IDENTIFICATION, MAPPING AND RANKING OF IMPORTANT PLANT AREAS IN OSHANA, OSHIKOTO, OMUSATI AND OHANGWENA REGIONS IN NAMIBIA

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ABSTRACT

The identification of IPAs (Important Plant Areas) has been at the forefront of conservation research in recent years however, there is no recent information on the IPAs in Namibia. Thus, the aim of this study was to identify, map, and rank the IPAs in the study regions using the IPA criteria established by Darbyshire (2017) and validate those demarcated based on expert knowledge (hereafter referred to as preliminary IPAs). New IPAs were identified using the global IPA criteria following Blasi et al. (2011) and Darbyshire et al. (2017). Similarly, preliminary IPAs were validated using the global IPA criteria. IPAs were ranked in terms of their conservation importance using a grid-based ranking system.

QGIS software was used to produce maps for new IPAs. In addition, current protected areas and non-protected areas do not differ significantly in terms of species richness based on this standard scoring method. Consequently, Cluster analysis produced four clusters with 10% similarity in species composition, indicating huge differences in species composition between protected and non-protected areas that satisfy the IPAs criteria. QDS with high conservation scores were identified as the new IPAs instead of the previously demarcated IPAs. This study recommends stakeholders, practitioners, and policymakers to prioritize IPAs that are not in protected areas for conservation. Additionally, this study revealed the effectiveness of identifying and recognizing IPAs using globally standardized IPA criteria and expert-opinion-based selection alone.

KEYWORDS: Important Plant Areas, Preliminary Important Plant Areas, Quarter Degree Square, Identification, Mapping, Ranking, Protected and Non-protected areas.

TABLE OF CONTENTS

TABLE OF FIGURES

ABBREVIATIONS AND ACRONYMS

IPAs Important Plant Areas

CBD Convention on Biological Diversity

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora

CR Critically Endangered

EN Endangered

IUCN World Conservation Union (formerly the International Union for the Conservation of Nature and Natural Resources)

LC Least Concern

MET Ministry of Environment and Tourism

NT Near Threatened

QDS Quarter Degree Square

QGIS Quantum Geographic Information System (software)

R Rare

RL Red List

UNSDGs United Nation Sustainable Development Goals

VU Vulnerable

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DECLARATIONS

I, Emilia Ndapandula Andreas, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

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1. INTRODUCTION

1.1 Background

One-fifth of the world's plant species are currently threatened with extinction and show no signs of recovery (Brummitt et al. 2015; UK 2016; Darbyshire et al. 2017; Plantlife 2018). Plant species are mainly threatened by habitat loss, fragmentation, degradation, overexploitation, invasive species, pollution, and anthropogenic climate change. Sustainable use of plant diversity and restoration has become one of the world's greatest challenges (Ren et al. 2019). To conserve and prevent further loss of plant diversity, the international community implemented various programs, such as the establishment of Important Plant Areas (IPA).

In response to the loss of wild plant species and habitats, Plantlife International has developed the IPA program (Al-Abbasi et al. 2010), inspired by the success of Birdlife International's Important Bird Area concept for promoting targeted birds and wider biodiversity conservation globally (Butchart et al. 2012). The IPA approach has been in use since 2001 and is an internationally proven method for identifying key sites for plant diversity (Darbyshire et al. 2017). The IPA method has been successfully tested in countries with varying degrees of data availability, ranging from data-rich countries such as the UK to relatively data-poor countries such as Egypt (Darbyshire et al. 2017).

An IPA is described as a natural or semi-natural site exhibiting exceptional botanical richness and supporting an outstanding assemblage of rare, threatened, or endemic plant species and vegetation of high botanic value (Anderson 2002). The IPA identification process is led by national constituencies, which use the best available national, regional, and global data in a clear and transparent manner to select and publish national potential IPA networks (Darbyshire 2017). According to Darbyshire (2017) and Plantlife International (2018) there are four globally accepted criteria used in identifying IPAs namely; (a) the use of socially, economically, and culturally valuable plants as a measure of the importance of a site; (b) an increased emphasis on assemblages of range-restricted species and other indicator species of high conservation importance as measures of botanical richness; (c) the inclusion of both nationally and globally threatened habitats as a measure of importance to reflect the varying degree of information held for habitats beyond Europe; and (d) the removal from the IPA criteria of specific references in the absence of specific data or in compliance with regional legislation. A site can qualify as an IPA if it satisfies one or more of the IPA criteria or any combination of these four criteria (Darbyshire et al. 2017).

The IPA criteria can be applied to all organism groups within the plant and fungal kingdoms (Darbyshire et al. 2017). These criteria are aligned with internationally recognized methods of assessing threats to biodiversity, such as the IUCN Red List, which is a powerful tool that uses quantitative criteria, namely: Extinct in the Wild, Critically Endangered, Endangered, and Vulnerable, and Species Threatened with Global Extinction, to assess the conservation status of species (IUCN 2021).

The IPA process is divided into two stages: firstly, identifying IPAs through the development of regional criteria, including establishing IPA national teams, collecting and collating data, creating an IPA database, conducting data analysis, and publishing an IPA list with site descriptions (Hofmeyr 2004). Secondly, the implementation of IPAs includes gaining recognition under existing protected area mechanisms, encouraging the development of incentive schemes, promoting the sustainable use of plant resources, undertaking immediate conservation action, and involving local communities and stakeholders (Hofmeyr 2004). It is not always possible to conserve all IPAs; therefore, potential IPA sites will have to be prioritized (Hofmeyr 2004; Hamidah et al. 2020).

The IPAs approach can be used to assess the importance and effectiveness of existing protected area mechanisms for plant conservation and also highlight gaps in the existing national protected areas, while forming the basis for community-based conservation and sustainable management initiatives for plant resources (Darbyshire et al. 2017). Furthermore, the IPA program supports the implementation of a number of global conservation treaties and initiatives, including the United Nations Sustainable Development Goals, the RAMSAR Convention, the Convention on Biological Diversity (CBD), and the CBD Global Strategy for Plant Conservation (GSPC) (Plantlife International 2004). Thus, national and sub-national engagement in IPA identification is essential, as it provides a primary route towards the long-term conservation of key sites for plant diversity throughout the world (Brodie et al. 2007).

Currently, about 69 nations across the world have initiated or completed IPA identification projects, including Namibia (Plantlife International 2018). Application of the IPA criteria has so far proved to be a popular and successful approach in the identification of sites of importance for plant diversity in Europe, North Africa, and the Middle East (Al-Abbasi et al. 2010). However, its application in southern Africa has been limited due to insufficient fine-scale plant distribution data available at the time (Young 2010).

Namibia is a country located in southern Africa, covering an area of about 823,680 km2, positioned between 17° and 29° South and 11° and 26° East (Barnard 1998; Kangombe 2012). The country is known to be the most arid country south of the Sahara (Liehr 2008). The rainfall increases strongly from west to east and from south to north, which influences the distribution, structure, and type of vegetation in the country (MET 2002; Okitsu 2005). Rainfall has a strong influence on Namibian vegetation, with height decreasing from the north-east and becoming sparser and shorter towards the west and south (Kangombe 2012).

The vegetation in Namibia varies across the country, mainly comprising savanna across the interior, desert in the western and southern parts, and woodland in the north-central and north-eastern parts of the country (Benkenstein, Hengari, & Mbongo 2014). The Namib Desert consists mainly of scattered, non-woody vegetation, mostly herbaceous and succulent plants (Okitsu 2005). The savannas of Namibia consist of different types in the northeastern part of the country and consist mainly of scattered, tall trees. In the central part of the country, the dominant form is tree-shrub savanna, and the Nama-karoo prevails in the southern and southeastern parts of the country (Wessels et al. 2019). One of the dominant species of the woodland's vegetation is Zambezi teak (*Baikiaea plurijuga*) (Okitsu 2005). About 65% of the country's territory is covered by sparsely wooded savannah, while denser woodlands occur in the wettest regions in the north-east, occupying about 20% of total land cover (Okitsu 2005).

