Socio-ecological dynamics of woodlands, forests and fire in southeast Angola

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Declaration

I declare that this thesis has been composed by myself and that the work has not been submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where otherwise acknowledged in the relevant chapters.

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Abstract

Angola, a country that endured a 13-year war for independence followed by a 27-year civil war, remains one of the most understudied countries in Africa. This study develops in southeast Angola, in the watershed of the Okavango Delta and the Zambezi River, an area that has been deemed one of the largest areas of undisturbed miombo in Africa. The highlands of southeast Angola, one of the country's most isolated and still heavily land-mined regions, contains well-preserved vegetation with scattered human populations that depend on natural resources. Because of its ecological richness and low population density, the region has been targeted for conservation interventions but the potential impact on livelihoods has not been investigated. Using a socio-ecological systems framework, this research investigates how human practices, knowledge systems, and historical events interact with ecological patterns and processes such as vegetation types, structure, floristics, and fire regimes, in a setting where human-environment relationships are primarily governed by customary practices rather than state governance. To achieve this, I begin this thesis by presenting an overview of the wooded ecosystems-livelihoods context, including savanna and miombo ecology, conservation approaches and ethical considerations during this study (chapter 1). I then present three chapters with the main questions and results from my research. For these, I executed three main tasks, each linked to one chapter. First, I mapped vegetation types according to local classifications (chapter 2), then I typified the vegetation bridging local classifications and Western scientific floristic approaches (chapter 3) and lastly, I studied the effects of the war on fire dynamics in the area (chapter 4). I end this thesis with the contributions that emerge overall across the chapters.

In Chapter 2, I address the challenges of solely using remote sensing for classifying vegetation, highlighting the potential oversimplification of complex landscapes when following this approach. This chapter incorporates participatory mapping in five rural villages to recognise local knowledge to classify woody ecosystems. My findings suggest that incorporating place-based knowledge can offer a deeper understanding of the landscape. The results reveal differences between local classifications and remote sensing ones, emphasizing the need for inclusive conservation approaches that align with local ecological knowledge. I argue that landscapes are complex socio-ecological systems and that their understanding can benefit from ground-based approaches that consider not only the physical features but also the social and cultural values of the land.

Chapter 3 focuses on woodland ecology, and challenges existing classifications of southeast Angola as a homogeneous miombo woodland. Through quantitative ecological surveys (establishment of 26 plots) and learnings from local knowledge, the study identifies five structurally and floristically distinct woodland formations, including a unique dry forest dominated by *Cryptosepalum exfoliatum pseudotaxus*. The latter differs greatly from miombo woodlands, as circumscribed in the literature. These findings call for a re-evaluation of current maps of Angolan vegetation, prompting the need for updated maps of African evergreen dry forests that are currently identified only in western Zambia. I argue that an accurate identification of the diverse vegetation formations in Angola is fundamental for their proper management, given that fire is widely used in miombo ecosystems but is likely not appropriate in evergreen forests.

Chapter 4 explores the impact of the Angolan civil war on fire and forest dynamics in southeast Angola, since local peoples indicate a decrease in fire events due to war, evident in satellite-derived time series. This chapter employs remote sensing, historical data, and interviews to reconstruct war-time (1985-2002) and post-war (2003-2018) fire dynamics, revealing the role of social dynamics in shaping fire regimes. The study challenges the idea that ecological and climatic factors are the main determinants of fire regimes, and highlights the intricate relationship between fire, war, and socio-ecological systems, showing that war can restrict the use of fire and change the fire dynamics of an entire ecosystem. It also advocates for interdisciplinary approaches to understand the complex socio-ecological dynamics of war.

Overall, this thesis highlights the importance of recognising local knowledge, challenging existing landscape classifications, and considering historical and socio-cultural contexts in understanding and managing vegetation and associated ecosystems in the highlands of southeast Angola. The findings emphasize the need for inclusive and multi-disciplinary approaches to vegetation classification, conservation and landscape management. Lastly, this study calls for ethical and reflective research practices that centre local voices and challenge dominant conservation narratives that often overlook lived experiences and place-based knowledge.

Lay Summary

Woodlands are not just natural systems, but social and cultural spaces where intricate relationships with human societies unfold, providing the base of subsistence for many rural communities. Woodlands and human practices are mutually influential, each shaping the other in both cultural and ecological ways, creating a dynamic relationship. Around 40% of Africa is dominated by tropical woody vegetation, supporting nearly 505 million people. The focus of this work is on Angola, a country which is 60% covered by woody vegetation and where nearly 80% of the population relies on tree biomass to meet essential livelihood needs. The dry forests and woodlands of Angola have received little attention from the international scientific community, likely a consequence of a 27-year civil war that impeded development and exacerbated poverty and inequality. Whilst national and international pressures to address environmental uncertainties are pushing for formal conservation mechanisms, the legacy of colonialism continues to influence various aspects of Angolan life, including negative perceptions of rural peoples' interactions with woodlands and the implementation of top-down conservation interventions. In recent years, southeast Angola has become a target for conservation because the region is crucial for the health of several southern Africa water systems, including the Okavango Delta and the Zambezi River. The region, one of the most isolated and remote of Angola, has been touted as containing some of the world's largest contiguous block of miombo woodland. Southeast Angola served as a stronghold for opposition 'guerrilla' forces and has remained largely inaccessible, likely due to the legacies of the civil war (1975-2002). This inaccessibility, in turn, has contributed to the preservation of the environment. This place offers a unique opportunity to understand human-wooded ecosystem dynamics in Southern Africa that are shaped by customary natural resource governance, limited external influence, and what appears to be sustainable resource use.

