximately two-thirds of the natural area. Most miombo woodlands, however, occur inland where they may be associated with other types of vegetation in areas where drainage is poor (Werger, 1978). In these areas acacia savannas or grassland may become locally dominant (Werger, 1978). Other vegetation associated with miombo includes dry deciduous forest and thicket, as well as deciduous riparian vegetation (White, 1983).

In this study, Coastal Miombo is mostly woodland and was found in Inhambane and Gaza. In Inhambane (Inhassoro and Vilanculos), Coastal Miombo may be found on the primary dune (this is the only place in Mozambique where this occurs). Here it is largely comprised of short woodland and thicket communities, with the trees growing up to 15 m in height. The most important species for this Dune Miombo are: *Julbernardia globiflora* and rarely *Brachystegia spiciformis*. In small patches forests may be found that are dominated by *Brachystegia torrei* and associated with *Androstachys jonsonnii*. This was observed in some inland areas (50 km from the sea) in Guvuro (Malovane to Saver river) and Vilanculos. In Guvuro, the vegetation is more degraded than elsewhere due to settlements and agriculture. In Vilanculos signs of timber collection were observed. In the remainder of the Coastal Miombo, the trees can grow up to 20 m tall in the absence of degradation. Wild & Barbosa (1967) have provided excellent descriptions of this vegetation type.

In order to visualize the difference between Coastal Miombo forest and woodland, Plate 10 is included.

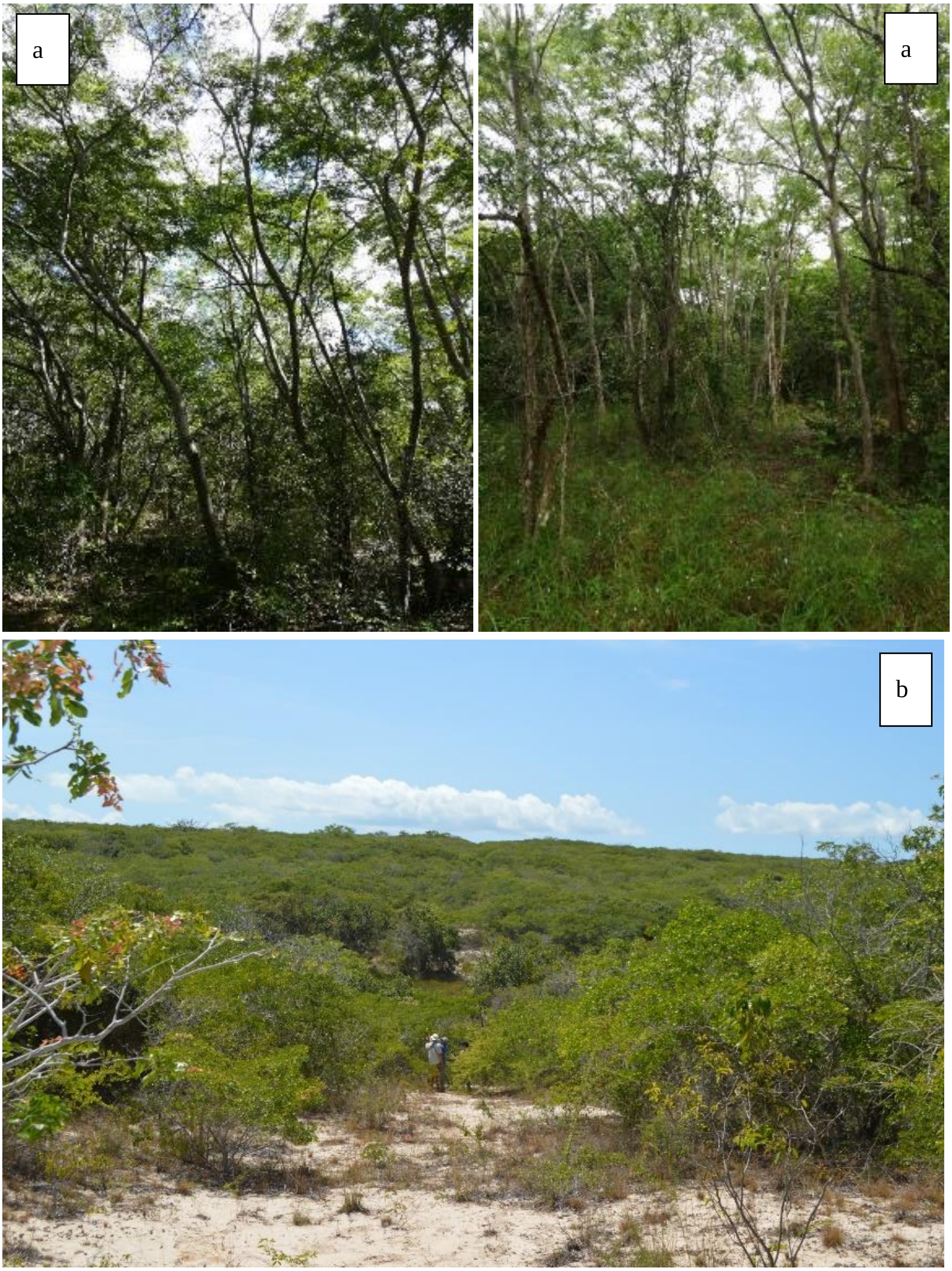

Plate 10. Coastal Miombo forest (a) and Coastal Miombo woodland (b).

3.3.5 Coastal Savanna

Moll & White (1978) and White (1983) distinguish two broad types of "grassland" in the Tongaland-Pondoland Regional Mosaic: edaphically controlled "grassland" associated with scattered palms on badly drained sandy soils, and secondary fire-maintained "grassland" that has replaced anthropogenically destroyed Coastal Forest. On deeper soils along the coast, grassland has been considered to be a phase in the succession to Dune Forest where it is maintained as a fire-subclimax. In the absence of fire, succession rapidly proceeds from grassland to dune scrub and climax forest (Weisser, 1978). All of these vegetation types were considered to be Coastal Savanna in this study, and the primary successional stage was taken to be primary savanna dune. In all these areas, there is a high abundance of trees and shrubs that can reach up to 3 to 5 m high and that dot the grassy landscape.

In the coastal zone of southern Mozambique, two types of Coastal Savanna were found in this study: one occurs in the Maputaland Centre of Endemism (Maputo and Gaza Province) and the second in Zanzibar-Inhambane Regional Mosaic (Inhambane). They differ mainly in species composition, the most important species observed for Coastal Savanna across the region are *Dichrostachys cinerea* and *Albizia versicolor*, however, in the Maputaland Centre of Endemism, the Coastal Savanna is dominated by *Syzygium cordatum*, and/or *Terminalia sericea*. There is also an association with the palms, *Phoenix reclinata* and *Hyphaene coriacea*. Smaller trees/shrubs such as *Parinari capensis* subsp. *incohata*, *Smilax anceps* and *Gymnosporia markwardii* were also found. In Matutuine, there are extensive areas of palm-veld, dominated by *Hyphaene coriacea*, *Phoenix reclinata*, *Dichrostachys cinerea*, *Garcinia livingstonei* and *Strychnos madagascariensis* scattered in the grassy matrix.

In the Bilene district (Gaza Province) and Manhiça (Kalanga) adjacent to Bilene it is common to find primary Dune Savanna just behind the mobile littoral dune. There is little difference in species composition of these communities, but the dominant woody species may differ: *Garcinia livingstonei*, *Syzygium cordatum* subsp. *cordatum* and/or *Terminalia sericea*. The latter two have been drastically reduced in abundance due to collection for firewood and charcoal in this area (personal observation). Its common to find small patches of aggregated shrubs of less than 3 m tall mainly in shade of *Syzygium cordatum* subsp. *cordatum*. In this case the main species are: *Phoenix reclinata*, *Erythroxylum delagoense* and *Apodytes dimidiatus*. Plate 11 provides a visual representation of the different types of Coastal Savanna.

Plate 11. Primary Dune Savanna (a) and the common Coastal Savanna (b) of southern Mozambique.

In Inhambane, the Coastal Savanna is dominated by *Senegalia nigrescens* sometimes surrounding small patches of *Spirostachys africana* or *Combretum* spp. The grasses are dominated by *Hyparrhenia* spp., and *Digitaria eriantha*.

An extensive area of palm-veld dominated by *Hyphaene coriacea* occurs in Matutuine (Maputo) and Panda (Inhambane). Palm-veld is quite common in Mozambique, but it differs regionally in the main species. In central and north Mozambique, the main palm species are *Hyphaene petersiana* and *Hyphaene compressa*.

3.3.6 Coastal Woodland

Coastal woodlands are mostly associated with Savanna. Both vegetation types are highly heterogeneous, and field observation shows similarities in terms of species composition with secondary vegetation types (vegetation that regrows after an area has been cleared for agriculture). The most important species of Coastal Woodland are *Margaritaria discoidea* var. *nitida* and *Albertisia delagoensis*. Coastal Woodland is most common in Maputo and Gaza Province with Miombo woodland most common in Inhambane Province. Coastal Woodlands inland of Xai-Xai to Macia are dominated by *Strychnos spinosa*, *S. madagascariensis* and *Vangueria infausta*.

3.4 Discussion

Six ecologically-interpretable Vegetation Types have been distinguished and described from the coastal zone of southern Mozambique. This information can be used for conservation planning, coastal zone management and land-use planning. This study could also lead to further ecological studies for Mozambique. In the section following this discussion, three Critically Endangered Vegetation Types of the Indian Ocean Coastal Belt are described in the style of Mucina & Rutherford (2006) aimed at initiating the compilation of a "Vegetation of Mozambique" similar to South Africa's *VegMap* descriptions.

Ordination and classification confirm these Vegetation Types, but also give an indication of floristic and associated habitat gradients. All the proposed Vegetation Types are distinguishable in the field based on structure, growth form, general species composition and indicator species – this is despite the environmental gradients that cause communities to merge into one another (note in particular the gradient of ordination centres for

Coastal Grassland → Savanna → Woodland → EITHER Miombo

→ OR Forest → Dune Forest

in Figure 21). The different woodland sub-communities often can be difficult to distinguish based on floristics alone, but structure and density may be used to do so. Analysis from different parts of southern Mozambique show that Dune Forest is related to the Coastal Forest. They have similarities of composition and this includes littoral dune and climax inland forests as was previously suggested by Matthews et al. (2003).

The coastal lowlands of southern Mozambique and the Inhassoro to Massinga area are commonly reported as a forest or forest transition region (White, 1983) or as a miombo savanna-woodland with a coastal thicket or forest along the shore (Wild & Barbosa, 1967). The Indian Ocean Coastal Belt is described as a mosaic of semi-deciduous forest, thickets, woodland, savannas and edaphic grasslands (Moll & White, 1978; Werger, 1978) that fits the study area well. In the phytogeographies of Werger (1978), Miombo savanna-woodland was suggested to be invasive on the coast with its original centre of endemism in south-central Africa (hence the name Zambesian phytochorion). Distribution of Miombo savanna-woodland in Mozambique has been attributed to revegetation of areas that were cleared of original coastal forests through agriculture and use of fire. Studies done by Ekblom (2008) and Ekblom et al. (2014) considered the presence of miombo in the coastal zone using palaeoecological data from Lake Nhauhache in the Vilankulo region. They report that *Brachystegia spiciformis*, one of the main Miombo species, has varied over time, with its variability apparently driven by hydrological changes related to climatic variability rather than by land-use changes. The debate concerning whether Coastal Miombo is secondary or not in the coastal zone of Mozambique remains unresolved.

Miombo is in fact, a colloquial term used for savanna-woodlands dominated by the genera *Brachystegia*, *Julbernardia* or *Isoberlinia* (Frost, 1996; Campbell et al., 1996). Coastal slopes in southern Mozambique carry coastal thickets, but the landscape is dominated by *Julbernardia globiflora* and *Strychnos spinosa* savannas, and *Brachystegia spiciformis* is actually very rare (see also De Castro & Grobler, 2014).

Coastal vegetation in north of Inhambane Province, mainly the Guvuro district, is more similar to that of central and north Mozambique. This can be seen in the presence of species such as *Fernandoa magnifica*, *Sterculia appendiculata*, and *Schinziophyton rautanenii*. The latter two were recorded in Inhassoro and north of Vilanculos (Mapinhane) also. The presence of acacia savanna (*Senegalia*) is quite common in central zone in Sofala. Along the Save River there is an abundance of *Borassus aethiopum*, a species that is common along the Rovuma River. A few individuals are also found near Inharrime.

There are two types of Miombo in the north: one dominated by *Brachystegia torrei* and the other one that occurs landward of the mangrove forests. The latter is similar to the Miombo that occurs in Cabo-Delgado (mainly in Palma district) and is dominated by *Julbernardia globiflora* and *Brachystegia spiciformis* but includes *Parinari curatellifolia* and *Uapaca nitida*. A small patch with *Pappea capensis* and *Tamarindis indica* was also found within this Miombo.

Savanna is one of the dominant vegetation types of Mozambique (Marzoli, 2007) and the Coastal Savanna was found in two different forms: the Inhambane *Senegalia-Combretum* savanna and the Gaza-Maputo savanna dominated by *Terminalia sericea* or *Syzygium cordatum.* Primary dune savanna is typical of Bilene and Kalanga.

Only the wooded grassland of Matthews et al. (1999) was considered to be grassland in this study. The grasslands as defined by other authors (see previous) were included in Coastal Savanna due to the presence of trees and shrubs that can reach 5 m high. Fire is the important factor to maintain savanna (or wooded grassland of Matthews et al., 1999). For example, during the field work it was clear that *Eugenia albanensis* only flowered after fire – this confirms the role of fire for savanna function. Fire frequency can be extremely high in the Coastal Savanna. This is clearly observed between the Reserva Especial de Maputo and Ponta de Ouro. According to Matthews et al. (1999) growth in the coastal grasses of Maputaland is not distinctly seasonal and herbage production is high, despite the infertile soils. Regular fires are a natural phenomenon, although today most are caused by humans. The same patch of grass may burn up to three times a year, with at least one fire a year being the norm. There can be no doubt that fire is an essential factor in maintaining the Coastal Savannas of Maputaland.

Except for the broad-scale classification of the coastal forest (Timberlake et al., 2011) and coastal grasslands (Myre, 1964, 1971) of northern Mozambique, and the detailed classification of coastal and inland communities elsewhere in South African Maputaland (Lubbe, 1996, Matthews et al., 1999), this study is the first attempt at a more detailed, smaller scale phytosociological classification of the vegetation types in the coastal zone of southern Mozambique. A correlation between the plant communities of this study and the various syntaxa described by others (Matthews et al., 1999; Matthews et al., 2001; Gaugris et al., 2004) for Maputaland are similar.

No additional attention was given in this study to the Licuati Forest as an important and different habitat for this region. However, a basic species list compiled for this Forest shows how different it is from what is called Coastal Forest (dry) in this study. According to Matthews et al. (2001), the composition of this Licuati Forest corresponds closely with what is called Sand Forest in South Africa. Included in the species list are also some species associated with thicket vegetation on sand and clay, e.g. *Spirostachys africana* and *Euphorbia ingens*. The Sand Forest described for the Sileza Nature Reserve (an *Artabotrys monteiroae-Dialium schlechteri* forest) matches the species found during this study. It is likely that the Licuati forest is a closed Thicket rather than a dry Coastal Forest.

Matimele (2016) suggested some 278 ha be declared as a Priority Area for Conservation. This was based only on the presence of endemics and near-endemics. In addition, this vegetation assessment implies that all Forest as a habitat, including forests at Inhaca Island and other patches from Bilene to Xai-Xai must be Priority Areas for Conservation – not also due to the presence of endemic species but because of the high diversity observed in this study. Olivier (2014) and Zungu et al. (2018) make similar recommendations for an uMlalazi Nature Reserve in KwaZulu-Natal using such an approach but also including KwaZulu-Natal forest birds as a justification.

3.5 Description of the vegetation types of the Indian Ocean Coastal Belt in southern Mozambique

The coastal zone in southern Mozambique covers a shoreline of 1 100 km and extends inland for between 50 and 100 km including the Provinces of Inhambane, Gaza and Maputo. In these provinces, most people live in the coastal zone.

The main threats to the coastal vegetation are the tourism industry, human settlements, clearing for agriculture and wood harvesting for charcoal production. Extensive areas of vegetated dunes have been developed for tourism infrastructure, and extensive areas have been deforested for charcoal production, particularly in areas near the big cities. Extensive areas of subsistence agriculture occur in underdeveloped areas. Coastal grasslands are often burnt indiscriminately to the disadvantage of many natural plant communities and wildlife in general. Urbanisation is rapidly expanding into the few natural areas remaining near the many tourism development nodes.

3.5.1 Coastal Forest

Distribution: Coastal Forest in this study is a dry forest or thicket formation that is commonly found within 50–100 km of the coast in Maputo and Gaza Province. It is most common between Matutuine to Xai-Xai. Between Vilanculos and Guvuro, the Coastal Forest becomes dominated by Miombo species (Miombo Forest).

Vegetation & Landscape: Coastal Forest has a closed or almost-closed canopy (70-80% cover or more when undisturbed) with a high proportion of deciduous woody species that lose their leaves during the long dry season (Timberlake et al., 2011).

Coastal Forests are dominated by *Afzelia quanzensis* and *Apodytes dimidiatus*, but in the Miombo Forest in Vilanculos and Guvuro the dominant species are *Brachystegia torrei* and in some areas of Vilanculos, with *Androstachys johnsonii*.

Endemic Taxa: *Cussonia arenicola*

Conservation: Critically endangered (Burgess et al., 2004). A very small area is conserved in Reserva National de Maputo. Transformation is due to cultivation and settlements.

3.5.2 Coastal Grasslands

Distribution: Coastal Grasslands also known as Maputaland Wooded Grasslands (Matthews et al., 1999) or Maputaland (Mucina & Rutherford, 2006) is limited to the Maputaland Centre of Endemism that is found along the coastal plain of northern KwaZulu-Natal and southern Mozambique (Van Wyk & Smith, 2001). In Mozambique it only occurs in Maputo Province, from Bela Vista to Ponta de Ouro with smaller patches in the Reserva Nacional de Maputo. This vegetation type is sometimes associated with the primary grasslands of interdune depressions as described by Matthews et al. (1999). These become waterlogged during wet season in Matutuine.

Vegetation & Landscape: The flat landscapes of the Maputaland coastal plain support sandy grasslands rich in geoxylic suffrutices and dwarf shrubs. The only trees sometimes found are *Hyphaene coriacea* and *Strychnos madagascariensis*.

Endemic Taxa: *Eugenia albanensis*

Conservation: Critically endangered (Burgess et al., 2004). A very small area is conserved in Reserva National de Maputo. Transformation is by cultivation, grazing by domestic animals is common, and settlements are growing because of the new road from Maputo city to the Ponta de Ouro border post.

3.5.3 Coastal Miombo

Distribution: Coastal Miombo woodland is the most common coastal vegetation type in Mozambique between just south of the Save River to the north of the country. In southern Mozambique, Coastal Miombo woodland occurs only in Inhambane Province between Inhassoro and Massinga.

Vegetation & Landscape: Miombo is used to define savanna-woodland dominated by the genera *Brachystegia*, *Julbernardia* or *Isoberlinia* (Frost, 1996). Coastal slopes between Inhassoro and Massinga have coastal thickets that are dominated by *Julbernardia globiflora* and *Strychnos spinosa*. *Brachystegia spiciformis* is actually very rare.

Conservation: Critically endangered (Burgess et al., 2004). A very small area is conserved in Reserva National de Pomene. The tourism industry and settlements are the main threats along the coast in this habitat and agriculture is an additional threat in inland areas.

Important taxa: *Brachystegia torrei* (most important), *Julbernardia globiflora*, and the rare *Brachystegia speciformis*.

Endemic taxa: *Xylia mendocae* (Plate 12)

Plate 12. *Xylia mendocae*, an endemic species to Miombo in the coastal area between Inhassoro and Vilanculos.