Namibia's woodland savannah is part of Southern Africa's wide dryland forests, which are being recognized as valuable assets that play an important role in supporting livelihoods in the region (Benkenstein, Hengari, & Mbongo 2014). Human disturbances such as mining activities, agriculture, and illegal collecting of plant materials are the main activities causing habitat destruction in Namibia (Loots 2005). Namibia is floristically diverse, with several highly distinct taxa of 4030 plant species, of which 602 are endemic and about 23 of them are threatened (Loots 2005).

Namibia is committed to biodiversity conservation as reflected in the Constitution, Article 95 (1). Article 95(1) provides the foundation for the formulation of policies, legislation, and programs aimed at safeguarding the country's biodiversity and ecosystems for the benefit of current and future generations (MET 2010). There are various legal measures in place to protect species and habitats, such as the use of protected areas, national parks, community forests, State forests and community conservancies. However, there is a clear gap in plant protection as plant diversity, including endemic, rare, and threatened species, is not effectively represented in the current protected area network in Namibia (Loots 2005a). These knowledge gaps have implications for conservation planning, as conservation measures outside protected areas may be necessary to complement any legal protection for plant species (Heywood 2019).

Identification, mapping, and ranking of IPAs will assist stakeholders, practitioners, and policymakers in setting conservation priorities that will ensure that plant diversity is effectively represented in the current protected area network in Namibia. The country ratified various international conventions, which include the United Nations Convention on Biological Diversity (UNCBD) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Mulonga 2010). These agreements have been influential in Namibia's efforts to realign its policies and laws, incorporating international best practices in order to effectively manage and conserve the environment (Department of Environmental Affairs 2014). Other related legislation and policies include, but are not limited to: the Environmental Protection and Assessment Bill; the Parks and Wildlife Bill; the Communal and Commercial Lands Acts; the Biodiversity Strategy and Action Plan; and the MET's policy on biodiversity conservation (1992) (Hofmeyr 2004).

In order to meet the national and global plant conservation targets, the National Botanical Research Institute organized the national IPA workshop for Namibia, and a total of 39 IPAs were proposed and circumscribed based on common sense and expert opinion, but not the established criteria (Hofmeyr 2004). The proposed 39 areas were selected as potential IPAs. This study adopts Darbyshire's (2017) definition of Important Plant Areas, which is predicated on the presence of threatened species, botanical richness, threatened habitats, or any combination of them.

IPAs are important not only for the global conservation of plant biodiversity but also for the conservation of wilderness, the preservation of ecosystem services and ecological processes, as well as the conservation of traditional cultural knowledge (Al-Abbasi et al. 2010). According to Watts (2003) and Strohbach (2018), the area under natural forest cover in Namibia has reduced from 15 percent of the overall land area to about 9.8%. Deforestation has escalated progressively in the north-central communal areas of Namibia; thus far, little quantitative information is available on the severity of this form of land degradation. Due to records of deforestation in the study area, reducing deforestation has been placed at the top of the environmental policy priority list by the Namibian authorities (Siiskonen 1996).

Decreasing the loss of plant resources would require a large-scale program that should include demographic, cultural, economic, and environmental components (Naidoo 2011). The IPA program in the study area will restore and conserve threatened and endemic species over time and in as many areas as possible while including demographic, cultural, economic, and environmental components. Thus, this study aimed at ranking and mapping IPAs to detect hotspots for plant diversity in the northern regions (Omusati, Ohangwena, Oshana, and Oshikoto) of Namibia. This study will contribute to the growing body of knowledge under the Threatened Plants Programme being undertaken under the National Botanical Research Institute of Namibia.

1.2 Statement of the Problem

The delimitation of Namibia's 39 potential IPAs was based on the knowledge and experience of experts, and not established global criteria for demarcating IPAs. This resulted in the circumscription of many sites of varying sizes. Typically, IPAs must not be too large, as they would be unmanageable, or too small, as they will fail to achieve adequate coverage for the conservation of the species (Hofmeyr 2004). Additionally, the areas were never accurately mapped, and the validity of these sites was never confirmed using on-site surveys and the IUCN criteria. Consequently, the proposed IPAs cannot be used to conserve plant species or make conservation decisions. The selection of protected areas in many countries is often based on large charismatic animals without a thorough scientific investigation of all biodiversity, including plants (Catullo, Montmollin, and Radford 2011). In addition, many plant species have not undergone a formal assessment of their threat and conservation status worldwide. To date, only about 5% of all plant species have been assessed using IUCN criteria (Bachman et al. 2016 as cited by Darbyshire et al. 2017).

1.3 Objectives

The general aim of this study was to identify, map, and rank the IPAs in the Oshana, Oshikoto, Omusati, and Ohangwena regions using the IPA criteria established by Darbyshire (2017) and validate those demarcated based on expert knowledge (hereafter referred to as preliminary IPAs).

(a) To map and rank IPAs in the northern-central regions using Darbyshire's (2017) IPA criteria.

(b) To validate the preliminary IPAs in the selected regions based on the IPA criteria established by Darbyshire (2017).

(c) To compare the plant species composition between IPAs in protected and non-protected areas.

1.4 Significance of the study

The introduction of the IPA identification projects provides data on threatened species and habitats, which has great potential to improve the conservation assessments for plant species in Namibia. Identification and mapping of IPAs provides a basis for the Namibian government and other countries throughout the world to achieve a series of biodiversity targets under international agreements and legislation, such as the CBD, Aichi Biodiversity Targets, Ecosystem Approach, and SDGs. Target 5 in the CBD Global Strategy for Plant Conservation (GSPC), which calls for the protection of 50%

of the most important areas (Anderson 2002), In addition, the IPA program contributes to Goal 1.1 of the CBD program of working on protected areas, particularly the rapid identification of biodiversity-rich sites that are not within current protected areas but that require urgent conservation protection (Al-Abbasi et al. 2010). The establishment and mapping of IPAs will assist stakeholders, practitioners, and policymakers in setting conservation priorities for these areas and other areas with a similar set of socio-economic and environmental situations.

2. LITERATURE REVIEW

The identification of IPAs has been at the forefront of conservation research in recent years. IPAs represent a practical and proven approach to national plant conservation (Darbyshire et al. 2017). Plantlife International has played an important role in research development for IPA identification (Anderson 2002; Darbyshire et al. 2017; Tojibaev et al. 2022) and establishment. Currently, there are programs and initiatives in place for IPAs in many countries, including Egypt, the Arabian Peninsula, Asiatic Russia, Lebanon. (Tojibaev et al. 2022). According to Darbyshire et al. (2017), conservation efforts targeting plant diversity are often hindered by a lack of suitable data (Southern Africa) for prioritizing conservation action, and as a result, plant species are not well managed in national conservation planning systems.

2.1 Progress to date on IPA identification

The establishment of IPAs has been successfully introduced in Europe, and other countries have since shown an interest in the IPA program (Smith & Smith 2005). The IPA network identification projects have since been carried out on small islands, in large, diverse countries, and in both data-rich and data-poor regions (Plantlife 2018). In 2004, a series of IPA workshops were held for the southern Africa region (African countries: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe) as part of the Southern African Botanical Diversity Network program (Smith & Smith 2005). A modified set of criteria suitable for regional use was developed during this workshop, and a series of country-specific workshops were held, including in South Africa (Smith 2005). It was later realized that inadequate plant distribution data were available at the time to allow practical implementation of the IPA process in these countries (von Staden and Lotter 2015). Namibia plant distribution data have improving through the IUCN Global Red List, the Namibia Biodiversity Database, and the Red Data Book of Namibian Plants.

The IPA assessment process has two steps (Darbyshire et al. 2017). The first step in the IPA program is identifying all potentially qualifying sites that meet one or more of the IPA criteria (according to Anderson (2002) and Darbyshire et al. (2017)) and associated thresholds, called preliminary IPAs. The IPA criteria are used to identify potential IPA sites across all countries in the world. The most common practical challenges in identifying IPAs involve: easily accessible data for species and habitats; the need for red lists at the national and regional level; the definition of practical boundaries; and the number and size of IPAs (Anderson 2002; Blasi et al. 2011). Incomplete and spatially biased databases may have a negative impact on conservation planning (Blasi et al. 2011).