The objective of this thesis is to explore human-wooded ecosystem interactions in southeast Angola. To that end, I first explore the value of community mapping as a means to provide valuable insights into land use and land classification, which is important for effective and just conservation initiatives. Then, I show that vegetation in southeast Angola contains woodland types other than miombo, including a unique dry forest previously reported as being restricted almost entirely to west Zambia. Identifying the diversity of vegetation formations is essential for appropriate management and thus, to protect wooded ecosystems as well as to give visibility to rural livelihoods that depend on woodland resources. Lastly, I explore how the civil war shaped decisions over the use of fire for livelihoods, and how it might continue to shape current perceptions and practices around fire use. Through the findings of this work, I argue that effective wooded ecosystem conservation requires an awareness of the communities that interact with and depend on such ecosystems, particularly by recognising and including local knowledge, and through understanding the complex socio-ecological dynamics that govern wooded landscapes.

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At the entrance of the Crew Building in the School of Geosciences, where I spent the past four years pursuing my PhD, a sign reads:

> *"To the advancement of science and to the service of mankind, this building is dedicated"*

For the past four years, I have worked relentlessly to fulfil that expectation. I'm not sure I succeeded. But in the attempt, I found a great amount of people who, with kindness and patience, advanced my own learning journey, and to whom I must thank. Although my name appears as the sole author of this document, this thesis is, in reality, the culmination of countless brilliant and thoughtful interactions with people who shared their insights, listened humbly, and, in doing so, became part of the transformative journey this process has been for me. I believe, more than before, that science must be done collaboratively. Perhaps if we focus less on advancing science as an end in itself and more on doing science *together*, we can not only push the boundaries of knowledge but also create better conditions for the scientific community and for society at large.

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Chapter 1. Introduction

At the centre of this thesis are the relationships between rural livelihoods and wooded ecosystems in the southeast of Angola. To contextualise my motivations, my research questions, and the conclusions I draw from my work, I believe it is important to first understand the context in which my study developed. For this reason, I will briefly describe my study area, after which I will shift to discuss the broader context with the aim of highlighting the relevance of this work from a larger perspective.

I arrived in the commune of Tempué, located in the Moxico province of the Angolan highlands, a region surrounded by forests, savannas, and rivers, with the National Geographic Okavango Wilderness Project (NGOWP). The project, managed by the Wild Bird Trust and by National Geographic, has been active in the region for the past ten years, developing conservation initiatives for the local ecosystems. Whilst I have experience working with rural communities in my home country (Mexico), I had never experienced reality such as I found in this place. People subsisted without easy access to markets or urban centres. Livelihoods were woven into the landscape and there seemed to be connectedness between people and natural resources. Though signs of human resource use were evident, these appeared to be offset by the general abundance of natural resources and their ability to regenerate. The highlands of Moxico in southeast Angola have been identified by the NGOWP as containing 'one of the largest undisturbed miombo woodland in Africa', although I argue in this thesis that the ecological, social, and cultural landscape is more complex than 'just' miombo and that the woodlands are well preserved, whilst people live and use them for many purposes.

Southeast Angola was the territory where the 'guerrilla' forces (who lost the civil war) were based during the recent conflict (1975-2002), and its remoteness and difficult accessibility are linked to the legacies of the war. Interestingly, the war and the lack of access offered protection to the environment in this location, creating the conditions for a case study evaluating a context of well-preserved miombo woodlands with a nearly absence of state. Hence, this place represented an opportunity to understand human-woodland dynamics with little external influence and with what appears to be sustainable resource use. This is possibly due to a mix of factors including low human density, abundance of natural resources, low to null presence of mega-herbivores, little commercial wood extraction, and the use of local knowledge to manage the environment.

Although my initial plan was to study the ecology of the woodlands, my curiosity quickly shifted as I realised that the woodlands could not be understood, at least by me, without studying the woodland users. As an attempt to understand these landscapes, this work recognises the role of local peoples and cultures in shaping the landscape, and the concern that could arise if they were to be excluded from decisions and policies regarding their land. This thesis then, aims to contribute to the understanding of the socio-ecological dynamics of woodlands and fire in the highlands of southeast Angola by bridging local ecological knowledge with scientific approaches. Using a socio-ecological systems framework, this research investigates how human practices, knowledge systems, and historical events interact with ecological patterns and processes such as vegetation types, structure, floristics and fire regimes, in a setting where human-environment relationships are primarily governed by customary practices rather than by state governance.

With this work, I aim to develop a holistic and grounded understanding of landscape dynamics in this region that can hopefully inform conservation and land management in socially just and ecologically meaningful ways. To address the overall aim, I focused on three research questions, each developed in a different chapter. The questions I explored were: 1) How do local communities define, classify, and use the wooded vegetation in southeast Angola? (Chapter 2), 2) How does the scientific characterisation of vegetation (i.e., floristic composition and structure) compare to local classification and local knowledge? (Chapter 3), 3) How have social and political dynamics, particularly the Angolan civil war, influenced fire regimes in the region? (Chapter 4).