4. Land use and degradation of the coastal vegetation of southern Mozambique

4.1 Introduction

Land is one of our most precious resources (Harris et al., 1996) and we need land to supply and meet our needs. Human utilization of land has led to all areas of the Earth being modified.

According to Ellis (2007), land-use and land-cover change are terms used for the human modification of Earth's terrestrial surface. Though humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of land change are far greater than ever in history. This drives unprecedented change in ecosystems and environmental processes at local, regional and global scales. These changes encompass the greatest environmental pressure on human populations today – including climate change, biodiversity loss and the pollution of water, soil and air.

Humans have significantly altered nearly all of Earth’s systems, including its atmosphere, hydrosphere, lithosphere and biosphere. According to Goudie (2013), in any consideration of the human impact on the environment it is probably appropriate to start with vegetation. Humankind has possibly had a greater influence on plant life than on any other components of the environment (Ellis, 2007).

One of the most general and irreversible anthropogenic changes observed across the terrestrial biosphere is altered patterns of biodiversity. Even in areas with low levels of anthropogenic disturbance, plant community structure and ecosystem related processes are altered by invasions of exotic species. Rural people in Africa (in this case, in Mozambique) use plants mainly as sources of medicines; firewood and building material and they will deforest areas for cultivation, which can further disturb the natural vegetation dynamics (Babweteera et al., 2007). The effect of people on vegetation through shifting cultivation can be temporary, as vegetation communities may recover after use provided the soil seed bank has remained intact (Ickowitz, 2006). High levels of human utilisation may, however, lead to general vegetation change, degradation and fragmentation of ecosystems, or even extirpation of species (Schmidt-Soltau, 2003; Ndangalasi et al., 2007).

According to Schmidt and Skidmore (2003) “effective management of vegetation requires information on where the vegetation occurs, the type of vegetation, past and continuing ecological processes that have shaped or maintain the vegetation, the roles it plays in the local landscape and how effectively these functions are performed. These latter characteristics are necessarily value judgments and require a context in which these judgments can be made".

The coasts have been the focus of human activity for a long time as they host the world's primary ports of commerce. Although the impact of human activity is pervasive in all natural ecosystems, the coastal areas have been particularly affected. For millennia humans have been attracted to the coastal areas and at present nearly 40% of the global population live within 100 km of the shoreline (Martínez et al., 2007). The impact of human activities near or at the coast is, therefore, intense. Mozambique is no exception to this global trend: here tourism and mining projects have developed rapidly, especially during the last few decades. Due to easy access to the coast of southern Mozambique, this area is an important destination for national and international tourism.

The coastal zone provides goods and services highly valuable to human society. The goods from marine and coastal habitats include food for humans and animals, salt, minerals, oil, construction materials (sand, rock, lime and wood) and biodiversity, including the genetic stock of plants that have potential applications in biotechnology and medicine. The services provided by coastal terrestrial ecosystems are not readily quantified in absolute terms but are invaluable to human society and to life on Earth. These include shoreline protection against extreme events such as storms and hurricanes, storage and cycling of nutrients, sustaining biodiversity, and water management. They also offer a valued habitat to live in, as well as areas for recreation and tourism (Carter, 1988).

According to Sitoe et al. (2012), Mozambique is one of the few countries in Africa with a considerable proportion of its area still covered with natural forests. Yet, at the same time, it is one of the poorest countries in the world, with a high rate of deforestation and forest degradation.

In Mozambique about 70% of people live in rural areas and use mainly agriculture and natural resources for their livelihood. Plants are used as food, medicine, timber and fuel. Medicinal plants used by local people make up more than 70% of basic healthcare treatment. Almost 59% of the people (estimated at a total of 20 million inhabitants) live near the coast in the 42 coastal districts (MICOA, 2007; Martínez et al., 2007). The incidence of poverty in rural areas is estimated at 57% of the population (Report on the Millennium Development Goals, 2010). Most of these people depend primarily on natural resources that are harvested for daily subsistence. "The continuous use of the coastal resources that include vegetation for economic purposes, such as fuel wood and timber extraction, grazing, tourism development, urban expansion, clearing for agriculture, fire and recently mining projects have caused extensive changes in the original vegetation structure" (Soto, 2007; Timberlake et al., 2011). The long-term sustainability however, is a cause of concern as communities will become poorer when there is a loss of biodiversity and habitats.

As coastal populations in Africa continue to grow, and pressures on the environment from land-based and marine human activities increase, coastal and marine living resources and their habitats are being lost or damaged in ways that are diminishing biodiversity, decreasing livelihood opportunities and aggravating poverty (Arthurton et al., 2006).

The coastal zone of Mozambique is likely to experience significant impacts as a result of human activity: fire, grazing and the physical removal of vegetation present a challenge to progress. Inadequate land-use planning and human pressure on natural resources in coastal zones render the Mozambican coastline highly vulnerable to the various impacts, including coastal erosion.

4.2 Methods

An assessment of the land use and degradation of study sites used for vegetation sampling was done by walking around the area. All land use was recorded in the area surrounding the quadrats for vegetation classification.

The analysis of land use and degradation were done using *Collect Earth* that is a free and open source software for land monitoring developed by Food and Agriculture Organization of United Nations (FAO). The software is part of the set of tools called *Open Foris* that was developed with Google Earth and Bing Maps.

Maps from between 2000 and 2016 were analysed and classified, in order to understand the changes in land along the coastal zone in southern Mozambique. Analysis of changes was done for forest, grassland, settlements and croplands. This was done for the whole study area, but also for each province to determine patterns of utilisation.

4.3 Results

Forested area has been steadily declining since 2000 (Figure 27) as was grassland (Figure 28). This was matched by an increase in croplands and settlements in the same period (Figures 29 and 30). It was evident during the field work that many developments have taken place in thecoastal zone of southern Mozambique, and the tourism industry is growing rapidly due to the beaches and warm waters of the Indian Ocean shore.

Analysing land use for each coastal province, Inhambane lost substantial areas of forest between 2000 and 2005 after which no futher loss was found (Figure 31). The same pattern was observed for the grasslands (Figure 32). These decreases are matched by an increase in the area of croplands and settlements (Figures 33 and 34).

In Gaza Province, the area of forest declined between 2000 and 2001, 2007 and 2008 as well as between 2012 and 2013 (Figure 35). This is likely to be because Gaza does not have much forest in coastal areas. Although the main activity for the local people is agriculture, in the coastal zone people are engaged in other activities. The area of grassland decreased only between 2000 and 2001 and remained constant after that (Figure 36). The loss of forest was due to an increase in agricultural activity (croplands) as shown in Figure 37. The settlement area in the province remained unchanged (Figure 38) probably because the most important settlements are not in the coastal zone. The small towns along the coast remain unchanged in terms of population expansion. The small tourist towns are densely populated because people prefer to live near the tourism industry for employment. There is not much agriculture due to infertile soils.

Maputo Province has a different pattern of land use. Forest was lost between 2003 and 2011 (Figure 39). A notable loss of grassland area was found between 2009 and 2014 (Figure 40). The increase in croplands (Figure 41) coincided with the decrease in the forest area. Settlements are growing in this region (Figure 42).

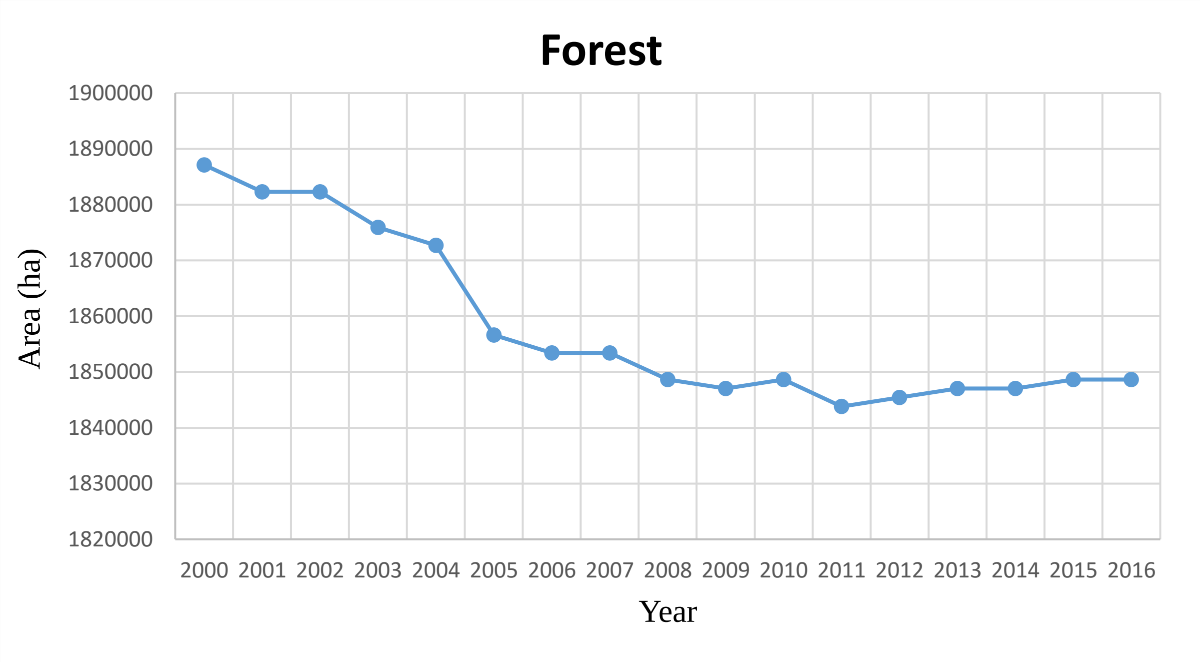

Figure 27. Decrease in the area of forest in the coastal zone of southern Mozambique between 2000 and 2016.

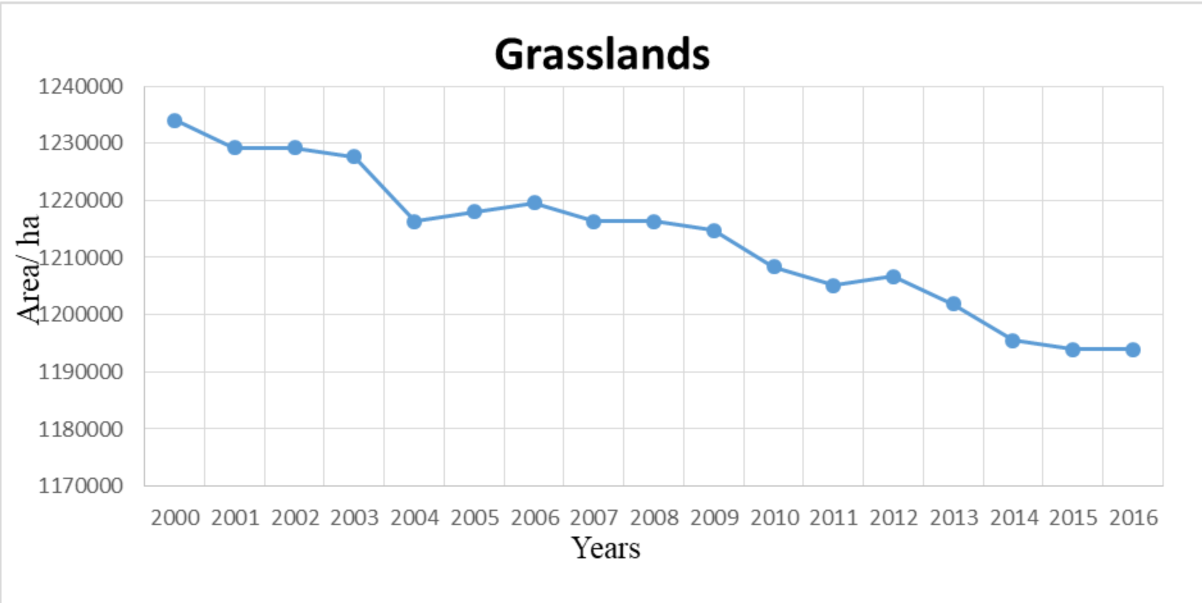

Figure 28. Decrease in the area of grassland in the coastal zone of southern Mozambique between 2000 and 2016.

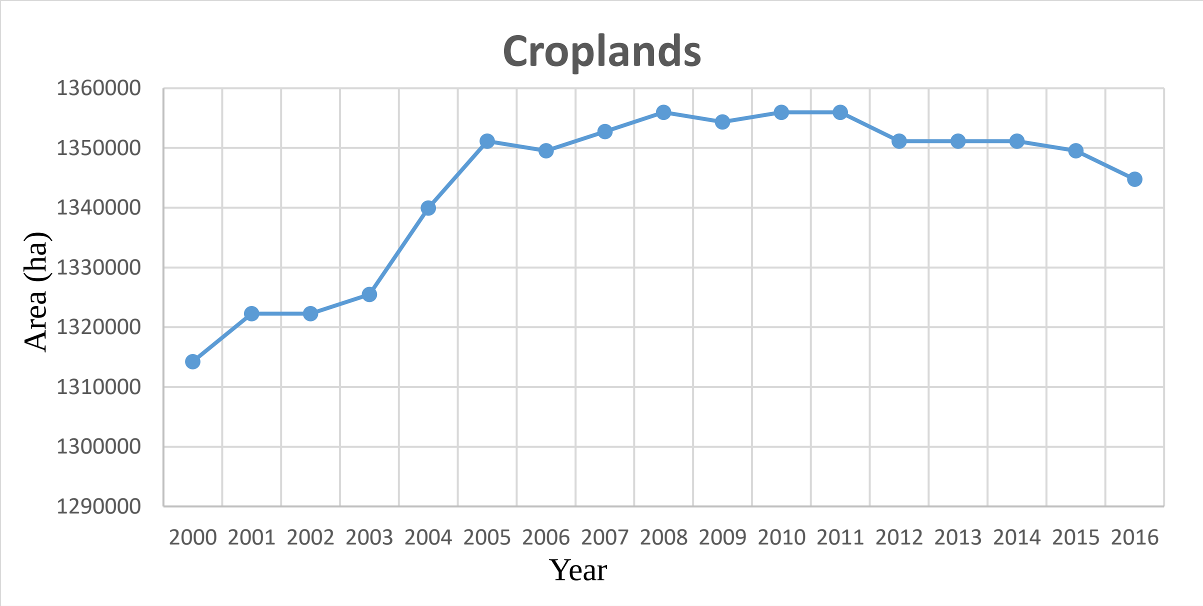

Figure 29. Change in the area of cropland in the coastal zone of southern Mozambique between 2000 and 2016.

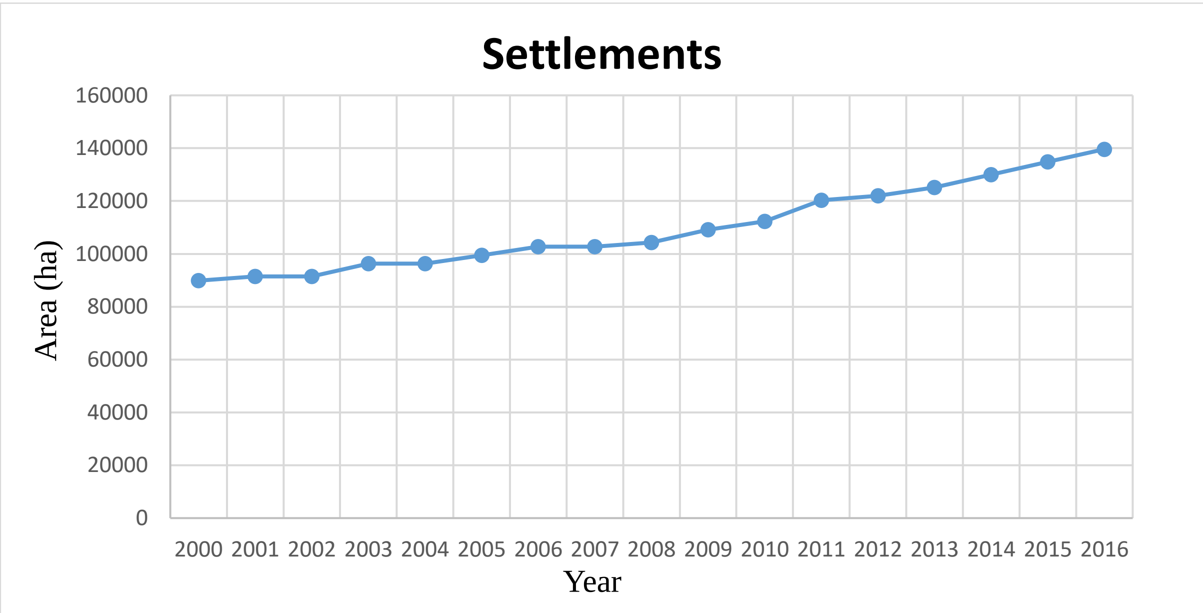

Figure 30. Increase in the area of settlements in the coastal zone of southern Mozambique between 2000 and 2016.

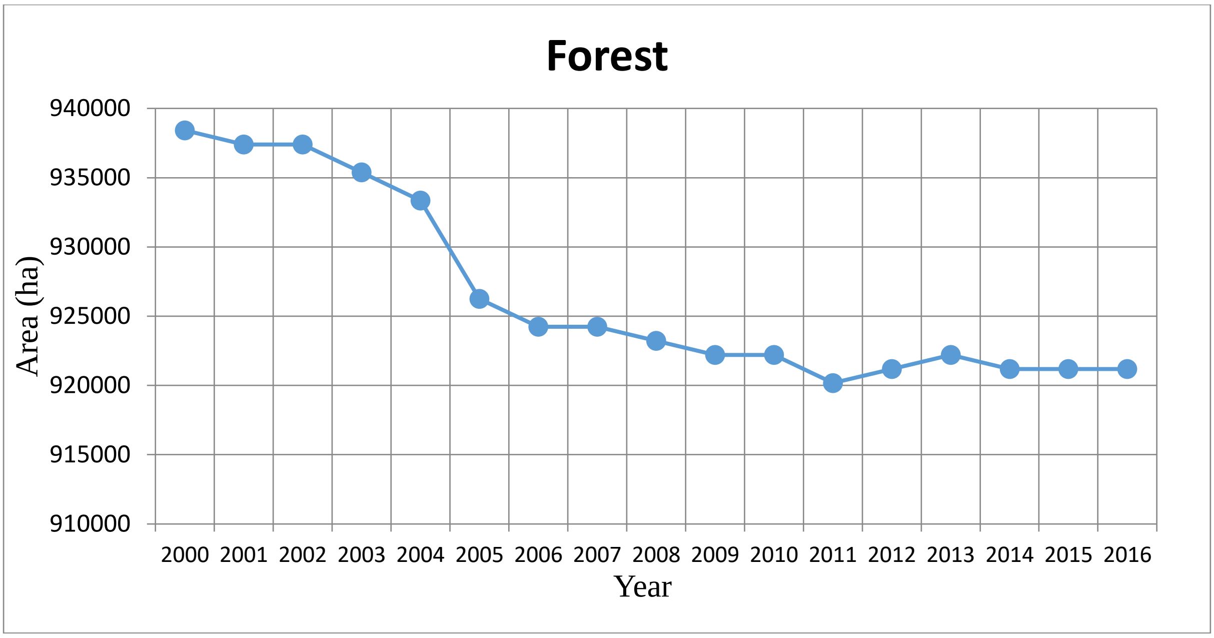

Figure 31. Decrease in the area of forest in the coastal zone of Inhambane Province between 2000 and 2016.