The second step is to involve other key stakeholders, including protected area managers, decision-makers, community groups, and individuals living in or around IPAs, as well as school and college teachers, to create awareness for IPA conservation. This initiative encourages participation, data accumulation, a sense of ownership of the resources, and the long-term conservation of IPA sites (Tojibaev 2022).

Initially, IPAs are not designated as legal sites, but they can be conserved by developing a national IPAs and protected area framework, preferably with a wide range of stakeholders, including botanical specialists, protected area specialists, community groups, and local and national government representatives (Darbyshire et al. 2017; Plantlife 2018). The realization of an IPA program will be determined by whether or not it leads to the conservation of plants and habitats in the future (Plantlife 2010). The IPA selection highlights areas of botanical richness and threatened habitats. However, management measures and monitoring are needed to prioritize actions and determine if there is positive or negative change in IPAs over time (Plantlife 2018).

2.2 The IPA criteria

The IPA criteria are designed to be applicable not only to vascular plants but to other organisms such as algae, hornworts, lichens, liverworts, mosses, and fungi (Darbyshire et al. 2017). The IPA criteria are aligned with internationally recognized measures of threat to biodiversity, notably the IUCN Red List of Threatened Species (2012). The identification of an IPA site should be based on sound data available and take into consideration the important role of peer-reviewed expert opinion at the national and regional level. According to Anderson (2002), Blasi et al. (2009, 2011) and Darbyshire et al. (2017), a site can qualify as an IPA if it satisfies one or more of the following global IPA criteria;

Criterion A: threatened species- populations of the most threatened plant qualifying species must be listed as threatened; "vulnerable (VU), endangered (EN) or critically endangered (CR)", on the IUCN global Red List or another regionally approved, peer-reviewed threat list, for example species of high socio-economic importance. Criterion B: botanical richness- selecting sites that contain high concentrations of species that indicate either high-quality habitat and/or species-rich sites and national endemic species or national Red List species not covered by criterion A. Criterion C: threatened habitat- selecting natural or semi-natural habitats that are severely declining and may once have been common.

According to Myers et al. (2000), endemics indicate higher vulnerability than other criteria, and as a result, they have been used as surrogate elements to identify the priorities for conservation. The majority of the South and East Mediterranean Region's richest sites for locally endemic species are existing national parks, such as Ifrane National Park (196) and Toubkal National Park (164) (Catullo, Montmollin, & Radford 2011). There is, however, little evidence that national parks are supported by well-structured management regimes or that plants and vegetation are taken into account (Darbyshire et al. 2017).

2.3 IPAs prioritizing and post-identification programmes

After identifying all potentially qualifying sites that meet one or more of the IPA criteria and associated thresholds, the national IPA constituency should reassess and rank the identified IPAs to select from amongst these the most important sites, considering the full range of considerations for identifying an effective network of sites (Darbyshire et al. 2017). Prioritizing IPAs has been practiced in many countries. In Morocco, a total of 57 IPAs has been identified, of which only five have been selected as priorities for conservation measures (Catullo, Montmollin, & Radford 2011). Twenty-one (21) IPAs have initially been identified for northern Algeria, and only five IPAs have been prioritized for conservation measures (Catullo, Montmollin, & Radford, 2011). Thirteen IPAs have been identified in Tunisia, and only six were prioritized for conservation measures (Catullo, Montmollin, & Radford 2011). Identifying and prioritizing IPA sites is a major process, but it is only one step in the long-term conservation of these sites, species, and habitats (Plantlife 2018).

Countries such as Belarus, Romania, and Croatia have integrated potential IPA networks into their national conservation planning and monitoring schemes

(Plantlife International 2010, as cited by Darbyshire et al. 2017). In the UK, Plantlife uses the IPA networks as the basis for its plant conservation program, including the targeting of species, habitat, and site management, raising public awareness, engaging land managers, and influencing legislation and policy (Plantlife 2018). Countries such as Turkey established a network of trained volunteers responsible for species monitoring and raising awareness of the critical IPAs (Darbyshire et al. 2017; Royal Botanic Gardens 2016). Currently, aside from the results of the IPAs workshop held in 2004, which is stage 1, there is no recent information on the IPAs in Southern Africa.

2.4 Protected areas versus non-protected areas

The questions regarding the effectiveness and conservation efforts of plant species in protected areas are still open in many countries (Vellak et al. 2010). The establishment of protected areas in many countries has not always been linked to plant diversity protection (Hofmeyr 2004; Deguise & Kerr 2006; Vellak et al. 2010). In addition, when IPAs are located within protected areas, their botanical value may not be well known by site managers or visitors or be included in the management plan for the site's conservation (Plantlife 2018). The IPAs program is an additional contribution to the existing protected areas system because there are gaps in plant species representation in the existing protected areas system. IPAs that fall entirely or partially within existing protected areas do not necessarily have to match the size or boundary of that protected area (Darbyshire et al. 2017). IPAs provide a framework to assess the effectiveness of conservation activities for plants and target sites for future conservation action in areas without legal protection (Darbyshire et al. 2017). Conservation measures in non-protected areas should be taken quickly, as these natural areas are facing imminent threats from unregulated development, overexploitation, and exotic species. There are many non-protected regions with important plant diversity, and botanical surveys must be urgently conducted to promote conservation priorities (Dagher-Kharrat, Zein, & Rouhan 2018).

2.5 IPA program in Namibia

The IPA program is in its initial phase in Namibia. The identification of the preliminary IPA sites was done using available physical features such as roads, rivers, and mountain ranges, or range boundaries of vegetation types as boundaries (Hofmeyr 2004). Each provisional IPA was made up of more than one QDS. Currently, aside from the results of the IPAs workshop held in 2004, which is stage 1, there is no recent information on the IPAs in Namibia. Namibia is one of the countries highlighted in pale green on the global IPA map (Figure 1), which means that there is resource limitation that is the primary reason for limited or delayed progress in IPA identification in some of the countries (Darbyshire et al. 2017). There has not been ongoing monitoring of the preliminary IPA sites in Namibia.

Not all the identified IPAs will become protected areas since available resources for such actions are limited; therefore, this study ranked and mapped the important plant areas so that limited resources can be targeted effectively (Walsh et al. 2019). The next step of the program is to raise awareness of these sites through mapping, publications, and workshops (Al-Abbasi et al. 2010). Mapping is a first step in sharing IPA data with different audiences to influence the conservation, management, and protection of IPAs. A high-precision map of IPAs produced by IPA studies could be used as a decision tool for stakeholders, practitioners, and decision-makers involved in plant conservation (Dagher-Kharrat 2018).

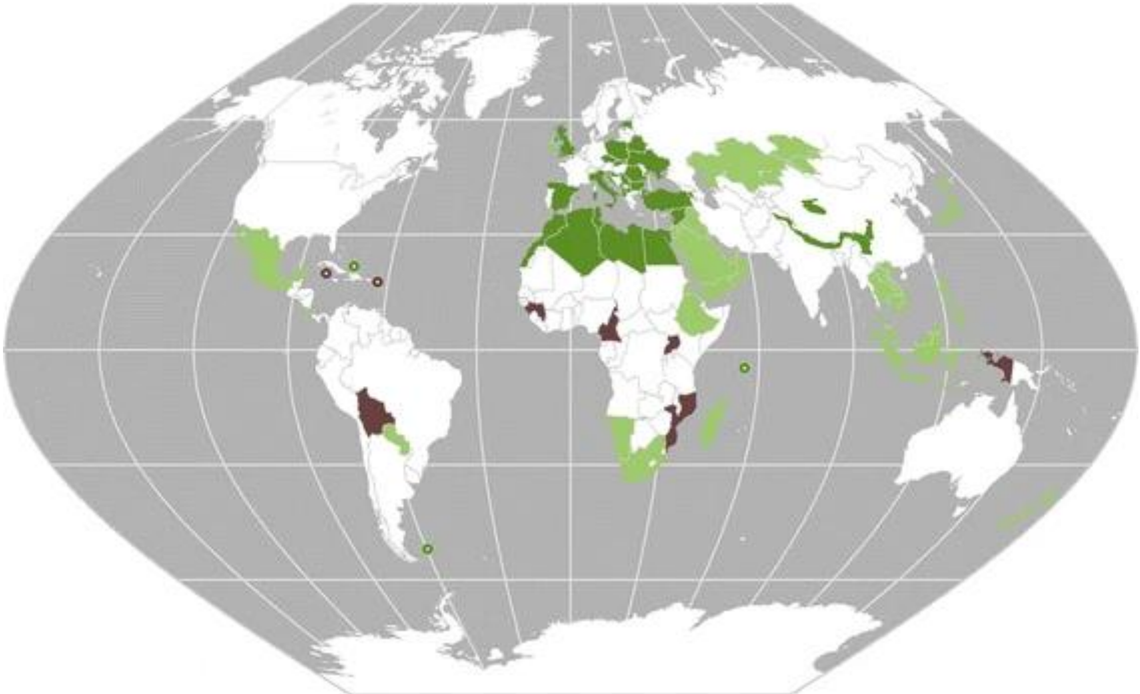

Figure 1: Countries and regions of the world with an IPA programme. Dark green indicate IPAs identified and documented, pale green IPA programme initiated but sites not fully documented (Namibia), dark brown tropical IPAs programme (Adapted from Anderson et al. (2016), as cited by Darbyshire et al. 2017).