In this introduction I will first reflect upon the relevance of this work within debates on the wooded ecosystem-livelihood paradigm. Throughout the introduction, I will use the term ‘wooded ecosystems’ to refer to ecosystems that are characterised by the presence of trees and other woody vegetation, ranging from dense forests to more open woodlands; since in my study area there are a variety of forests, woodlands and savannas, which I will describe in the next three chapters. Then, I will present generalities of Angola and specificities of the highlands in the southeast. Next, I will briefly explain the theoretical frameworks and concepts that support this work, followed by a brief justification and the relevance of the methods I used. I will then end the introduction acknowledging the ethical challenges that arose from this work and how my position as a researcher might have influenced the interpretation of my results.

Lastly, it is worth clarifying that the overlap in content, particularly in chapters 2–4, arises because, although this document is written to maintain connectedness, each chapter is also designed to be understood independently, aiming to provide a complete perspective for readers who may not engage with the entire document.

1.1 Setting the context: wooded ecosystems, livelihoods, and conservation

In ecology, wooded ecosystems are, for the most part, understood based on their physiological and ecological characteristics (i.e., canopy cover, grass cover, canopy height, etc). However, in this thesis I argue that wooded ecosystems are not just physical systems, but social and cultural spaces where complex and intricate relationships with human societies occur, and which provide the base of subsistence for many rural communities. Some of the most recognised resources that wooded ecosystems offer are trees. Trees provide fuelwood and timber, resources that are critical for subsistence and for local economies. Moreover, wooded ecosystems provide a wide array of services, namely provisioning services (supplying food, fresh water, timber, etc.); regulating services (climate regulation, erosion control, pollination); cultural services (recreation, aesthetic enjoyment); and supporting services (soil formation, photosynthesis, nutrient cycling) (Millennium Ecosystem Assessment, 2005), all of which contribute greatly to human wellbeing, directly and indirectly (Constanza et al., 1997). Wooded ecosystems provide a safety net for vulnerable populations by providing income and improving welfare and play an essential role in helping local communities to adapt to changes and threats (Cavendish, 1999; Chambers & Leach, 1998).

The contributions that non-timber forest products (NTFP), such as fruits, honey, medicinal plants, fibres, etc., represent to rural livelihoods are also essential for food security, health, and as sources of income (Arnold & Ruiz Pérez, 2001). Moreover, wooded ecosystems represent cultural heritage since many rural communities have spiritual, cultural and social connections with wooded ecosystems, and they are valued beyond what they can offer materially (Posey, 1999).

Wooded ecosystems are not only influenced by human practices, but also shape cultural and ecological practices in multiple ways, creating dynamic, mutual and reciprocal relationships (Mung'ong'o, 2009). In many regions, this dynamic interaction is evident, as seen in the African miombo, where the seasonality of plants defines the calendar of human activities. For example, flowering plants in the miombo region dictate two main honey harvesting seasons, with an extended fruit-harvesting period (Campbell, 1996). Social customs around firewood collection are also shaped by the distribution and abundance of firewood species. The abundance, size, and condition of natural resources directly influence how much time people spend harvesting resources, which in turn affects how much time remains for other important activities (Lowore, 2006). The relationship between people and wooded ecosystems is reciprocal; wooded ecosystems shape human livelihoods just as much as humans shape wooded ecosystems. This interdependence highlights the need to consider both ecological and human dimensions when studying wooded landscapes and when thinking about their conservation.

Effective wooded ecosystem conservation requires a well-developed understanding of the communities that interact with and depend on these ecosystems. Traditional management practices, local knowledge, governance institutions, and property rights, among others, play a critical role in shaping wooded ecosystems. Historically, conservation has been framed through the Western notion of nature versus human dichotomies, where human settlements have been seen as a threat for nature, resulting in, for example, the creation of reserves that excluded people (Adams & Hulme, 2001; Adams & Hutton, 2007). The idea of wilderness as land free from human influence has driven much of conservation approaches, leading to social impacts, particularly through the displacement of populations (Adams & Hutton, 2007) and frequently neglecting the needs of wooded ecosystem-dependent communities (Agrawal & Gibson, 1999; Arnold & Ruiz Pérez, 2001).

Over time, the idea that conservation can conflict with local interests has been recognised, and in some cases, there has been a shift towards alternative approaches to conservation, one of them being community conservation. Community conservation encourages sustainable livelihood systems and emphasizes involving local peoples in both the management of the environment and the development of conservation policies (Shackleton et al., 2002). This approach emphasizes empowering local communities with authority and decision-making power over natural resources and aligns conservation goals with their development needs (Adams & Hulme, 2001; Agrawal & Gibson, 1999). However, the actual effectiveness of community conservation does not always achieve those objectives.

Inclusive and effective conservation strategies involve challenging power structures and creating new institutional frameworks to balance biodiversity preservation with local livelihoods, all whilst avoiding undermining autonomy and marginalising local perspectives (Adams & Hulme, 2001; Adams & Hutton, 2007). Moving away from top-down policies towards context-specific strategies that reflect local values can enhance sustainability, benefiting both livelihoods and the environment (Arnold & Ruiz Pérez, 2001). Furthermore, acknowledging wooded ecosystems as intrinsically linked to complex social, cultural, economic and ecological dynamics (Adams & Hutton, 2007) is crucial to create effective and just policies.

1.2 Conceptual approaches and relevant terms

My study was guided by a set of frameworks and concepts that were fundamental to understand the place where I worked and what I learned from my work. These frameworks and concepts provided a set of variables and terms that guided and helped me organise the design of data collection, fieldwork, and subsequent analysis (McGinnis & Ostrom, 2014; Ostrom, 2009).

1.2.1 Concepts important for this thesis

Before I move on to present the theoretical frameworks that guided my work, I will describe concepts that I often use in this document, which are important to understand the context and the relevance of this study.