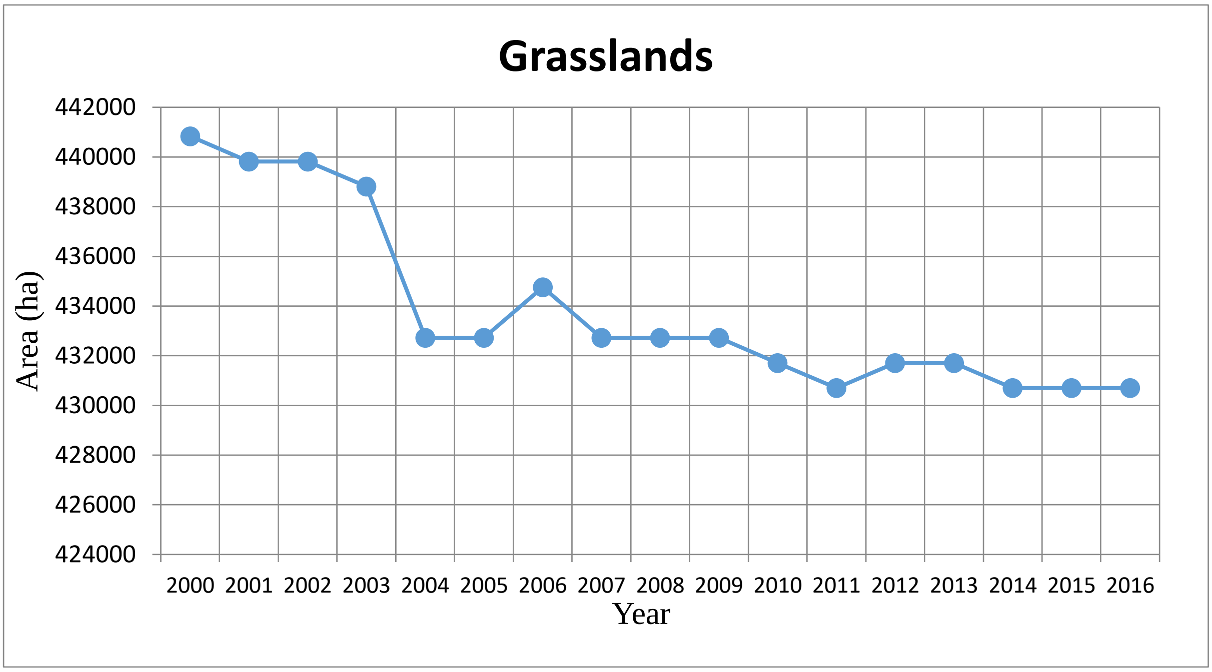

Figure 32. Decrease in the area of grassland area in the coastal zone of Inhambane Province between 2000 and 2016.

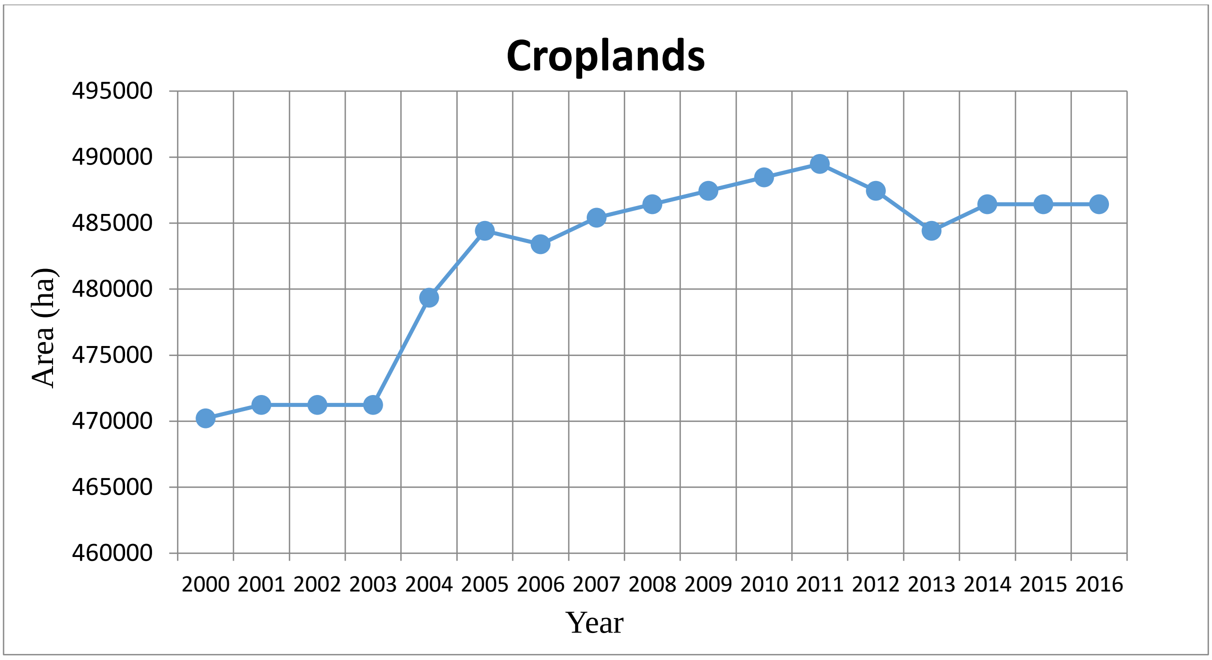

Figure 33. Change in the area of cropland area in the coastal zone of Inhambane Province between 2000 and 2016.

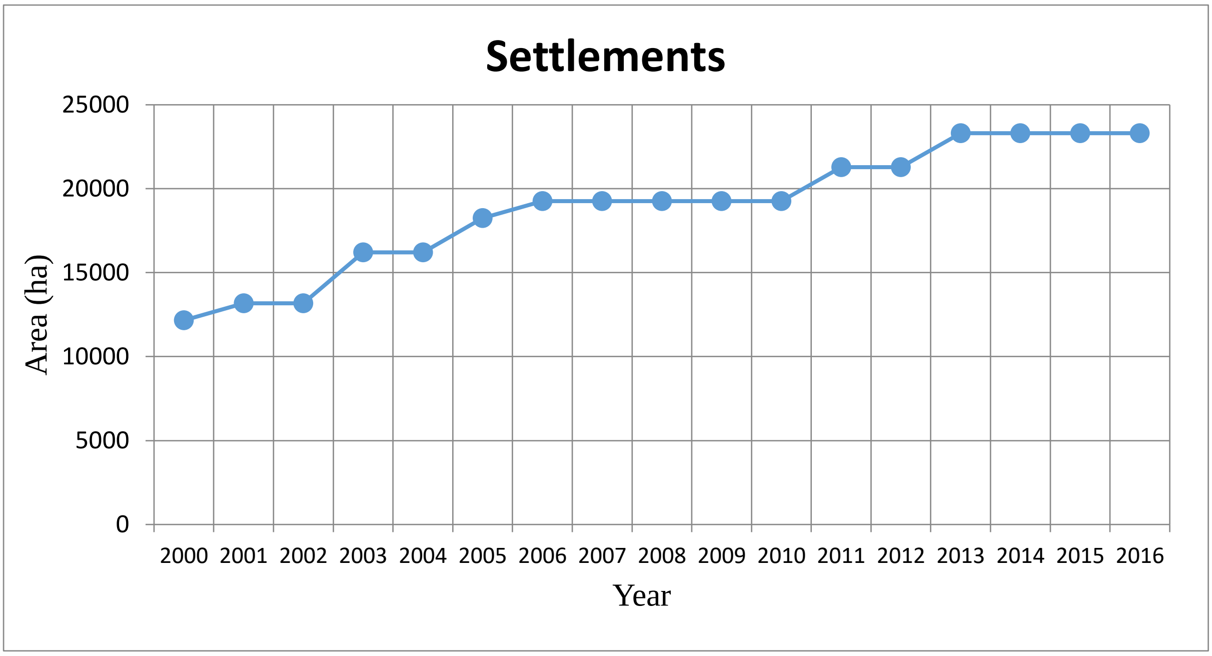

Figure 34. Increase in the area of settlements in the coastal zone of Inhambane Province between 2000 and 2016.

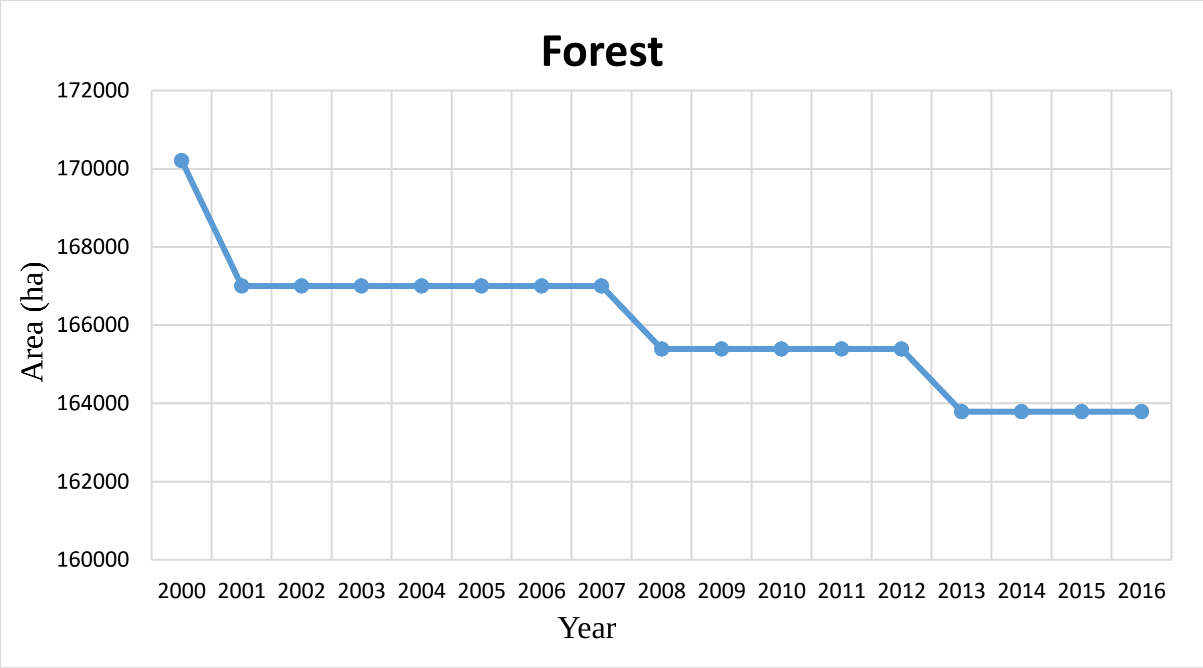

Figure 35. Decrease in the area of forest in the coastal zone of Gaza Province between 2000 and 2016.

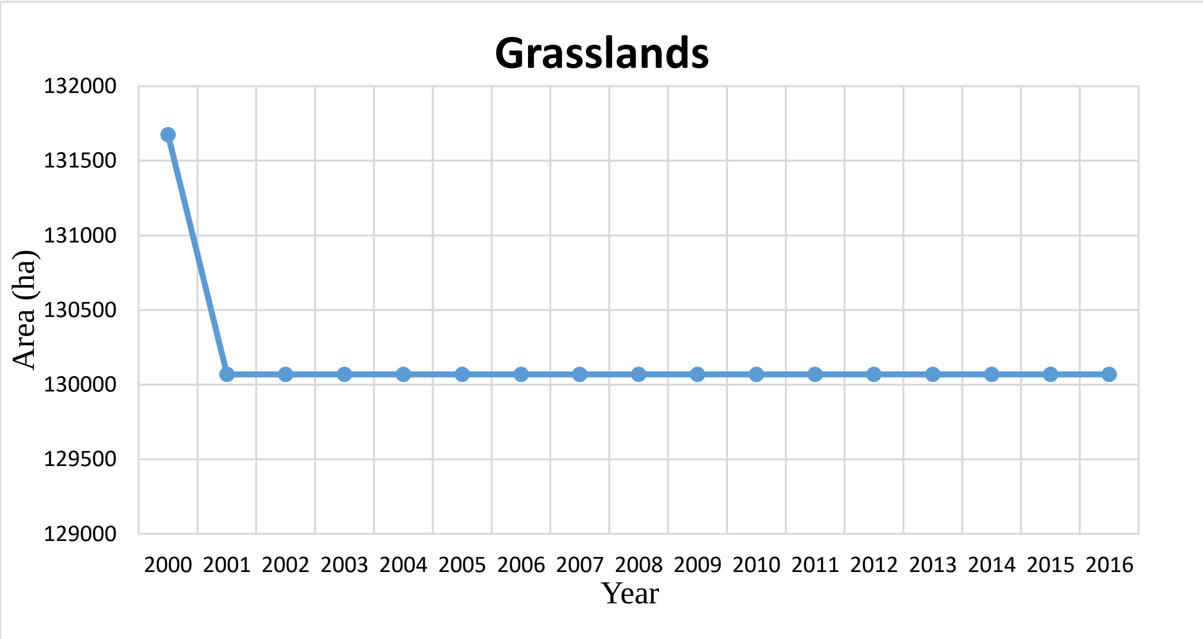

Figure 36. Decrease in the area of grassland in the coastal zone of Gaza Province between 2000 and 2016.

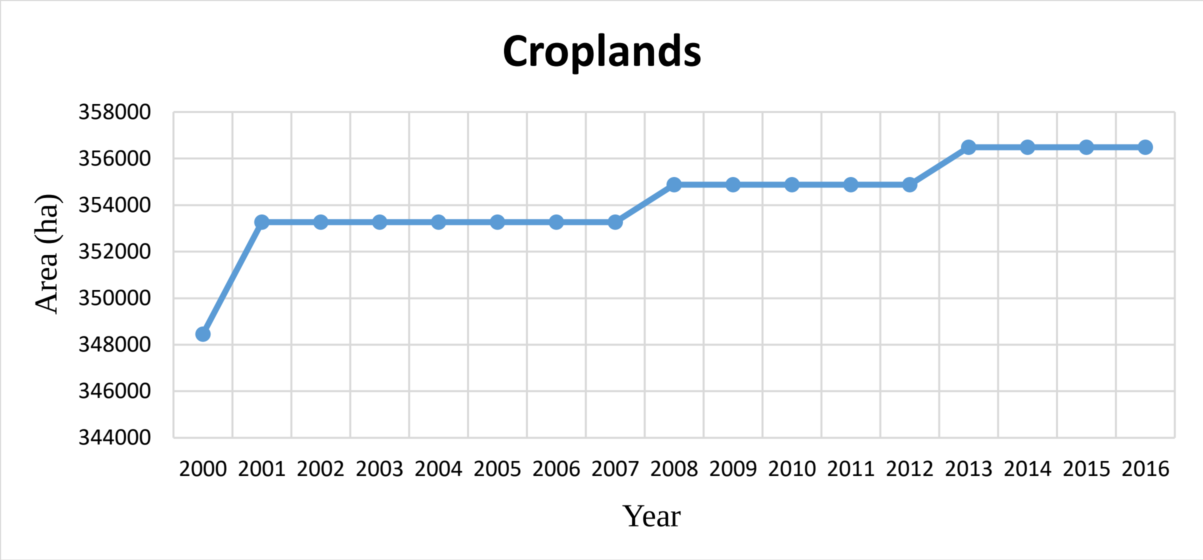

Figure 37. Increase in the area of croplands in coastal zone of Gaza Province between 2000 and 2016.

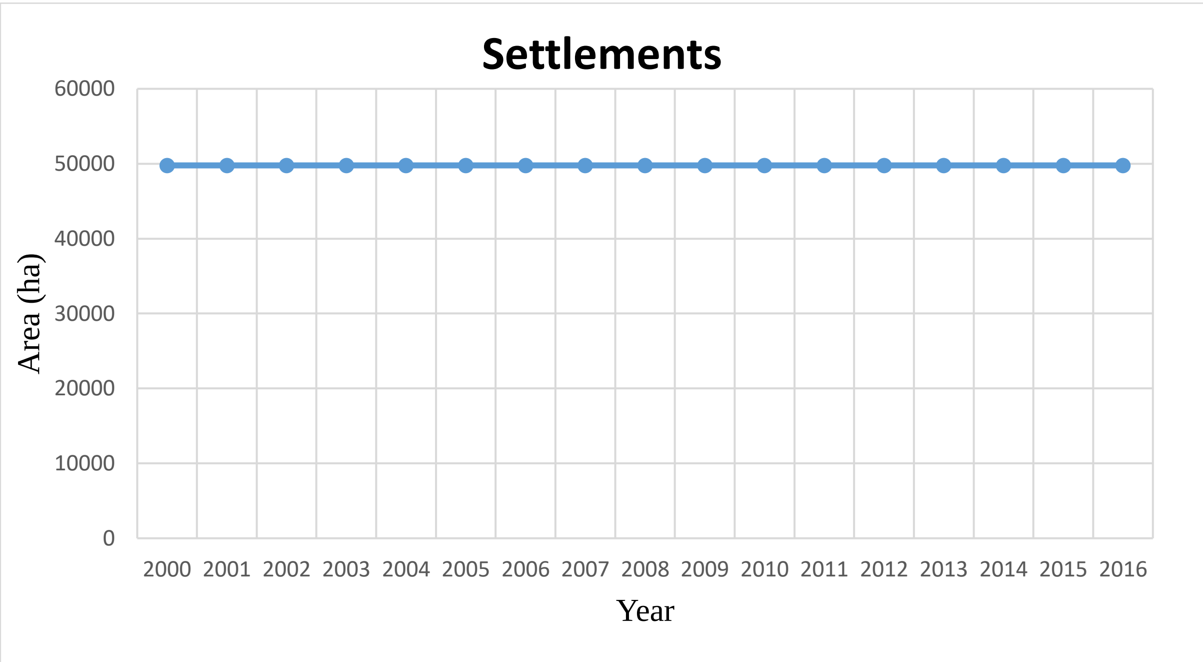

Figure 38. The area of settlements in coastal zone of Gaza Province between 2000 and 2016.

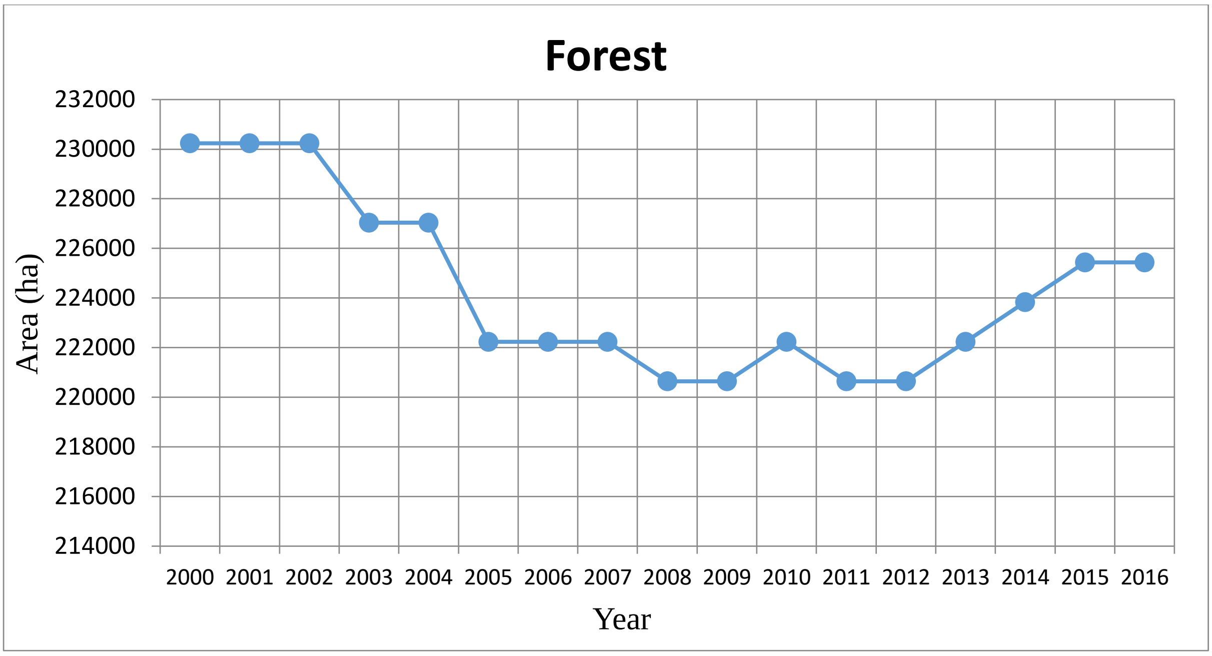

Figure 39. Change in the area of forest in coastal zone of Maputo Province between 2000 and 2016.