3. MATERIAL AND METHODS

3.1 Study Area

The central-northern Namibia consists of 4 regions and it borders Angola in the North, Kavango Region in the east, and Kunene Region in the West (Figure 2). It is home to an approximately 43% of the country’s population, a large proportion of which still depends directly on plant resources for their livelihoods (Kangombe 2012). As a result, large areas of natural vegetation have been cleared for cultivation, and most of the trees have been cut down for building and fencing looming material, leading to severe deforestation (Fujioka 2005). Desertification is a definite hazard over part of the study area. No proclaimed conservation areas exist in most parts of the regions, such as Oshana, Omusati, and Ohangwena. Due to the loss of wildlife habitat and heavy hunting pressure, only a small population of wildlife survived. The IPA will assure the survival and restoration of not only plant diversity but all of the living organisms and their habitat.

Central-northern Namibia comprises a large portion of the Kalahari sand basin and encompasses approximately 5.2 million hectares of land (Hangula 1998; Kangombe 2012). The central region is intersected by a network of seasonal wetland, locally known as "oshanas," which refer to shallow water courses that comprise the Cuvelai Delta (Yoshinori et al. 2016). Oshanas are recharged by flood waters that flow from the Angolan highlands as well as water from heavy rainfalls that are occasionally experienced in this part of the country (Tony et al. 1992; Kangombe 2012; Shaamhula 2021).

The sand dunes and shallow water courses known as omiramba dominate the southern part of central-northern Namibia (Erkkila & Sisskonen 1992). The soils in central-northern Namibia were deposited by wind and water, and a large proportion of them are classified as arenosols

or sandy soils (Erkkila & Siiskonen 1992; Kangombe 2012). The soils of these regions have low fertility as there is little organic matter that is returned to the soil (Yoshinori et al.2016; Fujioka et al. 2018) yet, the soils support a high suitability for crop cultivation (Kangombe 2012; Prudat, Bloemertz, & Kuhn 2018).

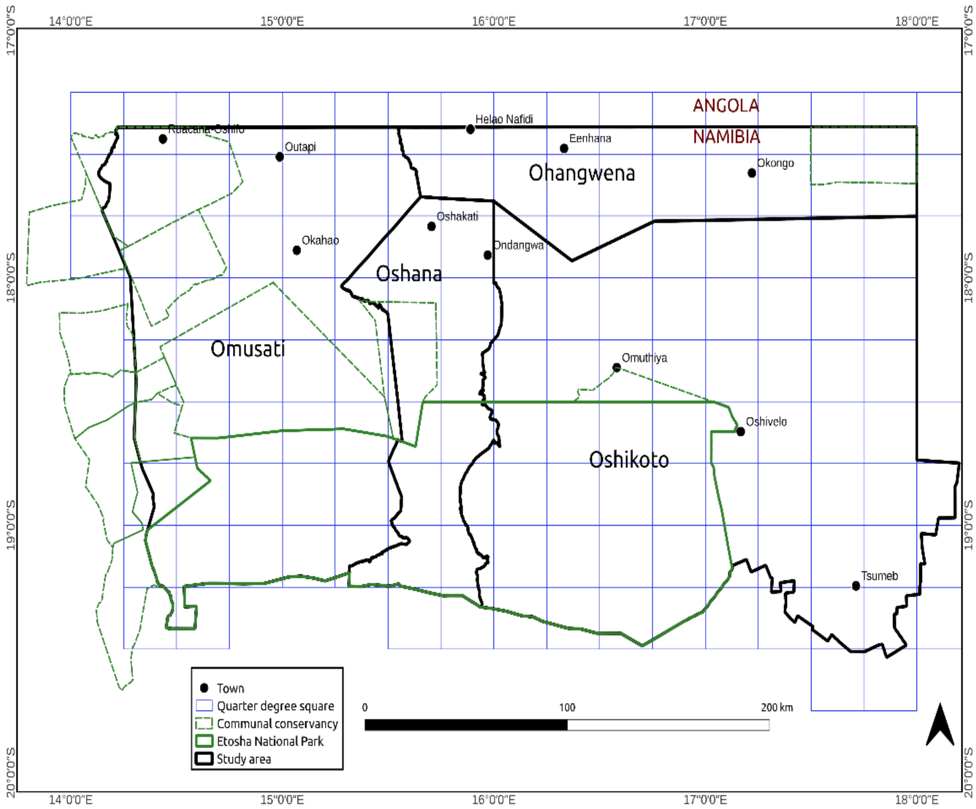

Figure 2: Namibian maps (a) with the 4 central-northern regions Omusati, Oshana, Ohangwena, and Oshikoto(the map was produced using the QGIS software).

The region is semi-arid, the annual average rainfall varies from 550–600 mm in the north-east and around Tsumeb to 250–300 mm per year in the drier south-western parts around Etosha (Kangombe 2012; Beyer et al. 2015; Awala et al. 2019). The temperature in central-northern Namibia varies greatly, with hot summers (average temperature 37.5 ^{o}C) and cold winters, with night temperatures dropping to freezing and day temperatures rising to 27 ^{o}C (Kangombe 2012).

About 43% of the Namibian population resides in these regions (Oshikoto, Oshana, Ohangwena, and Omusati), of which a large proportion still depends directly on natural resources for their livelihoods (Kangombe 2012). Ovambo agro-pastoralists (largest tribal group) primarily inhabit most of this region, and they use several tree species for various purposes (building materials and firewood), which led to changes in the vegetation structure of this region (Fujioka 2005). The vegetation can be classified into five major associations: mixed woodland of the deep aeolian sands; the palm tree savanna; mopane woodland and mopane savanna; *Sclerocarya ficus* savanna; and various scrub mopane-acacia (Yoshinori et al. 2016). The vegetation has been considerably disturbed in this area due to a high population density **(**Strohbach 2001**).**

The northern and central Namibia areas are all on heavily used communal land, and the only management there is communal (Byers 1997). Such as community forests areas within the communal lands of Namibia where community members have been granted legal community forest rights from the government and managed in a sustainable way by local communities in order to protect forest and tree resources and improve livelihoods (Parviainen 2012; Benkenstein et al. 2014). The government involves local people by giving community members management rights and benefits to the use of forest resources it gives a feeling of ownership (SCHuSSER 2012).

Etosha National Park, which covers an area of 22,800 km^2, is one of the largest wildlife reserves in the world, situated in northern Namibia (Sannier, Taylor, and

Plessis 2002). The Park is occupied by a large saline desert called the Etosha Pan, which covers about 25% of the area (Nakanyala, 2012). The Etosha climate is semi-arid, with an increasing average rainfall of 250 mm in the West and 400 mm in the East (Engert 1997). The summer temperatures range between a minimum of around 18 °C and a maximum of 35 °C, while temperatures in the winter range between 6 °C and 25 °C, respectively (Du Plessies, Bredenkamp and Trollope, 1998 as cited by Nakanyala, Hipondoka, & Graz 2015).