Local peoples

When I refer to the inhabitants of my study area, I use the terms local peoples. This term in this thesis, refers to human communities that form part of a distinct social and cultural group(s), displaying ancestral ties to the land and the surrounding natural resources, which are integral to their identities, cultures, and livelihoods. I use the plural ‘peoples’ to acknowledge the diversity within the communities in the area. These peoples maintain historical continuity with pre-colonial or pre-settler societies; they possess unique social, economic, or political systems, languages, cultures, and beliefs; they rely on customary leaders and organizations for representation; much of their land is held under customary ownership, and formal legal recognition is limited. This terminology corresponds to the definitions used by the United Nations (2024) and World Bank Group (2023) for ‘Indigenous Peoples’. However, I do not use the term ‘Indigenous peoples’ because I believe I do not know enough about these communities to assign a term that sometimes has a politicized nature and associated historical or political connotations.

Traditional ecological knowledge, traditional knowledge and local ecological knowledge

There is no universally accepted definition of Traditional Ecological Knowledge (TEK) or Local Ecological Knowledge (LEK), largely due to the diversity of cultural contexts, environmental settings, and the ways these knowledge systems are documented and used (Brook & McLachlan, 2008; Sinthumule, 2023). TEK is widely understood as a cumulative body of knowledge, practices, and beliefs about relationships among living beings and their environments, passed on through generations via cultural transmission (Berkes, 2003). TEK is typically rooted in societies with historical continuity in resource use, often non-industrial, indigenous, or ethnic groups, and embedded in social institutions regulated by customary rules and norms (Osemeobo, 2001; Sinthumule & Mashau, 2020).

TEK emerges from long-term, site-specific observation and is reinforced by intergenerational communication and shared experiences (Usher, 2000; Houde, 2007). It reflects a worldview that influences both environmental perception and social relations (Berkes et al., 1994). TEK is dynamic, continually evolving through innovation, adaptation, and interaction with external influences (Agrawal, 1995; Posey, 1999), and shaped by ongoing processes of loss and hybridisation (Reyes-García, 2015; Aswani et al., 2018), which makes it difficult to establish a fixed boundary around what constitutes 'traditional' knowledge (Berkes, 2003). TEK may be seen at multiple levels: as knowledge of species and landscapes, as resource management practices, as institutional arrangements supporting those practices, and as part of broader cultural worldviews (Berkes et al., 1994). TEK is closely linked to livelihood systems that emphasize cooperation, family ties, communication across generations, and respect for nature (Posey, 1999). Often, it informs local decision-making in agriculture, health, and education, and plays a key role in the sustainable management of natural resources (Berkes, 2012).

Understanding and working with TEK requires interdisciplinary approaches that bridge ecological and social sciences (Bélisle et al., 2018), often involving the recollection of historical environmental observations shared by local informants (Albuquerque et al., 2021). Beyond their cultural and historical value, this knowledge system offers legitimate and practical means for addressing local socio-environmental challenges (van Eijck & Roth, 2007, cited in Whyte, 2013).

In this thesis, I primarily use the term local knowledge (LK) to refer to the understanding, practices, and skills developed by communities in my study area in response to their environmental, cultural, and social contexts. This knowledge is essential for navigating everyday life and managing local resources. Since this research did not directly investigate how such knowledge is acquired, I do not refer to it as traditional knowledge. However, many participants described it as being passed down through generations, often intertwined with cultural heritage, highlighting overlaps with traditional knowledge. Thus, for the purposes of this study, LK is understood inclusively, encompassing traditional, indigenous, rural, and local forms of ecological knowledge held by local peoples in my study area. Rather than emphasizing a strict division between traditional and local knowledge, what is central for this study is to document how local knowledge systems support communities in their interactions with their environment and thus, are able to inform and enrich Western science.

Furthermore, when referring to local knowledge specifically related to ecological patterns and processes, such as tree species composition and plant uses, I use the term Local Ecological Knowledge (LEK). Whilst my focus on this thesis is on ecological aspects, I acknowledge that traditional and local knowledge systems also encompass social, spiritual, and cultural dimensions beyond ecology (Berkes et al., 2000).

Beyond documenting LEK in southeast Angola, this study also holds relevance in the context of a global trend of loss of traditional knowledge, particularly the oral transfer from elders to younger generations. Such loss is driven by a range of exogenous factors, including globalisation and cultural homogenisation, the expansion of formal Western education systems, rural exodus, urbanisation, deforestation, and the adoption of modern agricultural practices, which together affect the contexts in which such knowledge is used, maintained, and valued (Aswani et al., 2018; McCarter et al., 2014). LEK systems are deeply interlinked with cultural and biological diversity, suggesting that the loss of one is linked the decline of the other (Aswani et al., 2018).

Decolonising research

Rather than being a fixed methodology in this thesis, decolonising research principles represented a guidance and a reflective process (Diver & Higgins, 2014). Decolonising research involves challenging conventional research methodologies that have been shaped by colonialism, power imbalances, and Western epistemologies, embedded in academic disciplines, research practices, and knowledge production (Keikelame & Swartz, 2019; Datta, 2018). Decolonising research calls for engagement with different epistemologies (the ways we know) and ontologies (the ways we understand reality) (Smith, 2012). Epistemologies are strongly shaped by disciplinary training which influence our work, for example, by shaping the research questions we ask, the methods we use, and the narratives we construct based on such methods (Shanley & Laird, 2002). However, in formal education institutions, Western theoretical frameworks and research are usually prioritised, overlooking alternative views of the world (Chilisa, 2017). Conducting decolonising research requires reflecting on the spaces where research is conducted, the values that guide it, and the ways our identities as researchers and as outsiders (often in systems of privilege), intersect with power structures (Keikelame & Swartz, 2019; Sandoval et al., 2016).