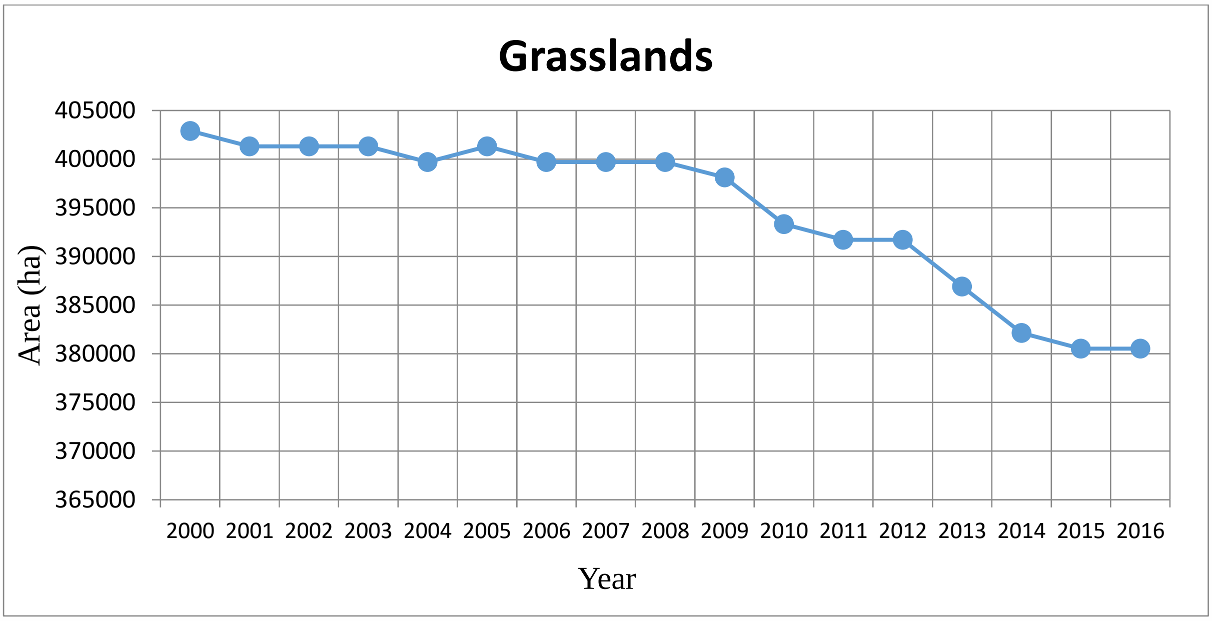

Figure 40. Decrease in the area of forest Grassland in coastal zone of Maputo Province between 2000 and 2016.

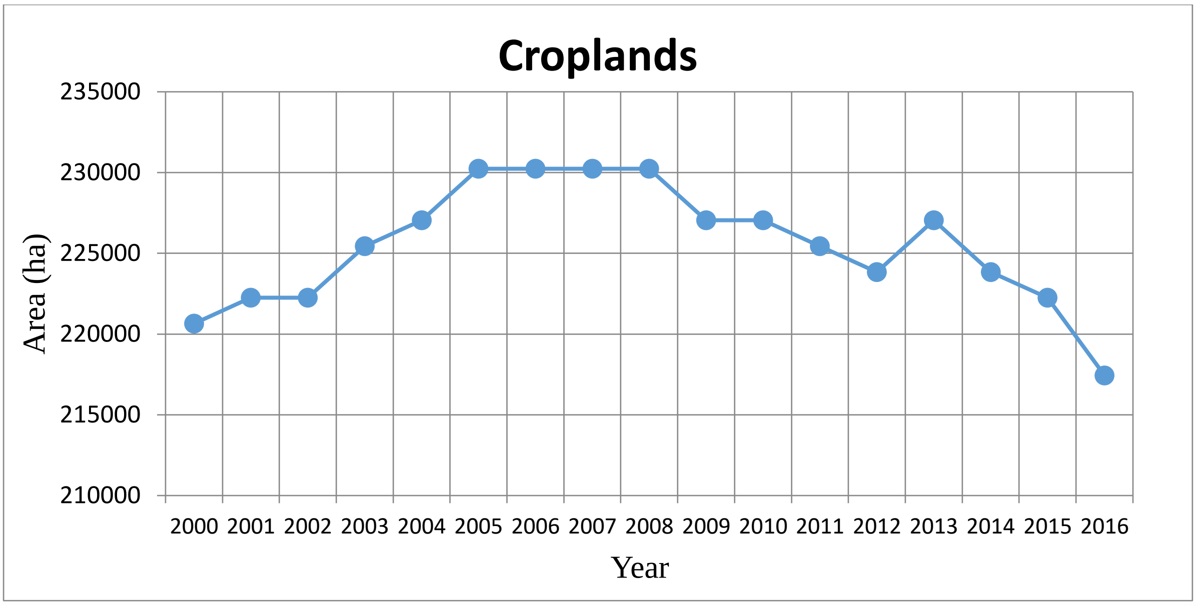

Figure 41. Change in the area of croplands in coastal zone of Maputo Province between 2000 and 2016.

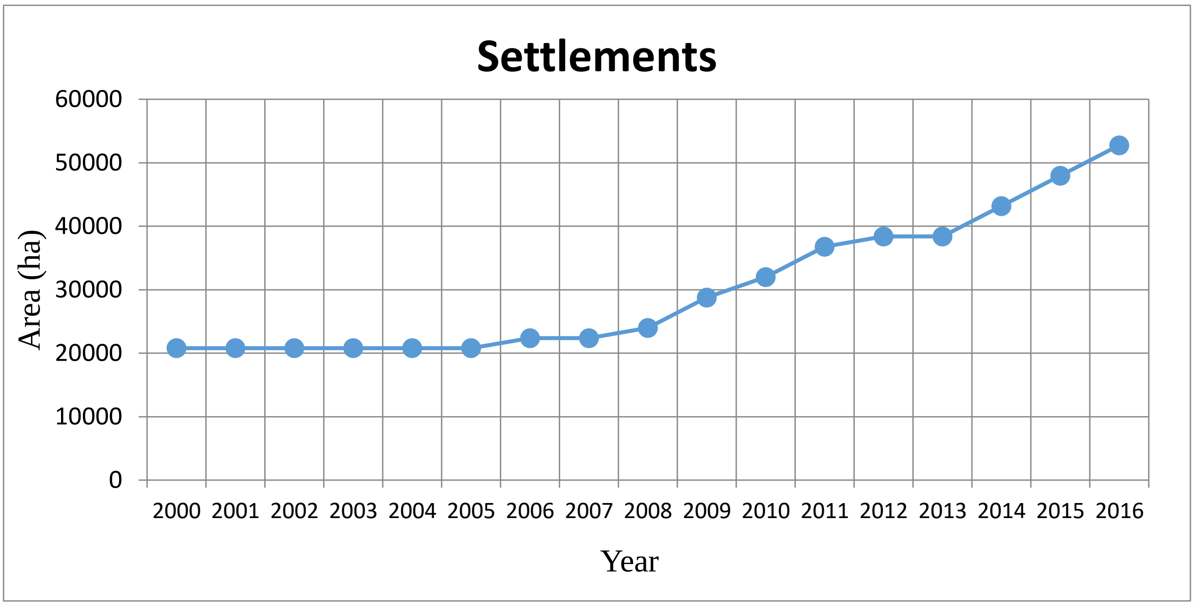

Figure 42. Increase in the area of settlements in coastal zone of Maputo Province between 2000 and 2016.

Vast areas of land in Maputo Province are used for agriculture. However, it is possible that no new areas of vegetation were cleared for agriculture. It could also be that agriculture had improved farming techniques so as to generate more income from smaller areas. Another reason may also be because the city of Maputo provides many other sources of income for the population of the province. During the war, most people moved to the big cities and this reduction of anthropogenic impact has given the forest an opportunity to recover. Forest recovery was observed during the field work and the local people that returned to the rural areas confirmed this.

Field observations yielded evidence of the threats facing the coastal zone of southern Mozambique (Plate 13). For example, *Hyphaene coriacea* palms, locally known as Uchema, are used for making palm wine that is important for the local economy. This harvesting was observed throughout the study area, but mostly in Matutuine (Maputo) and in the north of Inhambane Province, including Panda.

The effects of tourism are evident across the whole coastal zone of southern Mozambique (Plate 14).

4.4 Discussion

Rudel (2007) found many reasons for deforestation and land degradation, from direct (such as expansion of small-scale agricultural areas and poverty) to indirect causes (such as state policies and business interests inside and outside the forest sector). In Mozambique, Sitoe et al. (2012) emphasise itinerant agriculture as a direct cause of deforestation and land degradation, occupying more than 5 million ha (Sitoe et al., 2013).

The analysis of land use and degradation in the coastal zone of southern Mozambique showed a pattern of loss of natural areas. The main cause of vegetation loss is the tourism industry – most vegetation on the dunes were removed for the building of hotels and lodges. Ponta de Ouro, Bilene, Chidenguele, and Inhambane (Barra, Duvelas dune), Vilanculos and Inhassoro are the areas with the most development of hotels and lodges on the dunes and along the shoreline.

Although most local people have some agricultural activity, soils are not fertile in the coastal zone for this area. They use other activities to increase their income (e.g. fire wood and charcoal selling, and artisanal fisheries).

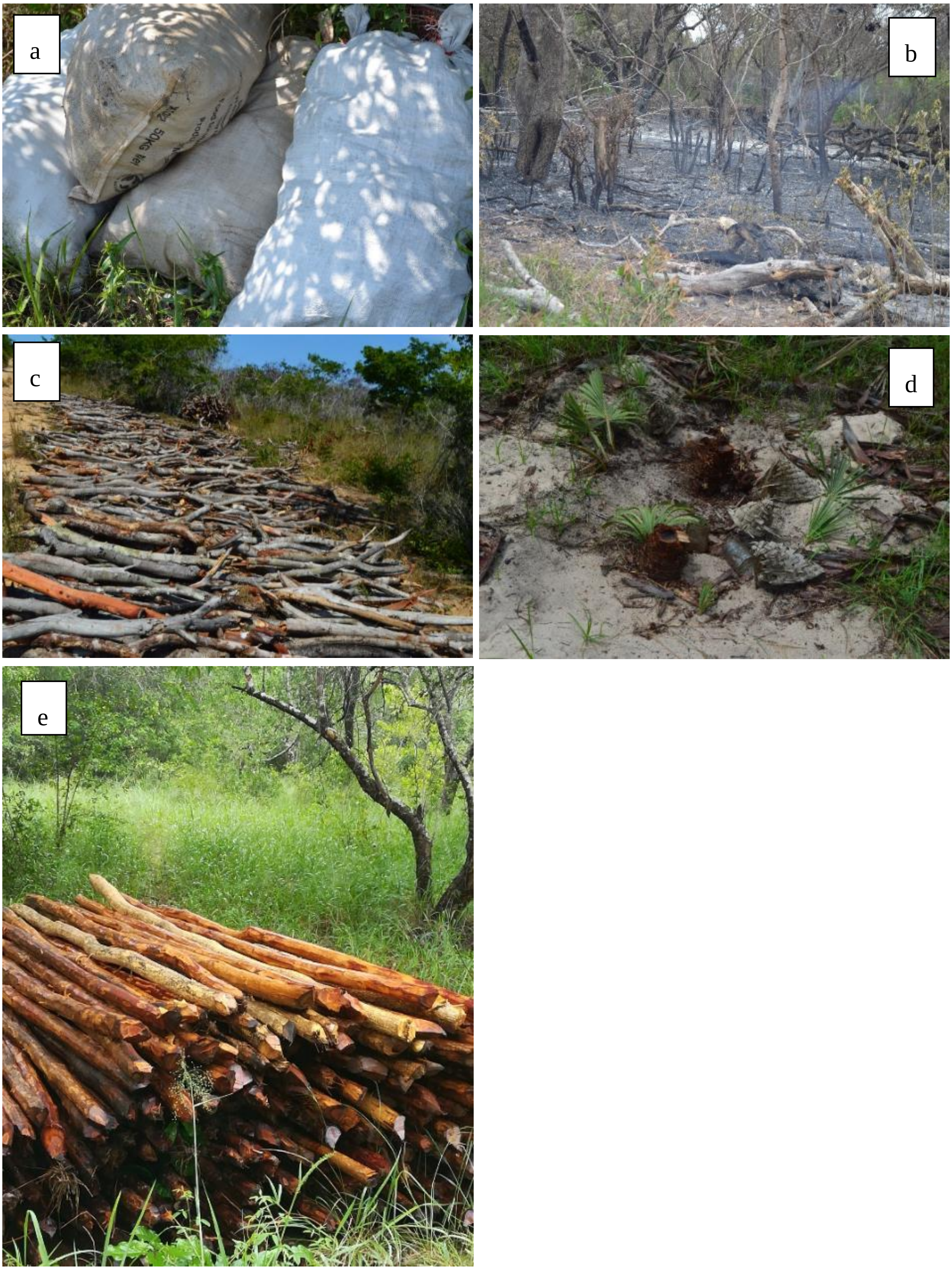

Plate 13. *Hypoxis hemerocallidea* for commerce (a); use of fire to clear land for agriculture (b); firewood for selling (c); collection of *Hyphaene coriacea* to make local wine (d) and *Androstachys johnsonii* logs used for construction of houses (e).

Plate 14. Tourism activities along the coastal dunes of southern Mozambique in Jangamo (a) and at Ponta de Ouro (b).

Each province has their main activity: in Inhambane the principal activity is fisheries; in Gaza most people work in the tourism industry; and in Maputo there are a variety of activities due to the city having more sectors that provide income for people. In areas such as Bilene, only the elderly people are still doing agriculture (small machambas for very few crops) with young people working in the tourism industry.

Thus, the main threat to coastal vegetation and flora in southern Mozambique is a loss of habitat due to tourism and human settlements, but in areas also because of agriculture. Graham et al. (2012) observed that some areas of sand forest between Mbazwana and Gezisa in KwaZulu-Natal South Africa, are also experiencing such ongoing degradation due to anthropogenic activities. Loss of forest and grassland along the coastal zone of southern Mozambique can be directly linked to increased areas of cropland and settlements. This is as reported by Sitoe et al. (2012; 2013) who found that commercial farming, relocation of farms for subsistence farming, charcoal production, development of new infrastructure, and expansion of urban areas are the direct causes of deforestation in Mozambique. They did however also mention that possibly weak governance of land and forest could play a role.

In this study it has been noted that in the Maputo coastal zone, forest vegetation is recovering in places. This contrasts with Sitoe et al. (2013) who found that the average farm size used for subsistence agriculture has increased from 60 ha in 2001 to 148 ha in 2010 per household in Maputo Province (an increase of 146%). However, they do report that collection of firewood in rural areas is no longer a cause of deforestation (Sitoe et al., 2013) and this possibly allows the forests to recover. Furthermore, agriculture is not the main human activity in the coastal zone of southern Mozambique. During this study it was also observed that there were some forest areas in Manhica (Kalanga and Bilene) where the vegetation was recovering because people did not return after the war (personal observation). Most importantly, where human pressures continue, forest recovery remains minimal. There is no doubt that the pressure will increase because of the population increase. A low potential for agriculture, the distance from major roads and the lack of water has kept people away from natural areas and this has contributed to the preservation of the environment. For example, in Bassane, the distance from where most people have settled is more than 15 km away from a major road – this distance, in such a poor community where vehicles and other means of transportation of goods and resources are not readily available, seems to be sufficient to prevent an excessive impact on the vegetation from human utilisation. People have to carry harvested wood and other plant material themselves, often as loads on their head, and this seems to have limited the utilisation of resources further than the immediate areas surrounding the settlements. The availability of adequate material close to the settlements may also have contributed to the protection of vegetation further away.

These findings do, however, only reflect issues pertaining to coastal vegetation. For example, direct observations of vegetation around Bilene over 30 years has shown that inland savanna degradation is taking place at a rapid rate.

Charcoal production and collection of firewood have a greater impact in areas close to major cities or settlements such as Maputo (Sitoe et al., 2013). Matimele (2016) found that the area of the greatest concern in Maputo Province is the Licuati Forest Reserve which is situated only 50 km south of the city of Maputo. In this study the main areas where fire wood and charcoal collection has an effect is in Matutuine and Manhica. However, the charcoal supply chain considers this to be a small supply for Maputo city. The industry indicated that the main source of charcoal for Maputo city is from Gaza (Mabalane) and Moamba (Chavana, 2014). According to the wholesalers and retailers of charcoal in Maputo city, they prefer charcoal from Gaza, due to its good quality (presumably due to the quality of the species used).

Collection of plants for various purposes forms one of the major activities of rural pople. They use plants for primary health care, as a food source and various other needs. However, some species, such as *Hypoxis hemerocallidea* (a medicinal plant) is collected commercially in Bilene (Gaza) or *Euclea natalensis* that is also collected commercially in Inhambane Province (pers. observation) and later confirmed to be sold for buccal hygiene products in a market in

Maputo city. These plants harvested in Inhambane have been sold in the Xipamanine Market (Maputo city) and Durban (South Africa) for medicinal purposes according to local people.

Although the tourism industry, followed by wood harvesting for charcoal, are the main causes of vegetation loss in the coastal areas of southern Mozambique, anthropogenic effects that also contribute are shifting agriculture, harvesting for firewood and construction material, cattle grazing (a minor impact only observed in small area of Maputo Province), and recurrent fires have modified the vegetation structure (Gaugris & Van Rooyen, 2010).

According to Massinga and Hatton (1997), the coastal area of Mozambique has long been recognised as an area of high tourism potential, but particularly so since the end of the civil war. With the return of peace and stability to Mozambique, an increase in tourism activities along the whole coastal zone of southern Mozambique is evident.

Degradation in the coastal zone is not only caused by anthropogenic impacts. Natural disasters also have an effect. Macamo et al. (2016) reported that most of the mangrove forests in Inhambane were destroyed during the Eline cyclone in 2000. Coastal erosion caused by large waves is a major challenge and has serious implications for tourism (Plate 15) and the vegetation on the dunes.

Plate 15. Sand dune erosion caused by storms in the coastal zone of southern Mozambique.

Sustainable land management is a central challenge in the management of Earth systems and resources. On the one hand, land management must ensure a growing supply of food and other resources for humans. On the other hand, management of land to procure these resources is linked with potentially negative consequences in the form of degradation, climate change, biodiversity loss and pollution (Ellis, 2007; Ellis et al., 2010). Moreover, local land use practices and removal of vegetation can have global consequences, requiring local and regional solutions to global problems and the cooperation of the world's policymakers, land managers, and other stakeholders at local, regional and global scales.

5. Soil properties of the plant communities of southern Mozambique

5.1 Introduction

According to the Burgess et al. (2000), the soil of an area reflects a complex interaction between rainfall seasonality, topography, organic material, living organisms and disturbance. The disturbance is mostly by anthropogenic action. Burgess et al. (2000) reports about eleven main types of soil in the coastal plain of eastern Africa. These range from sandy soils with imperfect drainage, sandy loams with excessive drainage, loams with moderately good drainage, loams with imperfect drainage to clays with imperfect drainage.

Ten agroecological zones (AEZ) of Mozambique have been identified based on climate, soil type, elevation, and farming system (Maria and Yost, 2006). Only one of these is found in the coastal zone of southern Mozambique: the no productivity zone. According Ray et al. (2014), this low productivity is attributed to the unfavourable agro-climatic conditions. Coastal soils are encountered with various abiotic stressors: salinity, acidity, waterlogging and sandy texture. Most of the coastal areas have such problematic soils, particularly in low-lying areas along the deltas. Salinity is the main factor responsible for poor yield of crops growing.