The Park is located at the intersection of three major biotic zones: the southern savannah woodland, the southwest arid zone, and the northern Namib Desert (Heydinger 2022). The park's soils are dominated by ascalcaric regosols, lithic arenosols, and molluscan lep-tesols, which are influenced by the underlying geology and aeolian and fluvial processes (Beugler-Bell & Buch 1997; Nakanyala, Hipondoka, & Graz 2015). Park can be subdivided into three distinct biomes: woodlands located in the far west and southeast portions of the park, open grassland plains, and a hypersaline pan where only extremophiles can live permanently (Heydinger 2022).

The relatively high temperatures, low rainfall, and poor soils largely determine the vegetative growth (Le Roux et al. 1998). The vegetation consists of grass and steppe, which grow mainly surrounding the pan and form very important grazing areas for game (Sannier, Taylor, & Plessis 2002). The tree cover in the savanna broadly follows the rainfall gradient, with the highest density in the north and east and decreasing towards the west, although there can be considerable local variation (Sannier, Taylor, & Plessis 2002).

Currently, there are five preliminary IPAs in the northern-central region, namely: Ekuma grassland, Cuvelai drainage, Kavango woodland, Omuramba Owambo, and Otavi mountains (figure 3). The delimitation of preliminary was based on the knowledge and experience of experts, and not established global criteria for demarcating IPAs, and the validity of these sites was never confirmed using on-site surveys and the global IPA criteria.

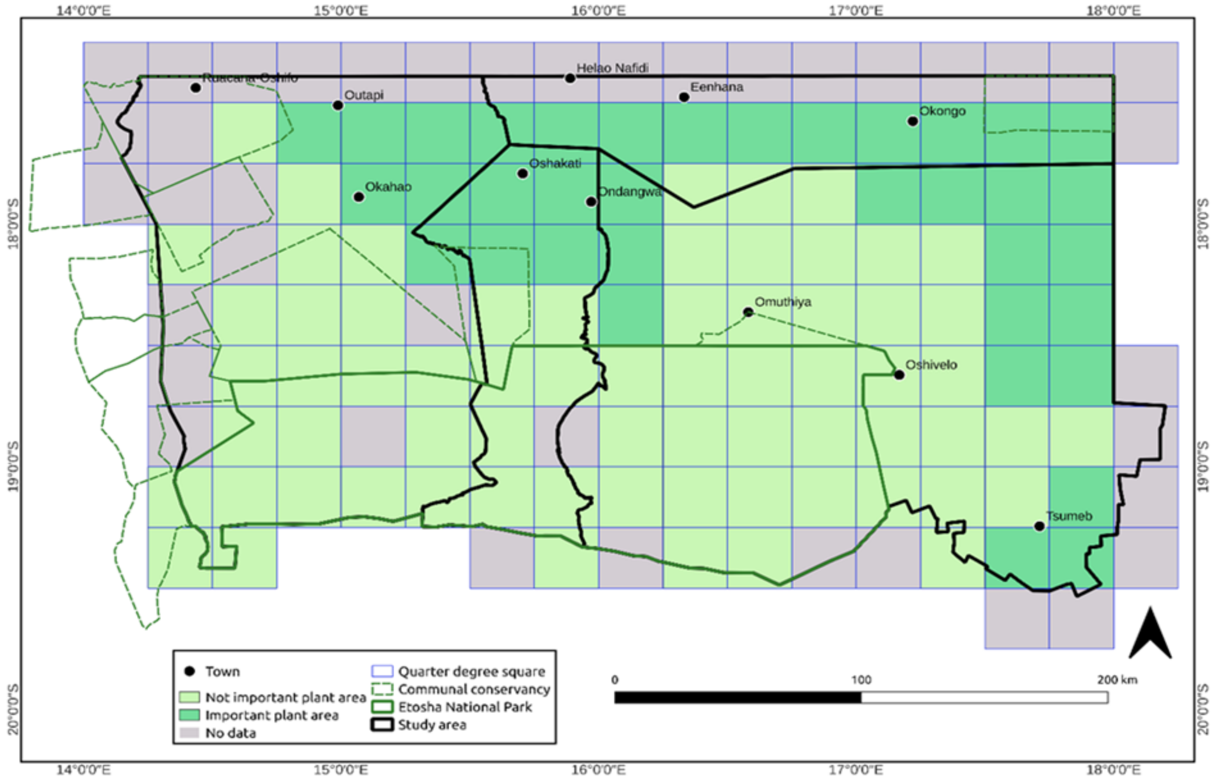

Figure 3: The map showing the QDS of the five preliminary IPAs in the study area (Oshana, Oshikoto, Omusati, and Ohangwena). Dark green color indicates QDS in preliminary IPAs, light green indicates not Preliminary IPAs, and white cells represent areas that contained no data.

3.2 Procedure

The data for plant species in each QDS was obtained from the Botanical Research and Herbarium Management System (BRAHMS) database at the Namibian National Herbarium. A total of 1557 plant species have been recorded by BRAHMS for the Central-northern Namibia. Each plant species in each QDS was identified as threatened or endemic using the IUCN Global Red List (Figure 4), the Namibia Biodiversity Database, and the Red Data Book of Namibian Plants. The IUCN Red List is an important tool for guiding IPA identification and conservation (Williams 2009), and it provides an internationally recognized conservation status assessment of a species.

To assist with the selection/ identification of IPAs, the regions were divided into QDS, which translates into blocks of approximately 27 km by 27 km. Since there is no fixed size for an IPA, it is recommended that the area be small enough to be conserved while at the same time adequate to support a sustainable population of plant species (Dagher-Kharrat, Zein, & Rouhan 2018; Plantlife 2018). This study considered the quarter-degree square (QDS) grid cells (27 km x 27 km) to be the size of an IPA, as they are small in size but sufficient to support a large population of plant species and other organisms. According to Craven and Vorster (2006), QDS are manageable, and sufficient information at that scale is available for Namibia.

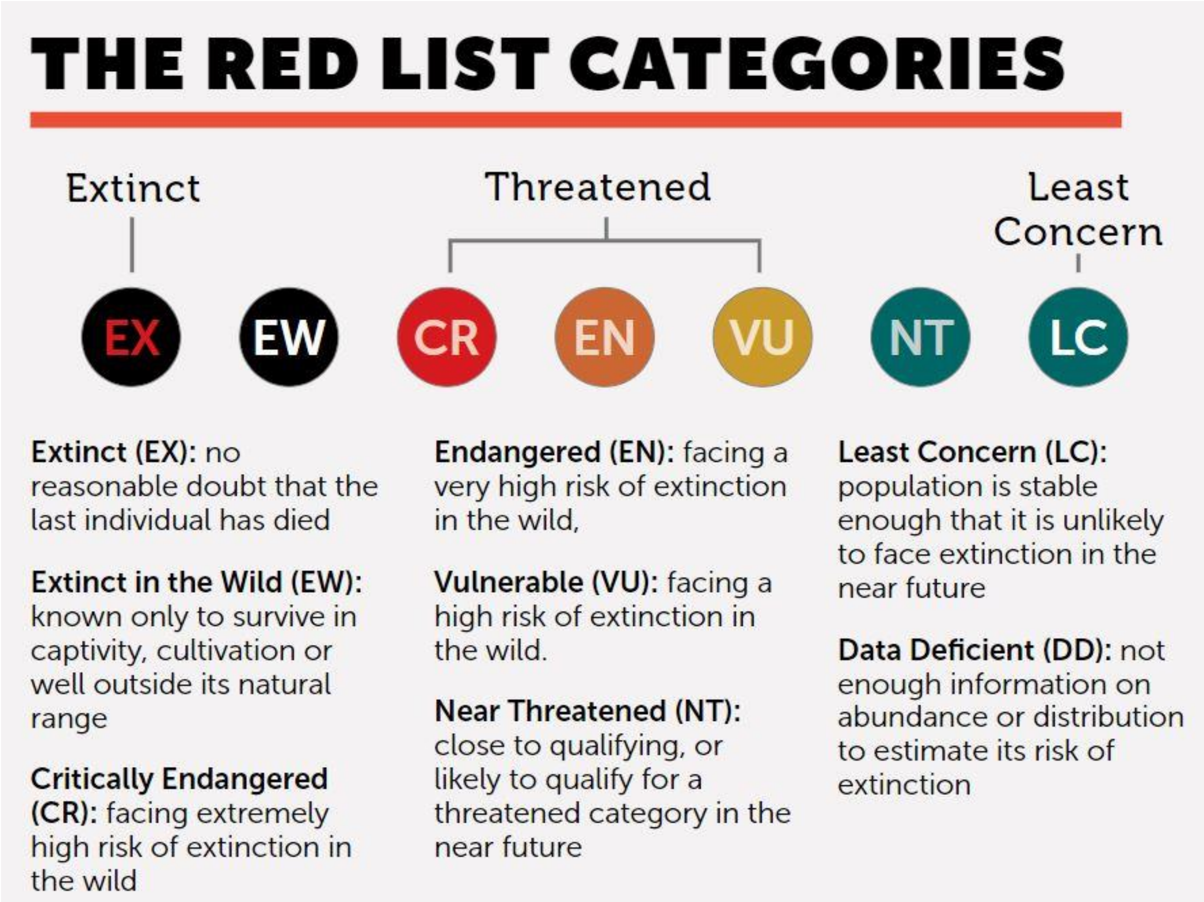

Figure 4: The IUCN red list criteria used in determining conservation status for plant species (World Environment Day 2020).