Learning to use decolonising methodologies involves continuous unlearning and relearning (Datta, 2018), and shifting from extractive models toward research grounded in reciprocity, accountability, and solidarity (Udah, 2024; Smith, 2012). It requires recognising participants not simply as data sources but as knowledge holders, and committing to practices that amplify their voices, respect their epistemologies, and reflect their realities (Udah, 2024; Diver & Higgins, 2014). This also calls for ongoing reflection of our motivations, values, and methods (Smith, 2012), and a commitment to work in ways that are not only ethical but also humanising and empowering (Udah, 2024). Such approaches open possibilities for doing research differently, flexibly, collaboratively, and contextually, enabling co-produced knowledge grounded in relationships of empathy and mutual respect (England, 1994).

Decolonising research requires recognising the historical and current effects of colonialism, in academia and in the communities we study, so that we can better understand the unequal world in which our research is always embedded (Datta, 2018; Staddon, 2022). Research conducted in post-colonial or customary contexts without accounting for these dynamics, risks reproducing the inequalities it might otherwise seek to address (Zavala, 2013; Baker et al., 2019). Ultimately, decolonising research is about acknowledging that research is never neutral.

Whilst disciplines like human geography and anthropology have been increasingly engaging with decolonial approaches, ecological sciences have been slower to reflect on its colonial influences (Baker et al., 2019). For instance, decolonial perspectives remain marginal in ecological conferences and journals (Soares et al., 2023). Even as ethical concerns are increasingly more visible, ecologists rarely confront the structural issues tied to colonial histories of land dispossession, loss of knowledge systems, and extractive practices (Soares et al., 2023). Decolonising research in ecology calls for a shift to rethink who produces knowledge about ecological systems, how fieldwork is conducted, and how research relates to local epistemologies and histories.

Furthermore, ecological knowledge often informs conservation practices, which have historically been an instrument of colonialism, with national parks and designated 'wilderness' areas in many cases established on ancestral lands of local peoples, who were forcibly removed through colonial conquest (Kashwan et al., 2021; Muller et al., 2019). These models of exclusionary (or fortress) conservation, based on the strict separation of people from nature, have historically been reinforced through legal frameworks inherited from colonial regimes that continue to deny local peoples' customary rights to land (Dominguez & Luoma, 2020). Moreover, conservation initiatives are often led by researchers trained in Western science, reinforcing epistemic hierarchies and marginalising other knowledge systems (Staddon et al., 2023).

Whilst community-based and rights-based approaches are currently given more recognition, fortress conservation has resurged in practice, especially in Africa, where protected areas fail to recognise the contributions and rights of local communities (Kashwan et al., 2021). Even when local knowledge is incorporated into conservation plans, power often remains centralised in external institutions. Without shifting decision-making authority to local communities, such efforts merely reproduce colonial dynamics (Muller et al., 2019).

Decolonising conservation, by contrast, recognises the agency of local peoples and their relationships with local environments (Smith, 2012). Its principles include local self-determination, co-existence of local and Western knowledge systems, and a shift toward equitable partnerships grounded in mutual listening and understanding (Kashwan et al., 2021; Dominguez & Luoma, 2020; Staddon et al., 2023). Recognising the relational values between people and nature, as well as those among people, is essential to reshape conservation into a practice that places justice at the centre (Staddon et al., 2023).

Because the previously mentioned concepts were important in shaping my methodologies, I used participatory methods that recognised local knowledge as one of the main guiding elements of my work, with the hopes to give voice and empower local communities as co-benefits besides my own academic objectives. However, I acknowledge the challenges of conducting decolonising research, particularly in ecology where such approaches are still far from common practice. However, through my methodological choices, ethical principles, and conduct in the field, I made a deliberate effort to contribute to decolonising research.

1.2.2 Landscapes as socio-ecological systems

This study employs the Socio-Ecological Systems (SES) framework, developed by Elinor Ostrom (2007; 2009) to explore the dynamics between humans and vegetation. The SES framework is particularly useful for studying the complexity of systems where natural resources are embedded. The SES approach views natural systems as biogeophysical units and social actors and institutions as units that interact, in the social, political, and economic sphere with biogeophysical units (Glaser et al., 2012). The framework breaks SES into the following subsystems: resource system (e.g., miombo woodland), resource units (e.g., *Julbernardia paniculata*), users/actors (e.g., honey producers), and governance systems (organisations and rules that govern forest use), highlighting how these components interact to produce outcomes that affect the entire system and the broader social, economic, and political setting, as well as other SES. This study applies these concepts to the landscape of southeast Angola (with a focus on wooded ecosystems), analysing the resource system and its subsystems (various vegetation types), and the actors/users whilst considering the key role that local knowledge and social structures play in resource management.

In terms of resource management, Ostrom (2009) identifies several conditions that favour effective governance and self-organization in SES. Factors such as moderate territory size, apparent resource scarcity, small group size, evident leadership, and high importance of resources to users, are critical elements for sustainability. Though my thesis does not focus on governance systems, it points out that the communities in southeast Angola appear capable of managing resources sustainably through cooperation and self-regulation. Drawing from Ostrom's framework (2009), I identified that these communities have established boundaries, collective decision-making mechanisms, and possess conflict-resolution systems that support sustainable resource use. However, the current characteristics of this system, this is high resource abundance, low population density and large areas of wooded ecosystems, might reduce the immediate need for self-organization in resource management (Ostrom, 2009).