Vegetation and soil are interrelated and exert reciprocal effects (Eni et al., 2012). Soil gives support in terms of moisture, nutrients, and anchorage to plants enabling them to grow effectively, and vegetation provides protective cover for soil, suppresses erosion as well as helps to maintain soil nutrient concentrations through litter accumulation and subsequent decay.

For this study soil texture, pH, and organic matter were measured in order to describe the relationship of the vegetation types found in the coastal zone of southern Mozambique with the soils.

5.2 Methods

Soil samples were randomly collected within each sampling area using a Dutch auger with a 25-cm blade. Samples were taken near the surface (representing between 0 and 20 cm depth). Soils were placed in plastic bags and taken to the laboratory for testing.

According to Fasham & Tucker (2005) determination of soil organic content can indicate overall biological activity as well as the speed of turnover of nutrients. For this study, soils were oven dried at 105ºC after which mass loss was measured after ashing at 400ºC (Jones, 2001).

Soil pH was measured using an electrometric method, according to The Non-Affiliated Soil Analysis Work Committee (1990).

The soil texture was measured by particle diameter composition using sieves (2 mm, 1 mm, 0.5mm, 0.25 mm, 0.125 mm, and 0.063 mm) to separate sand from silt and clay (Jones, 2001).

Data was tested for normality using the Shapiro-Wilks test in *R* (version 2.14, R Core Team, 2012). Comparisons of the means of normal data were done using the Welch Two Sample t-test and for non-parametric data a Kruskal-Wallis chi-squared test was used.

5.3 Results

The soil pH values were parametric (W = 0.988; p = 0.136). The soils sampled in the vegetated dunes were significantly higher (with a mean of 7.22) compared to those of the other vegetation types (they had a mean of 6.48; t = 3.510, d.f. = 48.945, p = 0.001). Forest soils also were significantly different (t = 3.905, df = 59.348, p = 0.0002). Forest soils were more acidic (a mean of 5.74) as opposed to the soil in the other types of vegetation. There were no significant differences when comparing soil pH of miombo and woodlands (t = 0.672, d.f. = 38, p = 0.504); miombo and savanna (t = 0.593, d.f. = 59.931, p = 0.556) as well as savanna and woodland (t = 1.313, d.f. = 65.581, p = 0.194).

Soil organic content (as a % of dry mass; data was parametric: W = 0.822; p < 0.001) only differed in the forests: where the organic content was higher in forest soils (with a mean of 1.434%) compared to the other vegetation types (with a mean of 1.011%; t = 3.037, d.f. = 79.543, p = 0.003). There were no differences when comparing organic content of dunes with the other vegetation types (t = 1.531, d.f. = 34.634, p = 0.135). There were also no differences between soil organic content of miombo and woodlands (t = 1.450, d.f. = 37.006, p = 0.156); miombo and savanna (t = 0.524, d.f. = 37.843, p = 0.603) as well as savanna and woodland (t = 1.842, d.f. = 102.59, p = 0.06835).

Soils in coastal zone of southern Mozambique are mostly sandy (Figure 41). Soil texture was found to be non-parametric (W = 0.782, p << 0.001). A Kruskal-Wallis chi-squared test (Benjamini-Hochberg) showed that dune soils were significantly more sandy compared to the other vegetation types (χ^2 = 20.951, d.f. = 3, p < 0.001; Dunn's Test vs Forest = 3.915; p =

0.0001; vs Savanna = 4.461, $p < 0.0001$; vs Woodland = 3.627, $p = 0.0003$). Dune soils had less silt than in the other vegetation types ($\chi^2 = 19.178$, d.f. = 3, $p < 0.001$; Dunn's Test vs Forest = 3.313; $p = 0.0009$; vs Savanna = 4.232, $p = 0.0001$; vs Woodland = 3.840, $p = 0.0002$).

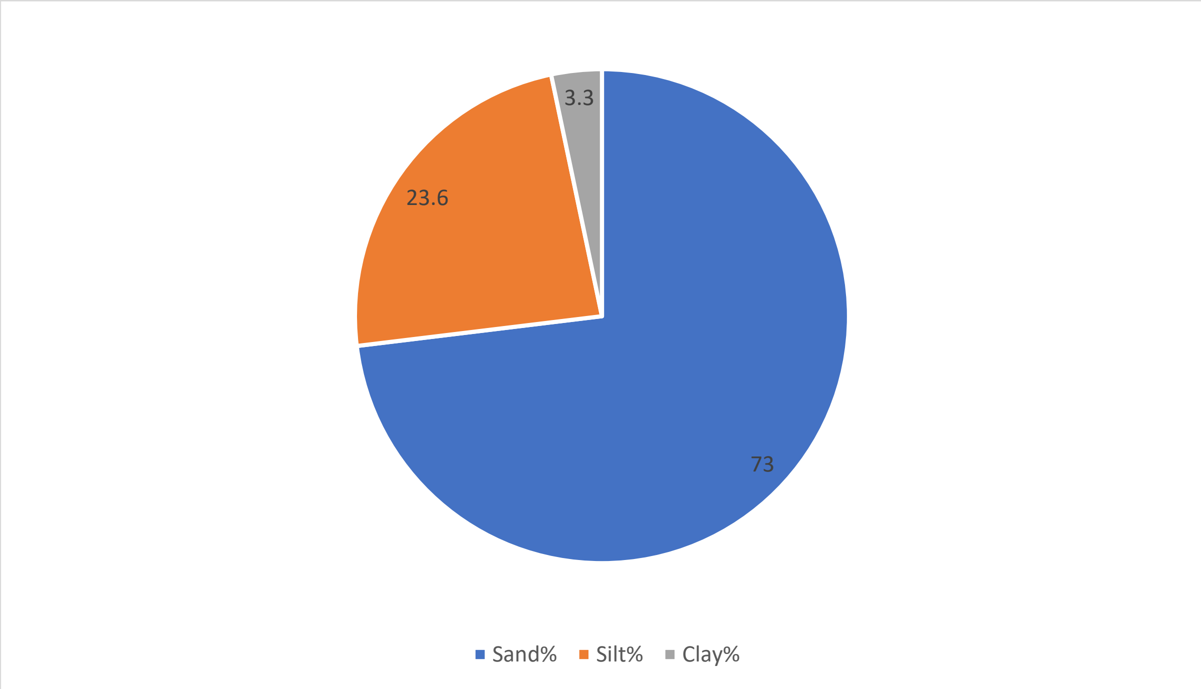

Figure 43. Soil composition in the coastal zone of southern Mozambique.

5.4 Discussion

Comparison of the data collected for this study with other studies is challenging due to the lack of information on soils in the coastal zone of Mozambique. However, in the coastal zone of east Africa (e.g. Tanzania) at least half of the land has major fertility problems with 45% having nutrient levels that will limit crop yield (Hathout, 1972).

In Mozambique, most of the soils in the coastal zone are sandy and have low organic content making them unsuitable for agriculture. This includes miombo, in agreement with Campbell et al. (1996) who reported that miombo woodland soils are typically nutrient-poor. These findings suggest that most of the coastal zone is suitable for wildlife conservation. All the soils sampled in this study have poor agricultural potential, and the coastal zone vegetation is adapted to the poor soils. Burgess et al. (2000) reports that low soil phosphorus concentrations may influence coastal forest vegetation in that more leguminous trees occur in these areas. In this study, coastal forests were found to contain many Fabaceae species, although soil nutrient contents were not measured. Considering that differing soil properties were most strongly linked to the different vegetation types (Chapter 3), the lack of studies on the soils of the coastal zone represents a substantial barrier to advancing our understanding of vegetation dynamics and function.

6. Recommendations for management of the flora and vegetation of the coastal zone of southern Mozambique

In the face of numerous threats endangering coastal habitats, the need for monitoring and active management of these environments has become a priority (Carnoni et al., 2009). Multiscale approaches are useful to study limited-area ecosystems of the world, such as coastal vegetation, in particular if they are close to urban areas.

An historical assessment of the vegetation in Mozambique identified factors that have led to losses of coastal ecosystems. Despite this however, adequate management of the flora and vegetation in Mozambique is still lacking, especially in coastal zones where uncontrolled harvesting is taking place, particularly around urban centres. Further pressure arises because of the tourism industry and mining projects.

The main causes of this degradation, apart from natural disasters, are related to poverty and the pressures of economic development in third-world countries both locally and at global scales. Economic gains, many bringing only short-term benefits, are being made at the expense of the integrity of ecosystems and the vulnerable communities that they support.

The management of ecosystems calls for interaction between science and society to ensure that environmental and socio-economic issues are integrated with government strategies. For this to take place, a number of conceptual frameworks exist as tools for communication between researchers and end users of environmental information such as government departments (USAID, 2002; MICOA, 2014).

For many people living in the coastal zone of Mozamibque, the only means of survival is subsistence farming and use of natural resources (Crookes, 2000). Financial income is predominantly acquired from cutting firewood and making charcoal to sell, by working on the mines or the commercial farms in the area. Overgrazing by domestic livestock has seriously degraded the vegetation in densely populated areas in and around Maputo Province (Matutuine, Catembe, Kalanga and 3 de Fevereiro) – this represents a threat to the endemics of the region. While there is little pressure from domestic livestock in the coastal zones of Gaza and Inhambane Provinces, in these areas the tourism industry is the major treat to vegetation integrity.

Although there are two national wildlife reserves along the southern coast of Mozambique (Reserva Nacional de Maputo and Reserva Nacional de Pomene), these only include a small area of dune coast. It is in this area where most tourism is developing.

Rapid development in the coastal zone of southern Mozambique is a threat not only to the common species that are used by the local inhabitants for firewood or charcoal, but also to the endemic plant species that are dependent on specific habitats. This is best illustrated by the fact that in this study the endemic *Xylia mendocae* that only occurs in coastal zone of Inhassoro and Vilanculos was only recorded in disturbed areas (Machamba and near households).

The biodiversity of the coastal zone is an important resource, both on land and marine. The coral reefs, sea grass beds, dunes, estuaries, mangrove forests and other wetlands that occur in the coastal zone provide valuable ecosystem services for humanity, as well as crucial nursery habitats for marine animals and sanctuaries for endangered species (Arthurton et al., 2006). Loss of these habitats will have major impacts for people living in the area and cause a decline in species diversity of both plants (as considered in this study) but also the associated fauna including those in the adjacent marine environment. For example, the destruction of dune vegetation and mangrove forests has resulted in a loss of coastline integrity (Gilbert & Janssen, 1998; Fondo & Martens, 1998; Mumby et al., 2003; Louro, 2005; Worm et al., 2006). This in turn, influences many species such marine turtles and coastal and migratory birds that use the littoral dunes as nesting places (Louro, 2005).

6.1 Future research

Mozambique is a country where little research has been done on the flora and vegetation. Similar studies such as this one should be extended to cover the whole country in this regard. This study was done along the coast of southern Mozambique, but particular attention should be focused on an investigation of endemic plant species in the northern and central coastal zone (Rovuma River to Save River).

Although it was found that the tourism industry is rapidly growing in the coastal zone of southern Mozambique, intact vegetated dunes still exist, and action must be taken in order to protect them. This should be done through government legislation and with the Non-Governmental Organisations that work with the tourism industry. Coastal zone planning should precede the development of management plans that will be required in order to control the expansion of settlements in coastal zones.

In this study, the influence of invasive species under the disturbance regime along the coastal zone was not considered. This remains an important issue for future research. Invasive species, such as *Lantana camara,* can be found in most patches of forest and woodland. This species has the potential to take over forest fragments as was observed in Reserva Especial de Maputo, mainly close to the roads and the electricity line to Machangulo.

6.2 Conclusions

In conclusion, this study has presented the current status of coastal vegetation in southern Mozambique. It has contributed to the understanding of the biogeography and sustainability of vegetation and flora and has identified the current threats to their long-term survival in Mozambique. There is an urgent need to alter current anthropogenic activities around these critically important ecosystems.

Species distribution models were used to analyse a group of species with restricted distribution. Two areas of importance were found: one in Inhambane Province and the other in the Maputaland Centre of Endemism in the south. These both fall in the single phytogeographical region of the Indian Ocean Coastal Belt. The results of this study demonstrate how Species Distribution Models can offer important new insights on the geographical ecology of endemic species. Firstly, at the scale of this study, the distribution of the endemic species studied was found to be determined by a combination of climatic and non-climatic variables. Of the nine predictor variables used to build the model, soil type, temperature annual range and precipitation of driest month emerged as the strongest range predictors. A combined map of the potential distribution of the seven endemics indicated two high-endemism areas, hereby confirming previous suggestions in the literature (White, 1983; Matimele, 2016). Of greatest significance is that these assessed ranges are poorly covered by the existing protected areas in southern Mozambique and urgent conservation action will be required to redress this. It is recommended that the establishment of additional major protected areas or Important Plant Areas (IPAs) are needed in order to safeguard the endemic biodiversity in particularly Inhambane Province against deforestation and other negative factors.

Coastal vegetation in Mozambique has been reasonably well described. However most detailed studies were carried out in northern Mozambique (Timberlake et al., 2011). This study is the first to consider coastal forests in the coastal zone of southern Mozambique. Findings from this study suggest that the vegetation of the coastal zone of southern Mozambique is no longer in the state previously described (Wild & Barbosa, 1967; Tinley, 1985; Werger, 1978; Moll, 1980). Currently more than 60% of population in Mozambique live in the coastal zone and they have altered the vegetation state.

Six Vegetation Types are described from the study area: Coastal Dune Thicket, Coastal Forest, Coastal Grassland, Coastal Miombo, Coastal Savanna and Coastal Woodland. Forest (including Miombo Forest) is most used by local people followed by the Savanna. Both are used for agriculture and wood harvesting for charcoal production, as a source of building poles and timber, and for firewood. Entire patches of forest have been logged unless protected in Reserva Especial de Maputo. Burgess et al. (1992) and Matimele (2016) report similar findings in different patches of forest in Tanzania and in Licuati Mozambique respectively. In this study, it was difficult to find mature *Terminalia sericea* trees in the Bilene savanna (in Bilene the dominant species are *Terminalia sericea* and *Syzygium cordatum*) because this species has become known for producing a good quality charcoal.

Although it seems to be difficult or even impossible to recover the lost vegetation, it is possible to draw up conservation plans that focus on the future. Preventing loss of forest and degradation of the other vegetation types should be a priority for conservation. Coastal forest restoration must be a high priority for immediate action. For example, a restoration of mangroves at Limpopo Mouth has been highly successful. Similar approaches can be applied to terrestrial vegetation. An immediate action recommended is for the Mozambique government to add Sacred Forests to the list of Protected Areas. This can be implemented by local communities as the “owners” of such places.

Findings from this study have shown that plants on the littoral dunes of southern Mozambique, although not of great economic value (apart from *Encephalartos ferox* subsp. *ferox* which is collected to sell for ornamental purposes), are important in terms of biodiversity conservation and habitat integrity. Most of the natural vegetation has been removed for the development of the tourism industry. Remnants of vegetation remain as isolated patches and these will soon disappear unless local inhabitants and government organisations take immediate action. Coastal vegetation, in general, is one of the most important ecosystems. However, the dune systems are particularly fragile and easily threatened environments, yet they provide fundamental ecosystem services to nearby urban areas acting for example as protective buffers against erosion. Correctly assessing their conservation status is a priority in order to manage them adequately and to plan urban development in the coastal zone.

Urgent action is required to designate the best of the remaining dune vegetation as reserves so that they may be protected in future. This should be done by instituting a coastal buffer zone that restricts development within a defined distance from the high-water mark. Further studies of the vegetation and the distribution of plants in Mozambique should be encouraged to fill in remaining gaps in our knowledge and to improve sustainable management of the coastal zone.

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Appendix A. Plant species recorded in the coastal zone of southern Mozambique. Only species that were found within or near the quadrats are listed.

Families	**Species**	**Habit**
Acanthaceae	*Asystasia pinguifolia* T.J.Edwards	herb
Acanthaceae	*Barleria gueinzii* Sond.	herb
Acanthaceae	*Barleria repens* Nees	herb
Acanthaceae	*Ecbolium hastatum* Vollesen	suffrutex
Acanthaceae	*Justicia flava* (Vahl) Vahl	shrub
Acanthaceae	*Sclerochiton coeruleus* (Lindau) S.Moore	herb
Acanthaceae	*Thunbergia neglecta* Sond.	herb
Achariaceae	*Buchnerodendron lasiocalyx* (Oliv.) Gilg	tree/shrub
Achariaceae	*Xylotheca kraussiana* Hochst.	shrub
Agavaceae	*Agave sisalana* Perrine	tree/shrub
Amaranthaceae	*Achyranthes aspera* L. var. *aspera*	herb
Amaranthaceae	*Cyathula lanceolata* Schinz	herb
Amaranthaceae	*Cyathula natalensis* Sond.	herb
Amaryllidaceae	*Crinum stuhlmannii* Baker	geophyte
Amaryllidaceae	*Scadoxus puniceus* (L.) Friis & Nordal	geophyte
Anacardiaceae	*Anacardium occidentale* L.	tree
Anacardiaceae	*Lannea antiscorbutica* (Hiern) Engl.	tree
Anacardiaceae	*Lannea discolor* (Sond.) Engl.	shrub
Anacardiaceae	*Lannea schweinfurthii* (Engl.) Engl. var. *stuhlmannii* (Engl.) Kokwaro	tree/shrub
Anacardiaceae	*Mangifera indica* L.	tree
Anacardiaceae	*Ozoroa engleri* R.Fern. & A.Fern.	tree/shrub
Anacardiaceae	*Ozoroa gomesiana* R.Fern. & A.Fern.	tree/shrub
Anacardiaceae	*Ozoroa obovata* (Oliv.) R.Fern. & A.Fern. var. *elliptica* R.Fern. & A.Fern.	tree/shrub
Anacardiaceae	*Ozoroa obovata* (Oliv.) R.Fern. & A.Fern.var. *obovata*	tree/shrub
Anacardiaceae	*Ozoroa reticulata* (Baker f.) R.Fern. & A.Fern.	tree/shrub
Anacardiaceae	*Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	tree
Anacardiaceae	*Searsia dentata* (Thunb.) F.A.Barkley	tree/shrub
Anacardiaceae	*Searsia gueinzii* (Sond.) F.A.Barkley	tree/shrub
Anacardiaceae	*Searsia natalensis* (Bernh. ex C.Krauss) F.A.Barkley	tree/shrub
Anacardiaceae	*Searsia refracta* (Eckl. & Zeyh.) Moffett	tree/shrub
Anacardiaceae	*Searsia rehmanniana* (Engl.) Moffett var. *rehmanniana*	shrub
Annonaceae	*Annona senegalensis* Pers. subsp. *senegalensis*	tree/shrub
Annonaceae	*Artabotrys brachypetalus* Benth.	tree/shrub/climber
Annonaceae	*Artabotrys monteiroae* Oliv.	tree/shrub/climber
Annonaceae	*Cleistochlamys kirkii* (Benth.) Oliv.	tree/shrub