3.21 IPA site identification

The global IPA criteria following Blasi et al. (2011) and Darbyshire et al. (2017) was used to select IPA sites. However, only criteria A (the site holds one or more threatened species) and B (Centers of endemism and species richness the site has an exceptionally rich flora in relation to its biogeographic zone) were used to identify IPA sites in this study. Criteria C (a threatened habitat or an outstanding example of a habitat type) could not be used due to lack of relevant habitat data. Species richness in this study refers to the number of species within a QDS. The QDS with no species observation were not considered in this study. The presence of one or more IPA criteria in a QDS qualifies it to become an important plant area.

3.22 IPA sites ranking

IPAs were ranked using the standard scoring procedure or ranking system (Marignani & Blasi (2012), Walsh et al. (2019), and Hamidah (2020). A standard scoring procedure involves the assignment of conservation values based on three criteria: species richness, the presence of threatened species, and endemism. This scoring procedure has been widely used in IPA identification to provide an easy-to-understand procedure for stakeholders, practitioners, and politicians involved in the conservation of plant resources at the national and regional level (Blasi et al. 2011). This scoring procedure is also used as a means of identifying the most important areas for plant diversity at the national level (Marignani & Blasi 2012). An endemic species in this study is defined as a species that is restricted to within the borders of Namibia, while species that spread slightly into another country are referred to as near-endemic (Craven & Vorster 2006).

This study therefore adopted the scoring method as follows: Criteria A was based on the number of threatened plant species (CR, EN, and VU (Figure 4)) in each QDS. Each threatened species was given a value of 1. Criteria B1 was based on species richness and calculated as the total number of species in each QDS. Each QDS was assigned a richness class and value (given in brackets): more than 100 taxa, especially rich (4); 51 to 100 species, rich (3); 11 to 50 species, moderately rich (2); 1 to 10 species, poor (1). Criteria B2 was based on the number of species that are endemic or near-endemic to Namibia in each QDS. Species listed as endemic to Namibia were given a value of 3, and those that are near endemic to Namibia have a value of 2. Each QDS was assigned a value for the three criteria, and the sum of the three values for each criterion (A+B+C) was calculated for each QDS to give the total conservation score. The final ranking of the QDS is obtained by combining the conservation scores and mapping the QDS into ranges. The total score for each QDS was put into intervals of low ranking, medium ranking, and high ranking.

The dataset was analysed to produce a plant species richness map, an endemic plant species map, an important QDS and non-important QDS map, and a total score map. All maps were produced using the QGIS software.

3.3 Data analysis

Shapiro-Wilk Test was used to test for the normality of all the conservation score data (endemic scores, species richness scores, and total scores). The Mann-Whitney U test was used to compare conservation scores (endemic scores, species richness scores, and the total scores) for IPAs in protected areas (Etosha National Park) and non-protected areas to determine whether the current protected include IPAs. A standard scoring technique was used in ranking Quarter Degree Squares (QDS) for their conservation importance. A presence-and-absence data matrix using the Hierarchical Cluster Analysis (HCA) based on the Bray-Curtis measure was used to determine the percentage similarity in species composition between protected areas and non-protected areas. QDS without a specimen's record were excluded from the analysis.

4. RESULTS

4.1 Identification of IPAs in the selected regions

About 71% of the total QDS qualified as IPAs in the selected regions based on the global IPA criteria (Figure 5b). The qualified QDS as IPAs fell in both protected areas such as Etosha National Park and communal conservancies as well as in non-protected areas.

Species richness values ranged between 1 and 267 plant species per QDS. 20% of the QDS had richness values for species ranging from 1 to 10 species, whereas 33% of the QDS had values ranging from 11 to 50 species, 15% of the QDS had values ranging from 51 to 100 species, and the remaining 7% had richness values for more than 100 plant species.

The highest concentration of endemic species was found around Etosha National Park, the Tsumab area, and the Outapi area. The number of endemic species ranges from 5 to 23 in the QDS with high endemic species. The final ranking of the QDS, obtained by combining the conservation scores (Figure 5a), detected 15% top-ranking QDS, 17% medium-ranking QDS, and 68% low-ranking QDS.

Of the 71% of QDS identified as IPAs, only 27% formed part of the five preliminary IPAs as crudely demarcated by Hofmeyr (2004). All the preliminary IPAs had QDS with records of vulnerable plant species, and 16% had records of threatened species, compared to Etosha National Park, which had only 3 QDS with endangered species and 1 QDS with a vulnerable species record.

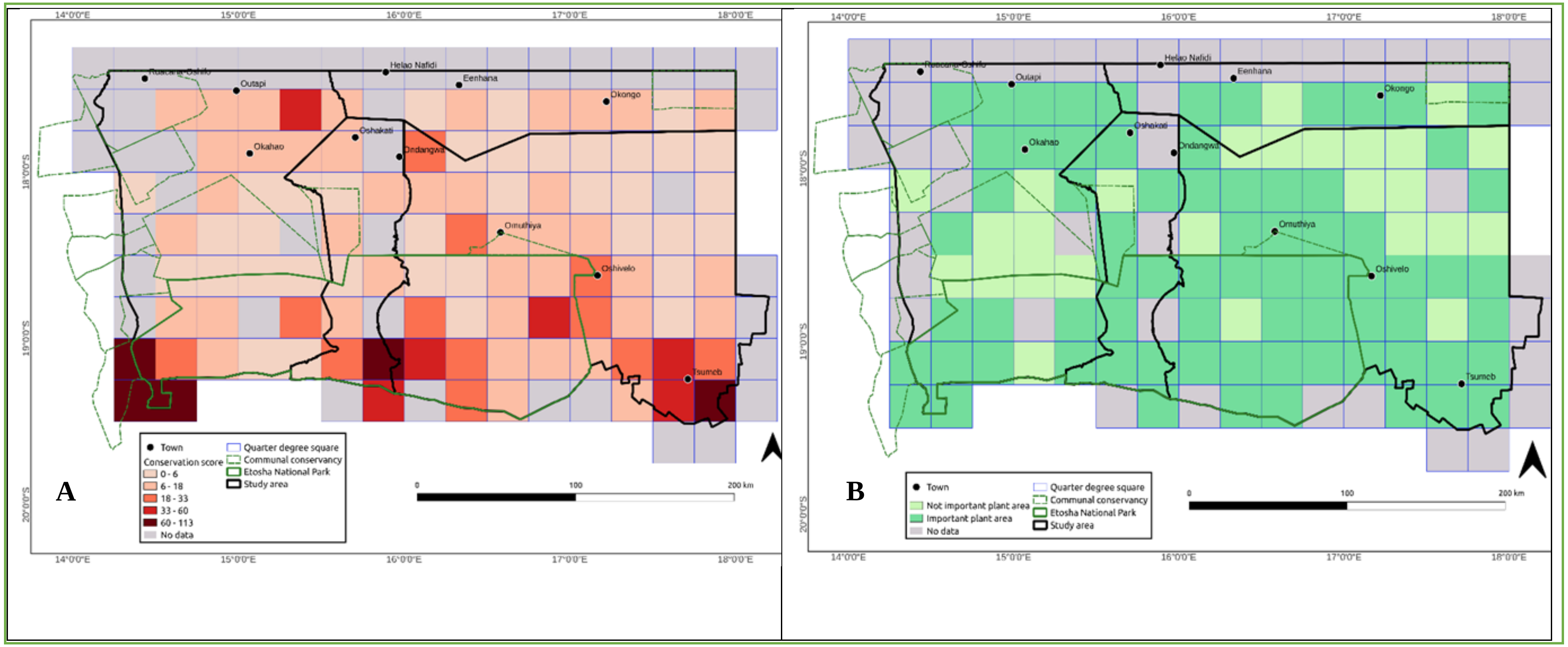

Figure 5: The maps showing the Ranked QDS based on the total score categories (a) identified Important Plant Areas using global IPA criteria (b) in the study area (Oshana, Oshikoto, Omusati, and Ohangwena). (a) QDS with darker colors has high conservation scores while QDS with lighter colors has low conservation scores (total score). (b) The dark green color indicates QDS that satisfy one or more IPA criteria, light green indicates QDS that did not satisfy any of the IPA criteria and white cells represent areas that contained no data.