Why a Socio-Ecological Systems Framework?

Although this thesis primarily focuses on documenting and analysing local ecological knowledge (LEK), the choice to frame it under the broader concept of socio-ecological systems (SES) is both intentional and essential. LEK is not merely a body of environmental observations; it is embedded within the lived experiences, social structures, and adaptive strategies of communities that depend on and manage natural resources. As such, it plays a vital role in shaping and sustaining the dynamics of the SES.

Indeed, LEK is now widely recognised as a core component of SES worldwide, particularly in contexts of biodiversity conservation and natural resource management (Tang & Gavin, 2016). LEK does not operate in isolation from ecological or social processes; rather, it emerges through the interplay between people and their environments contributing to the resilience of socio-ecological systems (Cheveau et al., 2008; Reyes-García, 2015; Gómez-Baggethun et al., 2013).

Importantly, taking a socio-ecological systems perspective enables a more comprehensive understanding of LEK itself. LEK is not only about species identification or vegetation classification, it encompasses resource use patterns, fire regimes, territorial relationships, seasonal cycles, and institutional arrangements. These dimensions are best understood within an SES framework, which explicitly considers feedbacks, adaptations, and linkages between human and ecological systems (Ostrom, 2007).

Finally, the methodological emphasis on participatory research in this thesis reinforces the appropriateness of an SES approach. Understanding SES, particularly in understudied regions like southeast Angola, requires long-term, grounded, and inclusive research practices that value local perspectives and community participation (Tang & Gavin, 2016). Thus, documenting LEK is not an isolated academic objective; it is also an important step to understand how woodlands and fire are experienced, known, used, and managed, socially and ecologically. In this context, studying the socio-ecology of southeast Angola is crucial for developing equitable conservation approaches and for making visible the rights and knowledge of local peoples.

Examples of how I used the SES framework through a mixed method approach are included in Chapter 2, where I contrasted quantitative and qualitative approaches to reveal that vegetation systems are influenced not only by ecological factors but also by social dynamics. In addition, in Chapter 4, I documented narratives from people who experienced the war alongside conducting quantitative analysis of fire regimes, adopting a socio-ecological approach to examine human-fire dynamics.

1.2.3 Scientific knowledge and local knowledge in the context of conservation

This work is grounded in the premise that local ecological knowledge (LEK), though epistemologically distinct from Western scientific knowledge, offers valuable and unique insights that can advance scientific understanding (not to place it in a subordinate position, but simply because this research is framed within a scientific context). Rather than viewing these knowledge systems as incompatible, their differences can create opportunities for mutual enrichment. Their differences are many; LEK is deeply rooted in local contexts and primarily oriented toward sustaining livelihoods, whilst Western science often seeks universality and abstract analysis, often detaching from everyday life (Berkes, 2003). LEK recognises connections across ecological, biological, and geographical phenomena, whilst science tends to isolate variables to understand specific processes (Agrawal, 1995; Berkes, 2012). However, such differences can yield innovative insights through complementarity and co-production of knowledge (Tengö et al., 2014; Nightingale, 2020).

However, LEK continues to be marginalised in ecological and conservation science. Its context-specific and epistemological differences from Western science, which tends to prioritize generalised, large-scale data and short-term studies, make it difficult to incorporate LEK into dominant scientific and institutional frameworks (Johnson et al., 2015; Joa et al., 2018; McGregor, 2004). This marginalisation reflects power asymmetries, where scientific knowledge dominates decision-making processes, often leaving LEK holders vulnerable to exploitation (McGregor, 2004; Barber & Jackson, 2015). Furthermore, calls to 'validate' LEK by scientific standards risk reinforcing its subordination to Western paradigms (Menzies & Butler, 2006).

Meaningful collaboration between LEK and scientific knowledge requires recognising that LEK does not just complement science but offers alternative epistemologies and practical insights (IPBES, 2018a; Albuquerque et al., 2021), as well as addressing power imbalances, and respecting the autonomy and rights of knowledge holders (Molnár & Babai, 2021). Inclusive approaches highlight the value of multidisciplinary methods grounded in customary worldviews, community engagement, and collaborative research to address such challenges (Huntington, 2000; Wilson, 2001). Furthermore, recognising that the application of LEK is shaped not only by internal dynamics (like values, social norms, and ecological conditions), but also by external pressures like economic constraints, state regulations, and dominant forest management policies (Joa et al., 2018) is essential to understand how LEK contributes to conservation in practice.

When combined with scientific methods, local ecological knowledge (LEK) can significantly enhance conservation efforts by aligning interventions with local practices and values, thereby improving community acceptance and sustainability (Schulz et al., 2019; Tengö et al., 2014; Berkes, 2003; Shackeroff & Campbell, 2007). Traditional knowledge systems often incorporate feedback learning and social mechanisms that guide sustainable resource use, fostering adaptability to environmental change (Berkes et al., 2000). Engaging with LEK also supports inclusive, participatory governance models (Armatas et al., 2016; Mason et al., 2012; Menzies, 2006; IPBES, 2018a; Albuquerque et al., 2021) that empower communities and strengthen their role in decision-making (McCall & Minang, 2005; Ogunbameru & Muller, 1996). Importantly, the potential of LEK to support biodiversity conservation and the sustainable use of natural resources is increasingly recognised (Mekonen, 2017; Ens et al., 2015; Cebrián-Piqueras et al., 2020; Shackeroff & Campbell, 2007).