Annonaceae	*Hexalobus monopetalus* (A.Rich.) Engl. & Diels var. *monopetalus*	tree/shrub
Annonaceae	*Monanthotaxis caffra* (Sond.) Verdc.	tree/shrub/climber
Annonaceae	*Monodora junodii* Engl. & Diels var. junodii	tree/shrub
Annonaceae	*Sphaerocoryne gracilis* (Engl. & Diels) Verdc.	shrub
Annonaceae	*Uvaria caffra* E.Mey. ex Sond.	tree/shrub/climber
Annonaceae	*Uvaria gracilipes* N.Robson	tree/shrub/climber
Annonaceae	*Xylopia torrei* N. Robson	shrub
Apiaceae	*Heteromorpha arborescens* (Spreng.) Cham. & Schltdl. var *abyssinica*	tree/shrub
Apocynaceae	*Acokanthera oblongifolia* (Hochst.) Codd	tree/shrub
Apocynaceae	*Ancylobotrys petersiana* (Klotzsch) Pierre	shrub/climber
Apocynaceae	*Callichilia orientalis* S.Moore	shrub
Apocynaceae	*Calotropis procera* (Aiton) R.Br.	shrub/small tree
Apocynaceae	*Carissa bispinosa* (L.) Desf. ex Brenan	shrub
Apocynaceae	*Carissa macrocarpa* (Eckl.) A.DC.	shrub
Apocynaceae	*Carissa praetermissa* Kupicha	shrub
Apocynaceae	*Carissa tetramera* (Sacleux) Stapf	shrub
Apocynaceae	*Ceropegia crassifolia* Schltr. var. *crassifolia*	succulent climber
Apocynaceae	*Cryptolepis obtusa* N.E.Br.	climber
Apocynaceae	*Cynanchum ellipticum* (Harv.) R.A.Dyer	climber
Apocynaceae	*Cynanchum gerrardii* (Harv.) Liede	climber
Apocynaceae	*Cynanchum obtusifolium* L.f.	climber
Apocynaceae	*Cynanchum viminale* (L.) L.	succulent
Apocynaceae	*Gomphocarpus fruticosus* (L.) Aiton f. subsp. *fruticosus*	herb
Apocynaceae	*Huernia zebrina* N.E.Br. subsp. *zebrina*	herb
Apocynaceae	*Landolphia kirkii* Dyer ex Hook.f.	tree/shrub
Apocynaceae	*Mondia whitei* (Hook.f.) Skeels	climber
Apocynaceae	*Pachycarpus appendiculatus* E.Mey.	geophytic herb
Apocynaceae	*Pentarrhinum abyssinicum* Decne. subsp. *abyssinicum*	climber
Apocynaceae	*Raphionacme flanaganii* Schltr.	climber
Apocynaceae	*Rauvolfia caffra* Sond.	tree
Apocynaceae	*Secamone delagoensis* Schltr.	climber
Apocynaceae	*Secamone filiformis* (L.f.) J.H.Ross	climber
Apocynaceae	*Secamone parvifolia* (Oliv.) Bullock	climber
Apocynaceae	*Stapelia gigantea* N.E.Br.	succulent
Apocynaceae	*Strophanthus kombe* Oliv.	shrub/climber
Apocynaceae	*Strophanthus petersianus* Klotzsch	shrub/climber
Apocynaceae	*Tabernaemontana elegans* Stapf	tree
Apocynaceae	*Tacazzea apiculata* Oliv.	liane
Apocynaceae	*Tylophora anomala* N.E.Br.	climber
Aquifoliaceae	*Ilex mitis* (L.) Radlk. var. *mitis*	tree/shrub

Araceae	*Gonatopus boivinii* (Decne.) Engl.	herb/geophyte
Araceae	*Stylochaeton natalensis* Schott	herb
Araceae	*Zamioculcas zamiifolia* (Lodd.) Engl.	herb
Araliaceae	*Cussonia arenicola* Strey	shrub
Araliaceae	*Cussonia spicata* Thunb.	tree
Araliaceae	*Cussonia zuluensis* Strey	tree
Arecaceae	*Borassus aethiopum* Mart.	tree
Arecaceae	*Hyphaene coriacea* Gaertn.	tree/shrub
Arecaceae	*Phoenix reclinata* Jacq.	tree/shrub
Arecaceae	*Raphia australis* Oberm. & Strey	tree
Arecaceae	*Raphia farinifera* (Gaertn.) Hyl.	tree
Asparagaceae	*Asparagus aethiopicus* L.	climber
Asparagaceae	*Asparagus africanus* Lam.	shrub
Asparagaceae	*Asparagus asiaticus* L.	shrub
Asparagaceae	*Asparagus falcatus* L.	climber
Asparagaceae	*Asparagus plumosus* Baker	shrub
Asparagaceae	*Asparagus virgatus* Baker	shrub
Asphodelaceae	*Aloe arborescens* Mill.	shrub
Asphodelaceae	*Aloe chabaudii* Schönland var. *chabaudii*	shrub
Asphodelaceae	*Aloe marlothii* A.Berger subsp. *orientalis* Glen & D.S.Hardy	shrub
Asphodelaceae	*Aloe parvibracteata* Schönland	herb
Asphodelaceae	*Aloe rupestris* Baker	tree
Asphodelaceae	*Aloe tongaensis* van Jaarsv.	tree
Asphodelaceae	*Aloe zebrina* Baker	herb
Asteraceae	*Blepharis maderaspatensis* (L.) Roth	tree
Asteraceae	*Brachylaena discolor* DC.	tree/shrub
Asteraceae	*Brachylaena huillensis* O.Hoffm.	tree
Asteraceae	*Chrysanthemoides monilifera* (L.) Norl. subsp. *rotundata* (DC.) Norl.	shrub
Asteraceae	*Chrysocoma mozambicensis* Ehr.Bayer	shrub
Asteraceae	*Crassocephalum bojeri* (DC.) Robyns	herb
Asteraceae	*Distephanus inhacensis* (G.V.Pope) Boon & Glen	tree/shrub
Asteraceae	*Gazania krebsiana* Less. subsp. *krebsiana*	herb
Asteraceae	*Gazania rigens* (L.) Gaertn. var. *rigens*	herb
Asteraceae	*Gerbera ambigua* (Cass.) Sch.Bip.	herb
Asteraceae	*Gnaphalium austroafricanum* Hilliard	herb
Asteraceae	*Helichrysopsis septentrionalis* (Vatke) Hilliard	tree/shrub
Asteraceae	*Helichrysum adenocarpum* DC. subsp. *adenocarpum*	herb
Asteraceae	*Helichrysum glumaceum* DC.	herb
Asteraceae	*Helichrysum kraussii* Sch.Bip.	shrub
Asteraceae	*Helichrysum krookii* Moeser	herb
Asteraceae	*Helichrysum longifolium* DC.	herb

Asteraceae	*Helichrysum silvaticum* Hilliard	herb
Asteraceae	*Hilliardiella aristata* (DC.) H.Rob.	tree/shrub
Asteraceae	*Hilliardiella oligocephala* (DC.) H.Rob.	shrub
Asteraceae	*Pupalia lappacea* (L.) A. Juss.	herb
Asteraceae	*Senecio deltoideus* Less.	herb
Asteraceae	*Senecio helminthioides* (Sch.Bip.) Hilliard	herb
Asteraceae	*Senecio viminalis* Bremek.	shrub
Asteraceae	*Sonchus oleraceus* L.	herb
Asteraceae	*Tridax procumbens* L.	herb
Asteraceae	*Vernonia colorata* Drake subsp. *colorata*	shrub
Asteraceae	*Vernonia poskeana* Vatke & Hildebr.	herb
Balanitaceae	*Balanites maughamii* Sprague subsp. *maughamii*	tree/shrub
Balanitaceae	*Balanites pedicellaris* Mildbr. & Schltr. subsp. *pedicellaris*	tree/shrub
Bignoniaceae	*Fernandoa magnifica* Seem.	tree
Bignoniaceae	*Kigelia africana* (Lam.) Benth.	tree
Bignoniaceae	*Rhigozum zambesiacum* Baker	shrub/small tree
Bignoniaceae	*Tecoma capensis* (Thunb.) Lindl.	shrub
Brexiaceae	*Brexia madagascariensis* (Lam.) Ker Gawl.	tree/shrub
Bromeliaceae	*Ananas comosus* (L.) Merr.	tree/shrub
Burseraceae	*Commiphora africana* (A.Rich.) Engl. var. *africana*	tree
Burseraceae	*Commiphora edulis* (Klotzsch) Engl. subsp. *edulis*	tree/shrub
Burseraceae	*Commiphora harveyi* (Engl.) Engl.	tree/shrub
Burseraceae	*Commiphora neglecta* I.Verd.	tree/shrub
Burseraceae	*Commiphora pyracanthoides* Engl.	tree
Burseraceae	*Commiphora shlechteri* Engl.	shrub
Burseraceae	*Commiphora zanzibarica* (Baill.) Engl.	tree
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	tree/shrub
Cactaceae	*Opuntia monacantha* (Wild.) Haw.	tree/shrub
Cactaceae	*Rhipsalis baccifera* (J.S.Mill.) Stearn subsp. *mauritiana* (DC.) Barthlott	herb
Campanulaceae	*Wahlenbergia undulata* (L.f.) A.DC.	tree/shrub
Canellaceae	*Warburgia salutaris* (G.Bertol.) Chiov.	herb
Capparaceae	*Boscia albitrunca* (Burch.) Gilg & Gilg-Ben.	tree/shrub
Capparaceae	*Capparis tomentosa* Lam.	tree/shrub/climber
Capparaceae	*Cladostemon kirkii* (Oliv.) Pax & Gilg	tree/shrub
Capparaceae	*Cleome angustifolia* Forssk. subsp. *diandra* (Burch.) Kers	climber/liane
Capparaceae	*Maerua angolensis* DC.	tree/shrub
Capparaceae	*Maerua cafra* (DC.) Pax	tree
Capparaceae	*Maerua juncea* subsp. *crustata* (Wild) Wild	tree/shrub
Capparaceae	*Maerua nervosa* (Hochst.) Oliv.	tree
Capparaceae	*Maerua triphylla* A.Rich. var. *pubescens* (Klotzsch) De Wolf	tree/shrub

Capparaceae	*Trilachium africanum* Lour.	tree/shrub
Caryophyllaceae	*Pollichia campestris* Aiton	herb
Caryophyllaceae	*Polycarpea corymbosa* (L.) Lam.	herb
Caryophyllaceae	*Polycarpon prostratum* (Forssk.) Asch. Schweinf.	herb
Caryophyllaceae	*Silene burchellii* Otth ex DC.	herb
Caryophyllaceae	*Spergula arvensis* L.	herb
Casuarinaceae	*Casuarina equisetifolia* L.	tree
Celastraceae	*Allocassine laurifolia* (Harv.) N.Robson	shrub/climber
Celastraceae	*Cassine peragua* L. subsp. *peragua*	tree/shrub
Celastraceae	*Elaeodendron fruticosum* N. Robson	shrub
Celastraceae	*Gymnosporia arenicola* Jordaan	shrub
Celastraceae	*Gymnosporia heterophylla* (Eckl. & Zeyh.) Loes.	shrub
Celastraceae	*Gymnosporia markwardii* Jordaan	shrub
Celastraceae	*Hyppocratea africana* (Willd.) Loes. var *richardiana* (Cambess.) N.Robson	shrub/climber
Celastraceae	*Hyppocratea indica* Willd.	shrub/climber
Celastraceae	*Maytenus procumbens* (L.f.) Loes.	tree
Celastraceae	*Mystroxylon aethiopicum* (Thunb.) Loes. subsp. *schlechteri* (Loes.) R.H.Archer	shrub/small tree
Celastraceae	*Pristimera longipetiolata* (Oliv.) N.Hall	shrub/climber
Celastraceae	*Salacia elegans* Welw. ex Oliv.	shrub
Celastraceae	*Salacia kraussii* (Harv.) Harv.	shrub/liane
Celastraceae	*Salacia leptoclada* Tul.	tree/shrub
Celtidaceae	*Celtis africana* Burm.f.	tree
Celtidaceae	*Chaetacme aristata* Planch.	shrub/tree
Chrysobalanaceae	*Parinari capensis* Harv. subsp. *incohata* F.White	shrub
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	tree
Clusiaceae	*Garcinia livingstonei* T.Anderson	tree
Clusiaceae	*Psorospermum febrifugum* Spach	tree
Colchicaceae	*Gloriosa superba* L.	geophyte//climber
Combretaceae	*Combretum apiculatum* Sond. subsp. *apiculatum*	shrub
Combretaceae	*Combretum butyrosum* (G.Bertol.) Tul.	tree
Combretaceae	*Combretum celastroides* Welw. ex. M.A. Lawson subsp. *orientale* Exell	shrub/climber
Combretaceae	*Combretum hereroense* Schinz subsp. *hereroense*	tree
Combretaceae	*Combretum imberbe* Wawra	tree
Combretaceae	*Combretum microphyllum* Klotzsch	shrub
Combretaceae	*Combretum molle* R.Br. ex G.Don	tree
Combretaceae	*Combretum pisoniiflorum* Engl.	shrub
Combretaceae	*Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels	tree
Combretaceae	*Terminalia sericea* Burch. ex DC.	tree/shrub
Commelinaceae	*Commelina benghalensis* L.	herb
Commelinaceae	*Cyanotis speciosa* (L.f.) Hassk.	herb
Convolvulaceae	*Convolvulus farinosus* L.	herb/climber

Convolvulaceae	*Ipomoea crassipes* Hook. var. *crassipes*	herb
Convolvulaceae	*Ipomoea ficifolia* Lindl.	herb/climber
Convolvulaceae	*Ipomoea pes-caprae* (L.) R.Br. subsp. *brasiliensis* (L.) Ooststr.	herb
Convolvulaceae	*Jacquemontia tamnifolia* (L.) Griseb.	herb/climber
Convolvulaceae	*Merremia tridentata* (L.) Hallier f.	herb/climber
Convolvulaceae	*Stictocardia laxiflora* (Baker) Hallier f.	shrub/climber
Cordiaceae	*Cordia caffra* Sond.	shrub
Cordiaceae	*Cordia subcordata* Lam.	tree
Crassulaceae	*Crassula alba* Forssk.	herb
Crassulaceae	*Kalanchoe paniculata* Harv.	shrub
Cucurbitaceae	*Coccinia rehmannii* Cogn.	herb/climber
Cucurbitaceae	*Corallocarpus bainesii* (Hook.f.) A.Meeuse	tree/shrub
Cucurbitaceae	*Momordica balsamina* L.	herb/climber
Cucurbitaceae	*Zehneria capillacea* (Schumach.) C.Jeffrey	herb/climber
Cyperaceae	*Bulbostylis burchellii* (Ficalho & Hiern) C.B.Clarke	herb
Cyperaceae	*Bulbostylis contexta* (Nees) M.Bodard	herb
Cyperaceae	*Cyperus corymbosus* Rottb.	herb
Cyperaceae	*Cyperus crassipes* Vahl	herb
Cyperaceae	*Cyperus obtusiflorus* Vahl var. *obtusiflorus*	herb
Dichapetalaceae	*Dichapetalum deflexum* (Klotzsch) Engl.	tree/shrub
Dichapetalaceae	*Dichapetalum madagascariense* Poir. var *madagascariense*	tree/shrub
Dioscoreaceae	*Dioscorea buchananii* Benth.	herb/climber
Dioscoreaceae	*Dioscorea hirtiflora* Benth.	herb/climber
Dipsacaceae	*Scabiosa columbaria* L.	tree/shrub
Dracaenaceae	*Sansevieria concinna* N.E.Br.	geophyte
Dracaenaceae	*Sansevieria cylindrica* Bojer ex Hook.	geophyte
Dracaenaceae	*Sansevieria hyacinthoides* (L.) Druce	geophyte
Ebenaceae	*Diospyros dichrophylla* (Gand.) De Winter	tree/shrub
Ebenaceae	*Diospyros inhacaensis* F.White	tree
Ebenaceae	*Diospyros loureiriana* G.Don subsp. *loureiriana*	tree
Ebenaceae	*Diospyros lycioides* Desf. subsp. *guerkei* (Kuntze) De Winter	tree/shrub
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC.	tree
Ebenaceae	*Diospyros natalens*is (Harv.) Brenan subsp. *natalensis*	tree
Ebenaceae	*Diospyros rotundifolia* Hiern	shrub
Ebenaceae	*Diospyros villosa* (L.) De Winter var. *villosa*	shrub/climber
Ebenaceae	*Euclea crispa* (Thunb.) Gürke subsp. *crispa*	tree/shrub
Ebenaceae	*Euclea daphnoides* Hiern	shrub
Ebenaceae	*Euclea divinorum* Hiern	tree/shrub
Ebenaceae	*Euclea natalensis* A.DC. subsp. *natalensis*	tree/shrub
Ebenaceae	*Euclea natalensis* A.DC. subsp. *obovata* F.White	tree/shrub

Ebenaceae	*Euclea racemosa* Murray subsp. *sinuata* F.White	tree/shrub
Ehretiaceae	*Ehretia amoena* Klotzsch	tree/shrub
Ehretiaceae	*Ehretia obtusifolia* Hochst. ex A.DC.	tree/shrub
Ehretiaceae	*Hilsenbergia nemoralis* (Gürke) J.S.Mill	tree/shrub
Ehretiaceae	*Hilsenbergia petiolaris* (Lam.) J.S.Mill.	tree/shrub
Ericaceae	*Erica algida* Bolus	shrub
Erythroxylaceae	*Erythroxylum delagoense* Schinz	shrub
Erythroxylaceae	*Erythroxylum emarginatum* Thonn.	tree/shrub
Euphorbiaceae	*Acalypha caperonioides* Baill. var. *caperonioides*	shrub
Euphorbiaceae	*Acalypha indica* L. var. *indica*	shrub
Euphorbiaceae	*Acalypha petiolaris* Hochst.	herb
Euphorbiaceae	*Alchornea laxiflora* (Benth.) Pax & K.Hoffm.	tree
Euphorbiaceae	*Androstachys johnsonii* Prain	tree
Euphorbiaceae	*Cavacoa aurea* (Cavaco) J.Léonard	tree
Euphorbiaceae	*Croton aceroides* Radcl.-Sm.	tree/shrub
Euphorbiaceae	*Croton gratissimus* Burch.	tree/shrub
Euphorbiaceae	*Croton inhambanensis* Radcl.-Sm.	tree/shrub
Euphorbiaceae	*Croton megalobotrys* Müll.Arg.	shrub
Euphorbiaceae	*Croton pseudopulchellus* Pax	shrub/small tree
Euphorbiaceae	*Croton steenkampianus* Gerstner	shrub/small tree
Euphorbiaceae	*Croton sylvaticus* Hochst.	shrub/small tree
Euphorbiaceae	*Erythrococca berberidea* Prain	tree/shrub
Euphorbiaceae	*Erythrococca menyharthii* (Pax) Prain	tree/shrub
Euphorbiaceae	*Euphorbia bougheyi* L.C.Leach	tree/shrub
Euphorbiaceae	*Euphorbia confinalis* R.A.Dyer	tree
Euphorbiaceae	*Euphorbia cooperi* N.E.Br. ex A.Berger	tree
Euphorbiaceae	*Euphorbia epicyparissias* E.Mey. ex Boiss.	shrub/herb
Euphorbiaceae	*Euphorbia grandidens* Haw.	tree/shrub
Euphorbiaceae	*Euphorbia tirucalli* L.	tree/shrub
Euphorbiaceae	*Euphorbia triangularis* Desf. ex A.Berger	tree/shrub
Euphorbiaceae	*Excoecaria bussei* (Pax) Pax	tree
Euphorbiaceae	*Maprounea africana* Müll.Arg.	tree
Euphorbiaceae	*Sapium integerrimum* (Hochst.) J.Léonard	tree/shrub
Euphorbiaceae	*Schinziophyton rautanenii* (Schinz) Radcl.-Sm	tree
Euphorbiaceae	*Spirostachys africana* Sond.	tree
Euphorbiaceae	*Suregada zanzibariensis* Baill.	tree
Euphorbiaceae	*Tragia okanyua* Pax	herb
Euphorbiaceae	*Uapaca nitida* Müll. Arg. var *nitida*	tree
Fabaceae	*Abrus precatorius* L. subsp. *africanus* Verdc.	climber
Fabaceae	*Abrus fruticulosus* Wight & Arn.	climber
Fabaceae	*Afzelia quanzensis* Welw.	tree
Fabaceae	*Albizia adianthifolia* (Schumach.) W.Wight var. *adianthifolia*	tree