The Mann-Whitney U test revealed a significant difference between the endemic species in Etosha and the preliminary IPAs ($U = 346.5$, $P<0.05$). There are more endemic species in Etosha National Park as compared to those in the provisional IPAs, resulting in a high endemism score in Etosha National Park. There was no statistically significant difference between the species richness scores per QDS between Etosha National Park and the preliminary IPAs ($U = 346.5$, $P > 0.05$). However, there was a significant difference between the total scores per QDS between Etosha National Park and the preliminary IPAs ($U = 346.5$, $P<0.05$). Etosha National Park QDS have higher conservation scores than the QDS in preliminary IPAs

4.2 Comparison of species composition among IPAs in protected and non-protected areas

The HCA produced 4 cluster at 5-10% similarity in species composition (Figure 5). Cluster 1 was composed of species from QDS in Okongo area; Cluster 2 consisted of Uukolonghadhi Ruacana, King Nahale, Outapi areas, Etosha National Park, and Tsumeb area; Cluster 3 was composed of Sheya Shuunona and Iipumbu ya Tsilongo; and Cluster 4 was composed of species from Uukwaluudhi. The highest percentage similarity in species composition was 50% observed between QDS in Etosha National Park (protected areas) and QDS in Tsumeb area (non-protected areas). Followed by Otavi area with the percentage similarity in species composition of 25%.

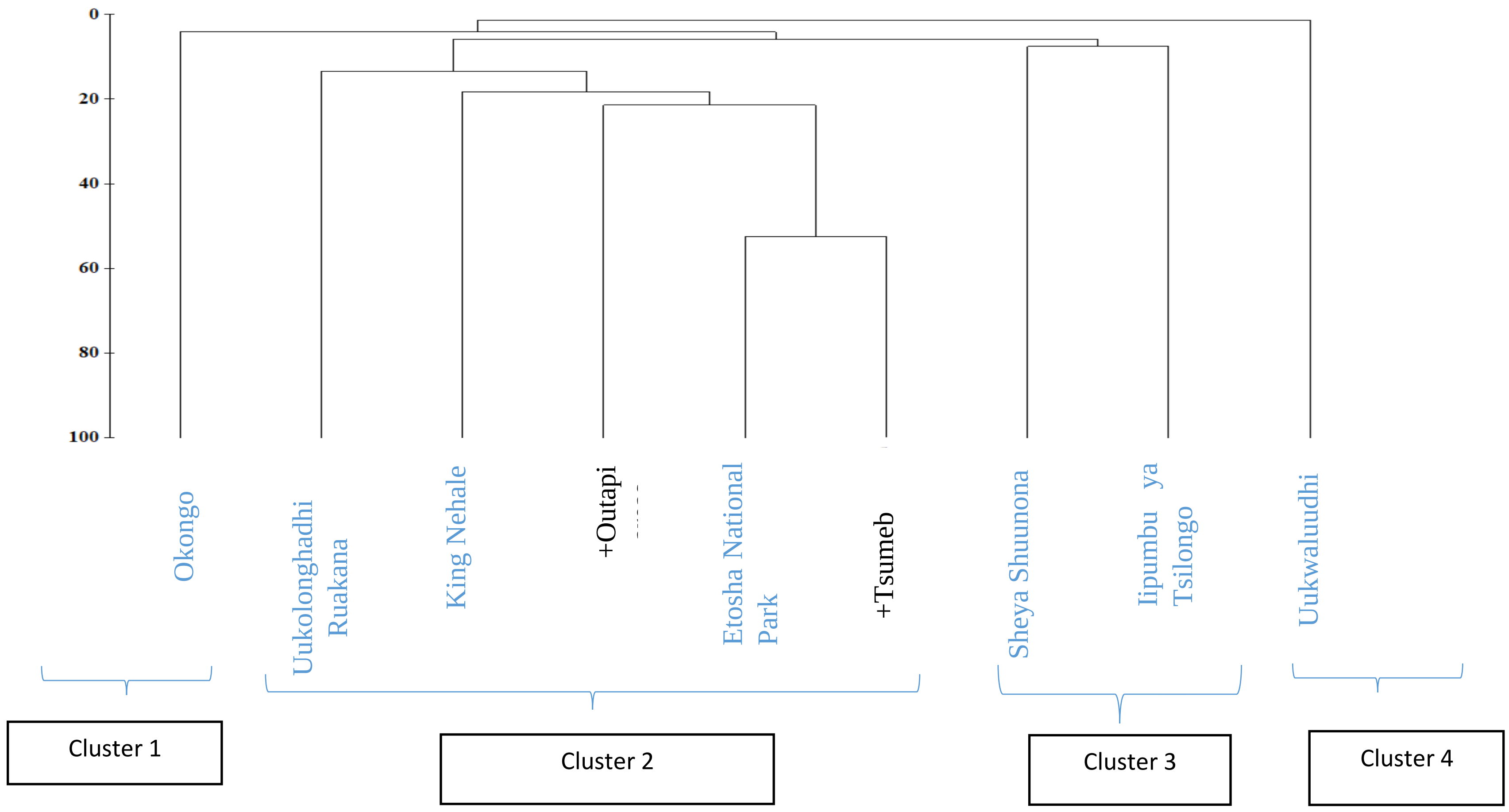

Figure 6:Hierarchical Cluster Analysis (HCA) Dendrogram showing a clustering of protected and non-protected (+) areas based on their species composition.

5. DISCUSSION

This study has clearly demarcated new IPAs in north-central Namibia that have significantly contributed to the IPA network, aside from the results of the IPAs workshop held in 2004. It can, therefore, be concluded with certainty that it is essential to identify and recognize IPAs using globally standardized IPA criteria. According to Darbishire (2017), the IPAs criteria system offers a practical yet scientifically rigorous means of delivering plant datasets, enabling informed national conservation prioritization. An expert-opinion-based selection of IPA sites alone cannot be used to identify and prioritize IPAs. Evidently, only 27% of the IPAs identified in this study formed part of the five preliminary IPAs that were demarcated by Hofmeyr (2004) in the study region.

Over 60% of the total QDS that satisfy the IPA criteria identified for northern central Namibia are located outside protected areas. Many of the QDS that satisfy the IPAs criteria might be affected by livestock, deforestation, and new developments, as the majority of them are not within protected areas. According to a study by Dagher-Kharrat, Zein, & Rouhan (2018), all IPAs recorded contain threats. The most significant threats to identified IPAs are mostly caused by an increase in agricultural activities and overgrazing of pastures, as well as deforestation largely due to collecting firewood (Hofmeyr 2004; Catullo, Montmollin, & Radford 2011). Droughts, flooding episodes, higher temperatures, and unpredictable variable rainfall in these areas (Angula & Kaundjua 2016; Spear & Chappel 2018) might also be contributing factors to the distribution of vulnerable and threatened plant species recorded in these areas.