As a consequence of the global recognition of the importance of engaging LEK holders as equal partners in knowledge production, the World Bank and the Millennium Ecosystem Assessment have highlighted LEK's role in sustaining biodiversity. This recognition is formalized in key international agreements, including the Convention on Biological Diversity (CBD), the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which emphasize the recognition and inclusion of local knowledge into environmental governance (Gómez-Baggethun et al., 2013; Sinthumule, 2023). The inclusion of local knowledge in international regulatory frameworks marks a concrete step toward more inclusive science-policy processes (Díaz et al., 2015; Joa et al., 2018), acknowledging the critical contributions of local communities to equitable and sustainable conservation outcomes.

1.3 Savanna and miombo ecology

Understanding the ecology of savannas and specifically of miombo woodlands, as a type of savanna, is essential for interpreting human–environment interactions in southeast Angola. These ecosystems are an essential part of the region’s landscape and support local livelihoods, fire regimes, and resource use. A review of their ecological characteristics provides critical context for analysing how people engage with, manage, and shape these wooded environments.

1.3.1 Savanna ecology

Savannas are ecosystems typically found in tropical and subtropical regions, where a mixture of grasses and a discontinuous tree layer dominates the landscape (Scholes & Archer, 1997; Lehmann et al., 2011). Savannas usually occur in areas with annual rainfall between 500 and

1500 mm, and are shaped by a pronounced seasonality that strongly influences plant growth and ecological dynamics (Bucini & Hanan, 2007; Mistry, 2014). Savannas are highly variable in structure and function (Archibald et al., 2020).

Savanna systems are shaped by multiple interacting drivers, particularly rainfall (or water availability), fire, herbivory, and soil fertility (Scholes & Walker, 1993; Bond, 2008; Mistry, 2014). In general, rainfall controls overall biomass production, whilst nutrient availability shapes vegetation structure and species composition (Lehmann et al., 2011). Fire plays a critical role, especially in savannas with high rainfall, by maintaining an open structure and preventing tree encroachment, particularly in regions with an extended dry season which increases flammability (Archibald et al., 2010; Bond & Keeley, 2005; Staver et al., 2011; Bond, 2008). Herbivory also shapes vegetation patterns by influencing species composition and reducing fuel loads for fire (Bond & Keeley, 2005). However, the loss of megafauna particularly in Africa, has shifted disturbance regimes more toward fire (Archibald et al., 2020). Rainfall in savannas is seasonal and often unpredictable, which, coupled with nutrient-poor soils, poses challenges for more than one-fifth of the global population that live in or near savannas (Mistry, 2014). In regions where rainfall alone could support closed forests, regular disturbance is key to preserving the savanna form (Lehmann et al., 2011).

The heterogeneity of savannas, both spatially and temporally, for long has resulted in different understanding and definitions of savannas. Topography, drainage, and disturbance (e.g., fire, grazing, and land use) promote fluctuating boundaries over time and mosaics of vegetation, from grass dominated areas to wooded areas with grassy understories (Bucini & Hanan, 2007; Mistry, 2014; Archibald et al., 2020). Because of this complexity, definitions of savannas vary, some are based on vegetation structure, others on functional traits like C4 grass dominance or life-history characteristics of woody plants (Sankaran et al., 2005; Ratnam et al., 2011). However, structural definitions do not fully capture what savannas are or how they function (Ratnam et al., 2011; Veldman, 2016). Indeed, some savannas have historically been thought to be degraded forests, but paleoecological evidence suggests that many are ancient and natural ecosystems (Mistry, 2014).

Despite their ecological importance, savannas remain difficult to define, map, and monitor, particularly using remote sensing, which tends to rely on arbitrary woody cover thresholds (Archibald et al., 2020). This is the case for distinguishing between degraded forests and naturally open woodlands (Veldman et al., 2015; Bucini & Hanan, 2007), which has implications for management and conservation (Anadón et al., 2014; Honda & Durigan, 2016).

Savannas have been shaped for millennia by human activities. Fire use for agriculture, hunting, and landscape management, along with grazing and harvesting of wild resources, are essential components of savanna dynamics (Laris, 2011; Archibald, 2016). Rather than being viewed as threats, these practices often maintain biodiversity and ecological resilience. A better understanding of savannas might thus be offered through their understanding not only in terms of their structural and ecological processes but also through the lens of how they are socially and culturally constructed (Mistry, 2014). Local perceptions of savannas, and the knowledge and practices to manage them, are critical to understand how these landscapes function and change over time. This emphasises the importance to understand savannas as coupled human-environment systems for their sustainable management (Mistry, 2014; Veldman et al., 2015). In the African context, especially in mesic areas like southeast Angola, miombo woodlands, a type of savanna, exemplify the complex interplay between vegetation, fire, and human activity.

1.3.2 Miombo ecology

Miombo woodlands are the most extensive tropical seasonal woodland formation in Africa, spreading across seven countries in southern Africa and covering an estimated 1.9 million km^2, whilst being home to nearly 250 million people (Ribeiro et al., 2020a). These woodlands serve as a transitional ecosystem between the humid forests of the Congo Basin and the semi-arid savannas of southern Africa, and they dominate the landscape in countries such as Angola, Zambia, Mozambique, and Tanzania (Vinya, 2010).