Fabaceae	*Albizia forbesii* Benth.	tree
Fabaceae	*Albizia versicolor* Welw. ex Oliv.	tree
Fabaceae	*Alysicarpus vaginalis* (L.) DC. var. *vaginalis*	herb.
Fabaceae	*Baphia massaiensis* Taub. subsp. *obovata* (Schinz) Brummitt var. *obovata*	tree/shrub
Fabaceae	*Baphia ovata* Sim	tree/shrub
Fabaceae	*Bauhinia burrowsii* E.J.D. Schmidt	tree/shrub
Fabaceae	*Bauhinia petersiana* Bolle subsp. *petersiana*	tree/shrub
Fabaceae	*Bauhinia tomentosa* L.	tree/shrub
Fabaceae	*Bolusanthus speciosus* (Bolus) Harms	tree
Fabaceae	*Brachystegia spiciformis* Benth.	tree/shrub
Fabaceae	*Brachystegia torrei* Hoyle	tree/shrub
Fabaceae	*Burkea africana* Hook.	tree
Fabaceae	*Canavalia rosea* (Sw.) DC.	climber
Fabaceae	*Cassia abbreviata* Oliv.subsp. *bereana* (Holmes) Brenan	tree/shrub
Fabaceae	*Cassia afrofistula* Brenan var. *patentipila* Brenan	tree/shrub
Fabaceae	*Chamaecrista mimosoides* (L.) Greene	herb
Fabaceae	*Chamaecrista paralias* (Brenan) Lock	shrub
Fabaceae	*Cordyla africana* Lour.	tree
Fabaceae	*Craibia zimmermannii* (Harms) Dunn	tree/shrub
Fabaceae	*Crotalaria distans* Benth. subsp. *distans*	shrub
Fabaceae	*Crotalaria dura* J.M.Wood & M.S.Evans subsp. *mozambica* Polhill	shrub
Fabaceae	*Crotalaria monteiroi* Taub. ex Baker f. var. *monteiroi*	shrub
Fabaceae	*Dalbergia melanoxylon* Guill. & Perr.	tree
Fabaceae	*Dalbergia nitidula* Baker	tree
Fabaceae	*Dalbergia obovata* E.Mey.	tree/shrub/climber
Fabaceae	*Desmodium dregeanum* Benth.	shrub/herb
Fabaceae	*Dialium schlechteri* Harms	tree
Fabaceae	*Dichrostachys cinerea* (L.) Wight & Arn. subsp. *africana* Brenan & Brummitt var. *africana*	tree
Fabaceae	*Elephantorrhiza elephantina* (Burch.) Skeels	shrub
Fabaceae	*Entada wahlbergii* Harv.	climber
Fabaceae	*Eriosema parviflorum* E.Mey. subsp. *parviflorum*	shrub
Fabaceae	*Eriosema salignum* E.Mey.	herb
Fabaceae	*Erythrina caffra* Thunb.	tree
Fabaceae	*Erythrina humeana* Spreng.	shrub
Fabaceae	*Erythrina livingstoniana* Baker	tree
Fabaceae	*Erythrophleum lasianthum* Corbishley	tree
Fabaceae	*Guibourtia conjugata* (Bolle) J.Léonard	tree
Fabaceae	*Guilandina bonduc* L.	tree/shrub
Fabaceae	*Indigofera podophylla* Benth. ex Harv.	tree
Fabaceae	*Julbernardia globiflora* (Benth.) Troupin	tree

Fabaceae	*Macrotyloma axillare* (E.Mey.) Verdc.	tree
Fabaceae	*Millettia ebenifera* (Bertol.) J.E.Burrows & Lötter	tree
Fabaceae	*Millettia stuhlmannii* Taub.	tree
Fabaceae	*Mundulea sericea* (Willd.) A.Chev. subsp. *sericea*	tree/shrub
Fabaceae	*Ormocarpum kirkii* S.Moore	tree/shrub
Fabaceae	*Ormocarpum trichocarpum* (Taub.) Engl.	tree/shrub
Fabaceae	*Peltophorum africanum* Sond.	tree
Fabaceae	*Piliostigma thonningii* (Schumach.) Milne-Redh.	tree
Fabaceae	*Pterocarpus angolensis* DC.	tree
Fabaceae	*Rhynchosia angulosa* Schinz	herb
Fabaceae	*Rhynchosia minima* (L.) DC. var. *minima*	herb/climber
Fabaceae	*Schotia brachypetala* Sond.	tree
Fabaceae	*Schotia capitata* Bolle	tree
Fabaceae	*Senegalia burkei* (Benth.) Kyal. & Boatwr.	tree
Fabaceae	*Senegalia kraussiana* (Meisn. ex Benth.) Kyal. & Boatwr.	shrub/climber
Fabaceae	*Senegalia nigrescens* (Oliv.) P.J.H. Hurter	tree
Fabaceae	*Senegalia polyacantha* (Willd.) Seigler & Ebinger subsp. *campylacantha* (Hochst. ex. A.Rich.) Kyal. & Boatwr.	tree
Fabaceae	*Senna bicapsularis* (L.) Roxb.	shrub
Fabaceae	*Senna occidentalis* (L.) Link	shrub
Fabaceae	*Senna petersiana* (Bolle) Lock	shrub
Fabaceae	*Sophora inhambanensis* Klotzsch	shrub
Fabaceae	*Tamarindus indica* L.	tree
Fabaceae	*Tephrosia longipes* Meisn. subsp. *longipes* var. *longipes*	shrub
Fabaceae	*Tephrosia purpurea* (L.) Pers. subsp. *canescens* (E.Mey.) Brummitt	shrub
Fabaceae	*Tephrosia purpurea* (L.) Pers. subsp. *purpurea*	shrub
Fabaceae	*Tylosema fassoglense* (Schweinf.) Torre & Hillc.	shrub/climber
Fabaceae	*Vachellia karroo* (Hayne) Banfi & Galasso	tree/shrub
Fabaceae	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb. var. *kraussiana* (Benth.) Kyal. & Boatwr.	tree
Fabaceae	*Vigna unguiculata* (L.) Walp. subsp. *unguiculata* var. *unguiculata*	herb/climber
Fabaceae	*Xanthocercis zambeziaca* (Baker) Dumaz-le Grand	tree/shrub
Fabaceae	*Xeroderris stuhlmannii* (Taub.) Mendonça & E.P.Sousa	tree/shrub
Fabaceae	*Xylia mendocae* Torre	tree
Fabaceae	*Xylia torreana* Brenan	tree
Flacourtiaceae	*Caloncoba welwitschii* (Oliv.) Gilg	shrub
Flacourtiaceae	*Flacourtia indica* (Burm.f.) Merr.	tree/shrub
Hyacinthaceae	*Ledebouria cooperi* (Hook.f.) Jessop	geophyte

Hypoxidaceae	*Hypoxis argentea* Harv. ex Baker	geophyte
Hypoxidaceae	*Hypoxis filiformis* Baker	geophyte
Hypoxidaceae	*Hypoxis hemerocallidea* Fisch. C.A.Mey. & Av-Lall.	geophyte
Icacinaceae	*Apodytes dimidiata* E.Mey. ex Arn. subsp. *dimidiata*	tree
Iridaceae	*Dietes iridioides* (L.) Sweet ex Klatt	herb
Iridaceae	*Freesia grandiflora* (Baker) Klatt	herb
Iridaceae	*Gladiolus dalenii* Van Geel subsp. *dalenii*	herb
Iridaceae	*Gladiolus grandiflorus* Andrews	herb
Iridaceae	*Lapeirousia erythrantha* (Klotzsch ex Klatt) Baker	herb
Kirkiaceae	*Kirkia acuminata* Oliv.	tree
Lamiaceae	*Clerodendrum capitatum* (Willd.) Schumach.	tree/shrub
Lamiaceae	*Clerodendrum cephalanthum* Oliv. subsp. *swynnertonii* (S.Moore) Verdc.	shrub
Lamiaceae	*Clerodendrum glabrum* E.Mey.	shrub/small tree
Lamiaceae	*Clerodendrum incisum* Klotzsch	shrub
Lamiaceae	*Clerodendrum kentrocaule* Baker	shrub
Lamiaceae	*Clerodendrum pleiosciadium* Gürke	shrub
Lamiaceae	*Clerodendrum robustum* Klotzsch var. *robustum*	shrub
Lamiaceae	*Hoslundia opposita* Vahl	shrub
Lamiaceae	*Lippia javanica* (Burm.f.) Spreng.	shrub
Lamiaceae	*Plectranthus verticillatus* (L.f.) Druce	herb
Lamiaceae	*Vitex doniana* Sweet	tree
Lamiaceae	*Vitex ferruginea* Schumach. & Thonn.	tree/shrub
Lamiaceae	*Vitex harveyana* H.Pearson	tree/shrub
Lamiaceae	*Vitex payos* (Lour.) Merr. var. *payos*	tree/shrub
Lamiaceae	*Vitex payos* (Lour.) Merr. var. *glabrescens* (W.Piep) Moldenke	tree
Lauraceae	*Cassytha filiformis* L.	herb
Liliaceae	*Dipcadi rigidifolium* Baker	shrub
Linaceae	*Hugonia orientalis* Engl.	tree/shrub
Loranthaceae	*Erianthemum dregei* (Eckl. & Zeyh.) Tiegh.	shrub
Lythraceae	*Galpinia transvaalica* N.E.Br.	shrub/small tree
Malpighiaceae	*Acridocarpus natalitius* A.Juss. var. *natalitius*	tree/shrub
Malpighiaceae	*Sphedamnocarpus pruriens* (A.Juss.) Szyszyl. subsp. *pruriens*	shrub/climber
Malpighiaceae	*Triaspis mozambica* A. Juss.	shrub/climber
Malpighiaceae	*Tristellateia africana* S. Moore	tree/shrub
Malvaceae	*Abutilon grantii* A.Meeuse	shrub
Malvaceae	*Adansonia digitata* L.	tree
Malvaceae	*Carpodiptera africana* Mast.	tree
Malvaceae	*Cola natalensis* Oliv.	tree
Malvaceae	*Corchorus junodii* (Schinz) N.E.Br.	climber
Malvaceae	*Dombeya kirkii* Harv.	tree/shrub
Malvaceae	*Gossypioides kirkii* (Mast.) J.B.Hutch.	shrub

Malvaceae	*Grewia bicolor* Juss. var. *bicolor*	shrub
Malvaceae	*Grewia caffra* Meisn.	shrub
Malvaceae	*Grewia hexamita* Burret	tree
Malvaceae	*Grewia microthyrsa* K.Schum. ex Burret	shrub
Malvaceae	*Grewia occidentalis* L. var. *occidentalis*	tree
Malvaceae	*Grewia sulcata* Mast.	tree
Malvaceae	*Hermannia micropetala* Harv.	shrub
Malvaceae	*Hibiscus meyeri* Harv. subsp. *meyeri*	shrub
Malvaceae	*Hibiscus surattensis* L.	shrub
Malvaceae	*Hibiscus tiliaceus* L. subsp. *tiliaceus*	tree/shrub
Malvaceae	*Melhania forbesii* Planch. ex Mast.	shrub
Malvaceae	*Pavonia leptocalyx* (Sond.) Ulbr.	shrub
Malvaceae	*Sida alba* L.	shrub
Malvaceae	*Sparrmannia ricinocarpa* (Eckl. & Zeyh.) Kuntze	shrub
Malvaceae	*Sterculia africana* (Lour.) Fiori var. *africana*	tree
Malvaceae	*Sterculia appendiculata* K. Schum.	tree
Malvaceae	*Sterculia rogersii* N.E.Br.	tree
Melastomataceae	*Dissotis phaeotricha* (Hochst.) Hook. f. var. *phaeotricha*	shrub
Melastomataceae	*Memecylon incisilobum* R.D.Stone & L.G. Mona	tree
Melastomataceae	*Warneckea sansibarica* (Taub.) Jack.-Fél. var *sansibarica*	tree
Meliaceae	*Pseudobersama mossambicensis* (Sim) Verdc.	tree
Meliaceae	*Trichilia capitata* Klotzsch	tree/shrub
Meliaceae	*Trichilia emetica* Vahl subsp. *emetica*	tree
Meliaceae	*Turraea floribunda* Hochst.	tree/shrub
Meliaceae	*Turraea nilotica* Kotschy & Peyr.	tree/shrub
Menispermaceae	*Albertisia delagoensis* (N.E.Br.) Forman	climber/shrub
Menispermaceae	*Cissampelos hirta* Klotzsch	herb/climber
Menispermaceae	*Cissampelos mucronata* A.Rich.	climber
Menispermaceae	*Cissampelos torulosa* E.Mey. ex Harv.	climber
Menispermaceae	*Cocculus hirsutus* (L.) Diels	shrub
Menispermaceae	*Tiliacora funifera* (Miers) Oliv.	climber
Moraceae	*Ficus craterostoma* Warb. ex Mildbr. & Burret	tree
Moraceae	*Ficus exasperata* Vahl	tree
Moraceae	*Ficus natalensis* Hochst. subsp. *natalensis*	tree/shrub
Moraceae	*Ficus polita* Vahl subsp. *polita*	tree/shrub
Moraceae	*Ficus stuhlmannii* Warb.	tree/shrub
Moraceae	*Ficus sycomorus* L. subsp. *sycomorus*	tree
Moraceae	*Ficus verruculosa* Warb.	tree
Moraceae	*Maclura africana* (Bureau) Corner	tree/shrub
Moraceae	*Milicia excelsa* (Welw.) C. Berg	tree
Moraceae	*Morus mesozygia* Stapf ex A.Chev.	tree

Myrtaceae	*Eugenia albanensis* Sond.	shrub
Myrtaceae	*Eugenia capensis* (Eckl. & Zeyh.) Sond. subsp. *capensis*	tree
Myrtaceae	*Eugenia capensis* subsp. *multiflora* Verdc.	tree
Myrtaceae	*Eugenia mossambicensis* Engl.	shrub
Myrtaceae	*Eugenia natalitia* Sond.	tree/shrub
Myrtaceae	*Eugenia* sp. A of Burrows et al., 2018	tree/shrub
Myrtaceae	*Syzygium cordatum* Hochst. ex C.Krauss subsp. *cordatum*	tree
Ochnaceae	*Ochna arborea* burch. ex DC. var *arborea*	tree/shrub
Ochnaceae	*Ochna barbosae* N.Robson	tree/shrub
Ochnaceae	*Ochna natalitia* (Meisn.) Walp.	tree/shrub
Olacaceae	*Olax dissitiflora* Oliv.	tree/shrub
Olacaceae	*Ximenia americana* L. var. *americana*	tree
Olacaceae	*Ximenia caffra* Sond. var. *caffra*	tree/shrub
Oleaceae	*Chionanthus foveolatus* (E.Mey.)	tree
Oleaceae	*Jasminum fluminense* Vell. subsp. *fluminense*	shrub/climber
Oleaceae	*Jasminum meyeri-johannis* Engl.	shrub/climber
Oleaceae	*Jasminum stenolobum* Rolfe	shrub/climber
Oleaceae	*Olea europaea* L. subsp. *africana* (Mill.) P.S.Green	tree/shrub
Orchidaceae	*Acampe pachyglossa* Rchb.f.	herb/epiphyte
Orchidaceae	*Aerangis alcicornis* (Rchb. f.) Garay	herb/epiphyte
Orchidaceae	*Angraecum stolzii* Schltr.	herb/epiphyte
Orchidaceae	*Ansellia africana* Lindl.	herb/epiphyte
Orchidaceae	*Bonatea speciosa* (L.f.) Willd.	herb/geophyte
Orchidaceae	*Cyrtorchis arcuata* (Lindl.) Schltr. subsp. *arcuata*	herb/epiphyte
Orchidaceae	*Cyrtorchis praetermissa* Summerh. subsp. *praetermissa*	herb/epiphyte
Orchidaceae	*Eulophia angolensis* (Rchb.f.) Summerh.	herb
Orchidaceae	*Eulophia cucullata* (Afzel. ex Sw.) Steud.	herb
Orchidaceae	*Eulophia ensata* Lindl.	herb
Orchidaceae	*Eulophia horsfallii* (Bateman) Summerh.	herb
Orchidaceae	*Eulophia longisepala* Rendle	herb
Orchidaceae	*Eulophia odontoglossa* Rchb.f.	herb
Orchidaceae	*Eulophia petersii* (Rchb.f.) Rchb.f.	herb
Orchidaceae	*Eulophia speciosa* (R.Br. ex Lindl.) Bolus	herb
Orchidaceae	*Microcoelia exilis* Lindl.	herb
Orchidaceae	*Mystacidium capense* (L.f.) Schltr.	herb
Orchidaceae	*Mystacidium venosum* Harv. ex Rolfe	herb
Orchidaceae	*Oeceoclades lonchophylla* (Rchb.f.) Garay & P.Taylor	herb
Orchidaceae	*Tridactyle bicaudata* (Lindl.) Schltr.	herb
Orchidaceae	*Vanilla roscheri* Rchb.f.	herb/climber
Orobanchaceae	*Sopubia simplex* (Hochst.) Hochst.	herb

Passifloraceae	*Adenia digitata* (Harv.) Engl.	shrub/climber
Passifloraceae	*Adenia glauca* Schinz	shrub/climber
Passifloraceae	*Adenia gummifera* (Harv.) Harms var. *gummifera*	climber
Passifloraceae	*Basananthe triloba* (Bolus) W.J.de Wilde	shrub/climber
Passifloraceae	*Paropsia braunii* Gilg	herb
Passifloraceae	*Schlechterina mitostemmatoides* Harms	shrub/climber
Pedaliaceae	*Dicerocaryum forbesii* (Decne.) A.E.van Wyk	herb
Pedaliaceae	*Dicerocaryum senecioides* (Klotzsch) Abels	herb
Phyllanthaceae	*Antidesma venosum* E.Mey. ex Tul.	tree
Phyllanthaceae	*Bridelia cathartica* G.Bertol. subsp. *cathartica*	tree/shrub
Phyllanthaceae	*Flueggea verrucosa* (Thunb.) G.L.Webster	tree/shrub
Phyllanthaceae	*Hymenocardia ulmoides* Oliv.	tree
Phyllanthaceae	*Margaritaria discoide*a (Baill.) G.L.Webster var. *fagifolia* (Pax) Radcl.-Sm.	tree
Phyllanthaceae	*Margaritaria discoidea* (Baill.) G.L.Webster var. *nitida* (Pax) Radcl.-Sm.	tree
Phyllanthaceae	*Phyllanthus amarus* Schumach. & Thonn.	herb
Phyllanthaceae	*Phyllanthus fraternus* G.L.Webster	herb
Phyllanthaceae	*Phyllanthus reticulatus* Poir. var. *reticulatus*	tree/shrub
Phyllanthaceae	*Pseudolachnostylis maprouneifolia* Pax var. *maprouneifolia*	tree/shrub
Poaceae	*Andropogon gayanus* Kunth	graminoid
Poaceae	*Aristida congesta* Roem. & Schult. subsp. *congesta*	graminoid
Poaceae	*Aristida stipitata* Hack. subsp. *stipitata*	graminoid
Poaceae	*Cenchrus biflorus* Roxb.	graminoid
Poaceae	*Cenchrus ciliaris* L.	graminoid
Poaceae	*Chloris gayana* Kunth	graminoid
Poaceae	*Cymbopogon excavatus* (Hochst.) Stapf ex Burtt Davy	graminoid
Poaceae	*Cynodon dactylon* (L.) Pers.	graminoid
Poaceae	*Dactyloctenium australe* Steud.	graminoid
Poaceae	*Digitaria ciliaris* (Retz.) Koeler	graminoid
Poaceae	*Digitaria eriantha* Steud.	graminoid
Poaceae	*Diheteropogon amplectens* (Nees) Clayton var. *amplectens*	graminoid
Poaceae	*Eragrostis chapelieri* (Kunth) Nees	graminoid
Poaceae	*Eragrostis ciliaris* (L.) R.Br.	graminoid
Poaceae	*Eragrostis inamoena* K.Schum.	graminoid
Poaceae	*Eragrostis superba* Peyr.	graminoid
Poaceae	*Halopyrum mucronatum* (Linn.) Stapf in Hook.	graminoid
Poaceae	*Heteropogon contortus* (L.) Roem. & Schult.	graminoid
Poaceae	*Hyperthelia dissoluta* (Nees ex Steud.) Clayton	graminoid
Poaceae	*Imperata cylindrica* (L.) Raeusch.	graminoid
Poaceae	*Megastachya mucronata* (Poir.) P.Beauv.	graminoid