The identification of IPAs outside protected areas in this study is consistent with other studies conducted in Europe and the Mediterranean. Identification of IPAs has sometimes highlighted low levels of overlap between IPAs and constitutional site protection (Darbyshire et al. 2017). A study by Plantlife (2010b) specified that one in four IPAs in Europe had no legal protection, and many were threatened. Smith and Smith (2004) also stated that, while some of the identified IPAs may already be within protected areas, a large number of IPAs will fall outside protected areas. For example, in the Fergana Valley, the existing protected area networks and national legislation frequently fail to protect key plant species and their habitats (Tojibaev et al. 2022).

The northern and central Namibia areas are all on heavily used communal land, and the only management there is communal (Byers 1997). The identified IPAs can serve as the foundation for communal conservancies for plant resource and sustainable management initiatives (Palmer & Smart 2001). Thus, conservation measures outside of protected areas may be necessary to complement any legal protection for vulnerable and threatened plant species.

Etosha National Park has QDS with high endemic species and low threatened species compared to other QDS in the study area. This partially strengthens an argument concerning the effective representation of plant diversity, including endemic, rare, and threatened plants, in the current protected area network in Namibia by Loots (2005a). This may result from the mountainous Kaokoveld of northwestern Namibia, which contains numerous endemic plants and animals whose ranges, in many cases, extend into the Etosha National Park (Cloudsley-Thompson 1990). Many sites with high endemism are mostly mountainous, and only certain plant species are adapted to thrive in this environment. Studies in the South and East Mediterranean Region on Priority Sites for Conservation established that mountainous sites typically have high local species endemism compared to other parts of the region in many countries (Catullo & Montmollin 2011). The results support a study by Thuiller et al. (2006), in which they stated that the current protected area network is predicted to meet its mandate by protecting most of the current endemic species in Namibia. The endemism patterns are used as key data for conservation plans as well as identifying hot spots and shaping protected areas along with important plant areas in many countries (Kruckeberg 2004; Mehrabian et al. 2020).

Plant species composition has significantly changed due to plant resource utilization in north-central Namibia, especially in the Omusati region (Mapaure 2011). The QDS in the study area indicates fewer similarities between the sites. The study area is geographically in northern-central Namibia, and one would therefore expect it to be more similar to each other. These areas are subjected to deforestation, land degradation, and invasion by alien species due to communal farming activities and grazing, as well as wood cutting (Hofmeyr 2004; Hamunyela 2019). Areas with moderate disturbances, such as the QDS in Etosh National Park and the Tsumeb area, have higher species composition similarities as compared to other areas. The high endemic species in Etosha National Park and Tsumeb can also explain the high species composition between the two areas.

The difference in the use of plant resources and human pressure in these areas may be a result of the low compositional similarity among QDS in the study area. The DCA ordination by Mapaure (2011) showed up to a 50% species turnover between the game park and central Omusati, and woodland utilization contributed significantly to the observed variation in species data. In addition to human pressure on plant resources, some of the plant composition variation is attributed to other factors such as variations in soils and geology, landscape type, and grazing pressure in the area.

Not every ideal IPA will become a protected area; rather than selecting every site that meets at least one of the IPA criteria, the most important sites from among those that meet the criteria should be selected. Setting conservation priorities (ranking) for identified IPAs is widely accepted as critical to minimizing biodiversity loss and maximizing the effectiveness of limited conservation resources (Dagher-Kharrat, Zein, & Rouhan 2018). QDS with low conservation scores that are not prioritized for conservation should be systematically monitored to preserve the endemic, threatened, and vulnerable fauna that they shelter (Dagher-Kharrat, Zein, & Rouhan 2018). The difference in conservation scores between QDS can be attributed to human pressure and other variations such as plant composition, soils and geology, landscape type, and grazing pressure in the areas.

According to Hofmeyr (2004), a practical focus should be on areas where working with local people on IPA implementation is often really necessary, as there are limited resources for conserving all IPAs. Setting priority sites for conservation is essential to minimizing biodiversity loss and maximizing the effectiveness of limited conservation resources (Dagher-Kharrat, Zein, & Rouhan, 2018). Hence the few numbers of QDS in medium and high-ranking intervals. The national IPA constituency selects the most important sites among those that meet the criteria (Darbyshire et al. 2017). This decision should be made in a well-informed and transparent manner, taking into consideration all the different factors that dictate the importance of a site. Factors such as threats to plant species and the benefits that local communities derive from plant species should be considered when prioritizing IPA sites.

The maps produced represent the probability of suitable habitat for new IPAs. According to Anderson (2002), it is crucial that maps outlining the boundaries of sites at the appropriate scale are included with site reports to form the basis of efforts to protect the contents of IPAs. A map is regarded as a first step in sharing data with different audiences to influence the conservation, management, and protection of the IPAs (Plantlife 2018). Defining the IPA sites and the areas that are protected or threatened is a necessary part of setting priorities for the IPA network (Dagher-Kharrat, Zein, & Rouhan 2018).

Since there is no fixed size for an IPA, it is recommended that the area be small enough to be conserved while at the same time adequate to support a sustainable population of plant species (Dagher-Kharrat, Zein, & Rouhan 2018; Plantlife 2018). Hofmeyr (2004) also mentioned that there is no fixed size or number of IPAs; what is really important is to ensure that adequate national coverage is obtained and that management of nationally identified IPAs is achievable. This study considered the QDS as presented on the map to be the size of an IPA, as they are small in size but sufficient to support a large population of plant species and other organisms. According to Craven and Vorster (2006), QDS are manageable, and sufficient information at that scale is available for Namibia.

6. CONCLUSION

This study was one of the first to reassess and rank IPAs in northern Namibia. The study provides a strong scientific basis on which to select the new IPA sites in Namibia. It is essential to identify and recognize IPAs using surrogate criteria, supplemented by expert opinion, as well as existing globally standardized IPA criteria. An expert-opinion-based selection of IPA sites alone cannot be used to identify IPAs. The majority of the new IPAs identified are located outside protected areas with no form of protection and consist of threatened and vulnerable species. QDS in Etosha National Park have low records of threatened plant species compared to QDS in non-protected areas. Thus, there is a need for conservation measures for IPAs outside of protected areas, as they might be subjected to an increase in agricultural activities and overgrazing of pastures, as well as deforestation. The maps produced in this study show areas that qualify as IPAs based on Darbyshire's (2017) IPA criteria, and they can be used to share data with different audiences to influence the conservation, management, and protection of the IPAs.

The biggest challenge in this IPA study included the data deficiency issue of some plant species' conservation status and habitation status, which caused difficulties in applying the criteria-based approach. Knowledge of habitant status is useful for assessing and ranking IPAs. QDS that lack or have low data collection intensity make analysis difficult or the results inaccurate. Areas with huge data collections were considered IPAs compared to the understudied areas, which may also be IPAs with the availability of data. Many plant species in the data set lacked geographical coordinates. This study revealed the effectiveness of continuously evaluating IPAs in Namibia since new areas can be newly designated as IPAs where the old IPAs no longer exist.

7. RECOMMENDATIONS

There are QDS with no plant records detected; these underexplored regions should be considered a priority for data collection to document their flora. As many understudied QDS can support high botanical richness, botanical surveys must be conducted to promote vegetation conservation priorities. Some plant species are not identified at the species level. The Botanical Research and Herbarium Management System (BRAHMS) plant species database should all be identified to a species level.

The results of this study (e.g., IPAs and maps) are recommended to be considered by stakeholders, practitioners, and policymakers in setting conservation priorities for these areas and in the formulation and updating of management and conservation plans, especially focusing on the important plant areas that are not in protected areas in Namibia. The habitat type of all preliminary IPAs and recommended IPAs should further be confirmed by extensive field surveys in addition to the IPA criteria that were used to validate the IPAs in this study. It is recommended to conduct the same study in all the other regions of the country, employing the same standardized assessment method.

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ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0066   Date: 02 June 2022

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project:	MAPPING AND RANKING OF IMPORTANT PLANT AREAS IN THE KAVANGO, ZAMBEZI, OSHANA, OSHIKOTO, OMUSATI, AND OHANGWENA REGIONS
Student:	EMILIA NDAPANDULA ANDREAS
Student Number:	201612939
Supervisor(s):	PROF. EZEKEIL KWEMBEYA

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,

ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

Dr. Zivayi Chiguvare (Chairperson Ethics Committee)

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)