Poaceae	*Melinis repens* (Willd.) Zizka subsp. *repens*	graminoid
Poaceae	*Panicum heterostachyum* Hack.	graminoid
Poaceae	*Panicum maximum* Jacq.	graminoid
Poaceae	*Perotis patens* Gand.	graminoid
Poaceae	*Pogonarthria squarrosa* (Roem. & Schult.) Pilg.	graminoid
Poaceae	*Schizachyrium sanguineum* (Retz.) Alston	graminoid
Poaceae	*Setaria incrassata* (Hochst.) Hack.	graminoid
Poaceae	*Setaria sphacelata* (Schumach.) Stapf & C.E.Hubb. ex M.B.Moss	graminoid
Poaceae	*Sporobolus africanus* (Poir.) Robyns & Tournay	graminoid
Poaceae	*Sporobolus pyramidalis* P.Beauv.	graminoid
Poaceae	*Sporobolus subtilis* Kunth	graminoid
Poaceae	*Sporobolus virginicus* (L.) Kunth	graminoid
Poaceae	*Themeda triandra* Forssk.	graminoid
Poaceae	*Trachypogon spicatus* (L.f.) Kuntze	graminoid
Poaceae	*Tristachya rehmannii* Hack.	graminoid
Poaceae	*Urelytrum agropyroides* (Hack.) Hack.	graminoid
Podocarpaceae	*Podocarpus falcatus* (Thunb.) R.Br. ex Mirb.	tree
Polygalaceae	*Carpolobia suaveolens* Meikle	tree
Polygalaceae	*Polygala capillaris* E.Mey. ex Harv. subsp. *capillaris*	herb
Polygalaceae	*Polygala hottentotta* C.Presl	shrub
Polygalaceae	*Polygala producta* N.E.Br.	shrub
Polygalaceae	*Securidaca longepedunculata* Fresen. var. *longepedunculata*	tree/shrub
Polypodiaceae	*Microgramma mauritiana* (Willd.) Tardieu	herb/fern
Portulacaceae	*Portulacaria afra* Jacq.	herb
Ptaeroxylaceae	*Ptaeroxylon obliquum* (Thunb.) Radlk.	tree/shrub
Pteridaceae	*Pelalea viridis* (Forssk.) Prantl	herb/fern
Putranjivaceae	*Drypetes arguta* (Müll.Arg.) Hutch.	tree/shrub
Putranjivaceae	*Drypetes mossambicensis* Hutch.	tree/shrub
Putranjivaceae	*Drypetes natalensis* (Harv.) Hutch. var. *natalensis*	tree
Rhamnaceae	*Berchemia discolor* (Klotzsch) Hemsl.	tree
Rhamnaceae	*Helinus integrifolius* (Lam.) Kuntze	shrub
Rhamnaceae	*Scutia myrtina* (Burm.f.) Kurz	shrub/small tree
Rhamnaceae	*Ziziphus mauritiana* Lam.	tree
Rhamnaceae	*Ziziphus mucronata* Willd. subsp. *mucronata*	tree
Rhizophoraceae	*Cassipourea malosana* (Baker) Alston	shrub/small tree
Rhizophoraceae	*Cassipourea mossambicensis* (Brehmer) Alston	shrub
Rubiaceae	*Afrocanthium lactescens* (Hiern) Lantz	tree
Rubiaceae	*Afrocanthium racemulosum* (S.Moore) Lantz	shrub
Rubiaceae	*Agathisanthemum bojeri* Klotzsch subsp. *bojeri*	shrub
Rubiaceae	*Bullockia setiflora* (Hiern) Razafim., Lantz & B. Bremer	tree/shrub
Rubiaceae	*Canthium inerme* (L.f.) Kuntze	tree/shrub

Rubiaceae	*Catunaregam obovata* (Hochst.) A.E.Gon	tree
Rubiaceae	*Coddia rudis* (E.Mey. ex Harv.) Verdc.	shrub
Rubiaceae	*Coffea racemosa* Lour.	tree/shrub
Rubiaceae	*Coptosperma littorale* (Hiern) Degreef	shrub
Rubiaceae	*Coptosperma nigrescens* Hook.f.	shrub/small tree
Rubiaceae	*Coptosperma supra-axillare* (Hemsl.) Degreef	shrub
Rubiaceae	*Crossopteryx febrifuga* (Afzel. ex G.Don) Benth.	tree
Rubiaceae	*Empogona coriacea* (Sond.) Tosh & Robbr.	shrub
Rubiaceae	*Empogona junodii* Schinz	shrub
Rubiaceae	*Empogona lanceolata* (Sond.) Tosh & Robbr.	shrub
Rubiaceae	*Empogona maputensis* (Bridson & A.E.van Wyk) Tosh & Robbr.	shrub
Rubiaceae	*Gardenia volkensii* K.Schum. subsp. *volkensii* var. *volkensii*	tree
Rubiaceae	*Geophila obvallata* Didr. subsp. *ioides* (K. Schum.) Verdc.	herb
Rubiaceae	*Heinsia crinita* (Afzel.) G.Taylor subsp. *parviflora* (K.Schum. & K.Krause) Verdc.	shrub
Rubiaceae	*Hyperacanthus microphyllus* (K.Schum.) Bridson	shrub
Rubiaceae	*Kraussia floribunda* Harv.	shrub
Rubiaceae	*Lagynias lasiantha* (Sond.) Bullock	shrub
Rubiaceae	*Lagynias monteiroi* (Oliv.) Bridson	shrub
Rubiaceae	*Mussaenda arcuata* Lam. ex Poir.	shrub
Rubiaceae	*Oxyanthus latifolius* Sond.	shrub
Rubiaceae	*Paederia bojeriana* (A.Rich.) Drake subsp. *foetens* (Hiern) Verdc.	shrub/climber
Rubiaceae	*Pavetta catophylla* K.Schum.	tree/shrub
Rubiaceae	*Pavetta gerstneri* Bremek.	tree/shrub
Rubiaceae	*Pavetta gracillima* S.Moore	tree
Rubiaceae	*Pavetta lanceolata* Eckl.	tree/shrub
Rubiaceae	*Pavetta revoluta* Hochst.	tree/shrub
Rubiaceae	*Pavetta schumanniana* F.Hoffm. ex K.Schum.	tree/shrub
Rubiaceae	*Pavetta vanwykiana* Bridson	tree/shrub
Rubiaceae	*Polysphaeria lanceolata* Hiern subsp. *lanceolata* var. *lanceolata*	geoxylic
Rubiaceae	*Psychotria amboniana* K.Schum. subsp. *mosambicensis* E.M.A.Petit.	tree
Rubiaceae	*Psychotria capensis* (Eckl.) Vatke	tree/shrub
Rubiaceae	*Psychotria pumila* Hiern	tree/shrub
Rubiaceae	*Psydrax fragrantissima* (K.Schum.) Bridson	shrub
Rubiaceae	*Psydrax locuples* (K.Schum.) Bridson	tree/shrub
Rubiaceae	*Psydrax moggii* Bridson	tree/shrub
Rubiaceae	*Psydrax obovata* (Eckl. & Zeyh.) Bridson subsp. *obovata*	tree/shrub
Rubiaceae	*Pyrostria bibracteata* (Baker) Cavaco	tree/shrub

Rubiaceae	*Rothmannia fischeri* (K.Schum.) Bullock subsp. *fischeri*	tree/shrub
Rubiaceae	*Rytigynia umbellulata* (Hiern) Robyns	shrub/small tree
Rubiaceae	*Tarenna junodii* (Schinz) Bremek.	shrub
Rubiaceae	*Triainolepis sancta* Verdc.	shrub
Rubiaceae	*Tricalysia capensis* (Meisn. ex Hochst.) Sim var. *capensis*	shrub/small tree
Rubiaceae	*Tricalysia delagoensis* Schinz	shrub
Rubiaceae	*Vangueria infausta* Burch. subsp. *infausta*	shrub
Rutaceae	*Clausena anisata* (Willd.) Hook.f. ex Benth. var. *anisata*	tree/shrub
Rutaceae	*Vepris gerrardii* (I.Vers.) E.J.E.D. Schmidt & J.E.Burrows	tree
Rutaceae	*Vepris lanceolata* (Lam.) G.Don	tree/shrub
Rutaceae	*Vepris reflexa* I.Verd.	tree/shrub
Rutaceae	*Zanthoxylum capense* (Thunb.) Harv.	tree/shrub
Rutaceae	*Zanthoxylum delagoensis* P.G.Waterman	tree/shrub
Rutaceae	*Zanthoxylum leprieurii* Guill. & Perr.	tree/shrub
Salicaceae	*Bivinia jalbertii* Tul.	tree
Salicaceae	*Dovyalis longispina* (Harv.) Warb.	tree/shrub
Salicaceae	*Trimeria grandifolia* (Hochst.) Warb. subsp. *grandifolia*	tree/shrub
Salvadoraceae	*Azima tetracantha* Lam.	shrub
Salvadoraceae	*Salvadora australis* Schweick.	shrub
Salvadoraceae	*Salvadora persica* L. var. *persica*	shrub
Samydaceae	*Casearia gladiiformis* Mast.	tree/shrub
Santalaceae	*Osyris compressa* (P.J.Bergius) A.DC.	shrub
Sapindaceae	*Allophylus africanus* P.Beauv. var. *africanus*	tree
Sapindaceae	*Allophylus natalensis* (Sond.) De Winter	tree/shrub
Sapindaceae	*Allophylus rubifolius* (Hochst. ex A.Rich.) Engl. var. *rubifolius*	tree/shrub
Sapindaceae	*Blighia unijugata* Baker	tree/shrub
Sapindaceae	*Deinbollia oblongifolia* (E.Mey. ex Arn.) Radlk.	tree/shrub
Sapindaceae	*Dodonaea viscosa* Jacq. var. *viscosa*	tree/shrub
Sapindaceae	*Dolichandrone alba* (Sim) Sprague	tree
Sapindaceae	*Filicium decipiens* (Wight & Arn.) Thwaites	tree
Sapindaceae	*Haplocoelum foliolosum* (Hiern) Bullock subsp. *mombasense* (Bullock) Verdc.	tree/shrub
Sapindaceae	*Lecaniodiscus fraxinifolius* Baker subsp. *fraxinifolius*	tree
Sapindaceae	*Macphersonia gracilis* O. Hoffm. var. *hildebrandtii* (O.Hoffm.) Capuron	tree/shrub
Sapindaceae	*Pancovia golungensis* (Hiern) Exell & Mendon	tree/shrub
Sapindaceae	*Pappea capensis* Eckl. & Zeyh.	tree/shrub
Sapotaceae	*Inhambanella henriquesii* (Engl. & Warb.) Dubard	tree
Sapotaceae	*Manilkara concolor* (Harv.) Gerstner	tree

Sapotaceae	*Manilkara discolor* (Sond.) J.H.Hemsl.	tree
Sapotaceae	*Manilkara mochisia* (Baker) Dubard	tree
Sapotaceae	*Mimusops caffra* E.Mey. ex A.DC.	tree
Sapotaceae	*Mimusops obtusifolia* Lam.	tree/shrub
Sapotaceae	*Sideroxylon inerme* L. subsp. *inerme*	tree
Sapotaceae	*Vitellariopsis marginata* (N.E.Br.) Aubrv.	tree
Sinopteridaceae	*Cheilanthes viridis* (Forssk.) Sw. var. *viridis*	herb/fern
Smilacaceae	*Smilax anceps* Willd.	shrub
Solanaceae	*Solanum campylacanthum* A.Rich.	shrub
Solanaceae	*Solanum terminale* Forssk. subsp. *terminale*	shrub/climber
Strychnaceae	*Strychnos decussata* (Pappe) Gilg	shrub/small tree
Strychnaceae	*Strychnos gerrardii* N.E.Br.	shrub/small tree
Strychnaceae	*Strychnos henningsii* Gilg	shrub/small tree
Strychnaceae	*Strychnos madagascariensis* Poir.	shrub/small tree
Strychnaceae	*Strychnos panganensis* Gilg	climber
Strychnaceae	*Strychnos potatorum* L.f.	shrub/small tree
Strychnaceae	*Strychnos spinosa* Lam. subsp. *spinosa*	shrub/small tree
Strychnaceae	*Strychnos usambarensis* Gilg	shrub/small tree
Taccaceae	*Tacca leontopetaloides* (L.) Kuntze	herb
Thymelaeaceae	*Peddiea africana* Harv.	shrub/small tree
Thymelaeaceae	*Synaptolepis oliveriana* Gilg	shrub
Turneraceae	*Tricliceras mossambicense* R.Fern.	herb
Turneraceae	*Tricliceras schinzii* (Urb.) R.Fern.	tree
Verbenaceae	*Chascanum angolense* Moldenke subsp. *zambesiacum* (R. Fern.) R. Fern.	shrub
Verbenaceae	*Lantana camara* L.	shrub
Verbenaceae	*Lantana rugosa* Thunb.	shrub
Violacea	*Rinorea arborea* (Thouars) Baill.	shrub
Vitaceae	*Ampelocissus obtusata* (Welw. ex Baker) Planch. subsp. *kirkiana* (Planch.) Wild & R.B.Drumm.	climber
Vitaceae	*Cissus cactiformis* Gilg	climber
Vitaceae	*Cissus cornifolia* (Baker) Planch.	shrub/climber
Vitaceae	*Cissus integrifolia* (Baker) Planch.	climber/liane
Vitaceae	*Cissus quadrangularis* L. var. *quadrangularis*	climber
Vitaceae	*Cissus rotundifolia* (Forssk.) Vahl var. *rotundifolia*	climber
Vitaceae	*Cyphostemma bororense* (Klotzsch) Desc. ex Wild & R.B.Drumm.	climber
Vitaceae	*Cyphostemma paucidentatum* (Klatt) Desc. ex Wild & R.B.Drumm.	climber
Vitaceae	*Rhoicissus digitata* (L.f.) Gilg & M.Brandt	climber
Vitaceae	*Rhoicissus revoilii* Planch.	climber/liane
Vitaceae	*Rhoicissus tomentosa* (Lam.) Wild & R.B.Drumm.	climber
Vitaceae	*Rhoicissus tridentata* (L.f.) Wild & R.B.Drumm. subsp. *cuneifolia* (Eckl. & Zeyh.) Urton	climber

Xyridaceae	*Xyris anceps* Lam. var. *anceps*	herb
Zamiaceae	*Encephalartos ferox* G.Bertol. subsp. *emersus* Rousseau, Vorster & A.E.van Wyk	shrub
Zamiaceae	*Encephalartos ferox* G.Bertol. subsp. *ferox*	shrub

Appendix B. Summary of the environments of the different vegetation types of the coastal zone of southern Mozambique.

Table 9. Descriptive statistics for the dune environments of the coastal zone of southern Mozambique.

Parameters	**Dune**			
	minimum	**median**	**median absolute deviation**	**maximum**
Altitude (m)	0	28	21	84
Mean Temperature (°C)	22.3	22.8	0.3	23.6
form*	2	5	0	5
Soil organic content (% of DM)	0.3	1.08	0.51	3.7
Soil pH	6.2	7.2	0.82	9.1
Precipitation – driest quarter	87	101	8.9	120
Precipitation – wettest quarter	349	375	10.38	487
Precipitation – annual	856	907	35.58	992
Clay content (%)	0.38	2.27	1.76	7.27
Sand content (%)	34.94	120.1	24.09	140.33
Silt content (%)	7.44	26.72	23.18	111.51

Table 10. Descriptive statistics for the forest environments of the coastal zone of southern Mozambique.

Parameters	**Forest**			
	minimum	**median**	**median absolute deviation**	**maximum**
Altitude (m)	3.9	5.7	0.65	7.8
Mean Temperature (°C)	2.57	108.93	29.36	145.48
form*	2.88	26.48	20.92	90.79
Soil organic content (% of DM)	0.45	3	1.91	11.5
Soil pH	0.03	1.21	0.65	4.59
Precipitation – driest quarter	6	39	20.76	81
Precipitation – wettest quarter	1	5	0	6
Precipitation – annual	21.6	22.5	0.3	23.8
Clay content (%)	675	866	71.16	918
Sand content (%)	320	358	45.96	464
Silt content (%)	51	94	5.93	106

Table 11. Descriptive statistics for the grassland environments of the coastal zone of southern Mozambique.

Parameters	**Grasslands**			
	minimum	**median**	**median absolute deviation**	**maximum**
Altitude (m)	5.3	6.1	0.44	7
Mean Temperature (°C)	38.64	53.5	9.52	112.26
form*	22.22	93.34	17.33	111.68
Soil organic content (% of DM)	7.35	9.35	1.47	11.09
Soil pH	0.26	0.33	0.1	2.31
Precipitation – driest quarter	21	31	8.9	38
Precipitation – wettest quarter	1	1	0	5
Precipitation – annual	22.2	22.3	0	22.4
Clay content (%)	787	889	26.69	907
Sand content (%)	334	369	5.93	373
Silt content (%)	88	105	1.48	112

Table 12. Descriptive statistics for the miombo environments of the coastal zone of southern Mozambique.

Parameters	**Miombo**			
	minimum	**median**	**median absolute deviation**	**maximum**
Altitude (m)	4.5	6.7	0.52	9
Mean Temperature (°C)	86.93	123.23	7.12	138.56
form*	8.25	21.24	7.37	47.17
Soil organic content (% of DM)	2.2	3.25	0.85	13.08
Soil pH	0.16	0.83	0.56	5.99
Precipitation – driest quarter	5	42.5	43.74	191
Precipitation – wettest quarter	1	4	1.48	7
Precipitation – annual	22.5	23.5	0.15	24.2
Clay content (%)	697	837	31.88	990
Sand content (%)	348	461.5	15.57	493
Silt content (%)	32	55.5	10.38	89

Table 13. Descriptive statistics for the savanna environments of the coastal zone of southern Mozambique.

Parameters	Savanna			
	minimum	median	median absolute deviation	maximum
Altitude (m)	5.2	6.4	0.59	8
Mean Temperature (°C)	5.8	103.75	24.34	137.77
form*	3.32	30.01	15.54	72.99
Soil organic content (% of DM)	0.17	5.68	4.73	16.77
Soil pH	0.21	0.81	0.57	3.43
Precipitation – driest quarter	0	44	25.2	156
Precipitation – wettest quarter	1	4	2.97	6
Precipitation – annual	21.5	22.7	0.59	23.6
Clay content (%)	700	836	94.89	982
Sand content (%)	318	386	57.82	488
Silt content (%)	39	88	23.72	117

Table 14. Descriptive statistics for the woodland environments of the coastal zone of southern Mozambique.

Parameters	Woodland			
	minimum	median	median absolute deviation	maximum
Altitude (m)	4.2	6.3	0.74	8.5
Mean Temperature (°C)	52.96	111.34	16.74	145.48
form*	2.88	32.2	12.78	86.79
Soil organic content (% of DM)	0.48	5.06	2.51	9.94
Soil pH	0.01	0.64	0.32	2.71
Precipitation – driest quarter	7	56.5	20.02	136
Precipitation – wettest quarter	1	4	2.97	6
Precipitation – annual	21.6	23.1	0.44	23.7
Clay content (%)	653	781	50.41	940
Sand content (%)	319	355	48.93	457
Silt content (%)	40	54	11.86	105

Appendix C. The Bray-Curtis distance indices for classification of vegetation types

Woody Plants

Distance index (Bray-Curtis)

	1	2	3	4	5
2	0.568				
3	0.977	0.971			
4	0.766	0.73	0.958		
5	0.849	0.803	0.573	0.766	
6	0.76	0.608	0.855	0.727	0.615

Herbaceous Plants

Distance index (Bray-Curtis)

	1	2	3	4	5
2	0.820442				
3	0.9814548	0.9798477			
4	0.9059829	0.7422861	0.9455074		
5	0.8887005	0.9070273	0.749643	0.7323514	
6	0.6731335	0.8124002	0.9180477	0.6978061	0.671774