Ecologically, miombo is characterized by a distinct dominance of tree species in the Fabaceae family, especially the Detarioideae subfamily, including the genera *Brachystegia*, *Julbernardia*, and *Isoberlinia* (Frost, 1996). These trees form open to closed woodlands interspersed with a grassy or shrubby understory. Miombo vegetation contains many fire-adapted plant species, as fire plays a critical role in shaping miombo structure and species composition (Chidumayo, 1997; Ryan et al., 2016). Structurally, miombo woodlands vary from dense woodlands to open landscapes with scattered trees and bare soils, depending on climate, topography, and disturbance regimes (Ribeiro et al., 2015), whilst floristically tree species distribution seems to be influenced by edaphic gradients (Chidumayo, 1997). Such variability has led to a wide range of definitions in the literature (Table 1.1).

Table 1.1. Definition and main characteristics of miombo woodlands according to different authors

Author	Definition
Morris, 1970	Miombo woodlands are a secondary type of vegetation that has successfully asserted itself and assumed a degree of stability on degraded and impoverished soils. This woodland is a plagioclimax community formed and maintained by continuous human activities.
Freson et al., 1974	Miombo woodland is the sub-climax to evergreen or semi-evergreen forest, maintained as such by frequent fires and exploitation by people and wildlife.
Lawton, 1978	Miombo woodland is regarded as a vegetation that has transitioned from past vegetation types to miombo, and has been maintained by humans through a long history of cutting, cultivation and frequent dry season fires over the last 55 000 years.
Malaisse, 1978	Miombo woodland is characterized by the widespread occurrence of the tree genera *Brachystegia*, *Julbernardia* and *Isoberlinia.*
Huntley, 1982	Miombo woodland is a moist-dystrophic savanna.
Walker 1981	Over most of its range, mature undisturbed miombo woodland is a closed deciduous woodland within the spectrum of savanna ecosystems.
White, 1983	Miombo woodland is nearly always dominated by species of *Brachystegia*, either alone or with *Julbernardia* or *Isoberlinia*, and these dominants rarely occur in other vegetation types.
Frost et al., 1986	Miombo woodlands represent those tropical and near tropical ecosystems characterised by continuous herbaceous cover consisting mostly of C4 grasses and sedges that show seasonality related to water stress. Woody species occur but seldom form a continuous cover paralleling that of the grassy layer.
Campbell, 1996	Miombo woodlands refer to the central, southern and eastern African woodlands dominated by the genera *Brachystegia*, *Julbernardia* and/or *Isoberlinia*. They generally occur on geologically old, nutrient poor soils in the uni-modal rainfall zone. Miombo woodland is a closed deciduous woodland within the spectrum of savanna ecosystems, grading into seasonal dry forest at above 1200 mm mean annual precipitation. The main feature of miombo vegetation is the dominance of *Brachystegia*, *Julbernardia* and *Isoberlinia*.

Frost, 1996	Miombo woodland is the most extensive tropical seasonal woodland and dry forest formation in Africa, receiving >700 mm mean annual rainfall on nutrient-poor soils. Miombo woodlands is distinguished by the dominance of tree species in the genera *Brachystegia*, *Julbernardia* and *Isoberlinia*. These genera are seldom found outside miombo. The diversity of canopy tree species is low, although the overall species richness of the flora is high.
Rodgers, 1996	Miombo woodlands are classified into three major categories: 1) the *Brachystegia* woodland or proper miombo; 2) a community typical of greater fire intensities called 'chipya' in northern Zambia and southwestern Tanzania, or 'Chao' in southeast Tanzania; 3) a less common thicket/forest climax community called 'msitu' in Tanzania and 'mushitu' in Zambia. These three types exhibit divergent structural and compositional entities depending on rainfall patterns.
Chidumayo, 1997	Miombo woodland is characterised by the presence of leguminous trees of the genera *Brachystegia*, *Isoberlinia* and *Julbernardia*. Edaphic gradients determine the distribution of miombo species and edaphic changes can occur over short distances and result in complex patterns of species dominance.
Campbell et al., 2007	Miombo woodland is characterized by the trees *Brachystegia*, *Julbernardia* and *Isoberlinia*. Patchy occurrence of resource-rich vegetation types (forests) and *Terminalia* patches on deep sands within the miombo also occur.
Banda et al., 2008	The tendency to lump the miombo woodland into a relatively uniform ecosystem based on the dominance of three genera (*Brachystegia*, *Julbernardia*, and *Isoberlinia*) is too coarse. These genera are not representative of all miombo ecosystems and ecosystem may be more diverse than previously described.
Vinya, 2010	Miombo woodlands form a transitional system between the closed rainforests in central Africa and open semi-arid savannas of southern Africa. These woodlands represent the most extensive savannah woodland type.
Kutsch et al., 2011	Tree cover in miombo exceeds 40%, a threshold that separates the open savannas from the more closed woodlands, and where mean annual precipitation exceeds 800 mm, tree cover may be larger than 60%.
Ratnam et al., 2011	Many of miombo woodlands have a flammable grassy understorey and thus, are also considered to be a form of savanna.
FAO, 2012	Miombo woodlands represent one of the largest areas of global tropical dry forests, defined as vegetation formations experiencing a tropical climate with summer rainfall and a dry period of 5–8 months.
Ribeiro et al., 2015	Miombo woodlands are characterised by the dominance of *Brachystegia*, *Julbernardia* and *Isoberlinia*, associated with a variety of other woody plants such as *Pseudolachnostylis maprouneifolia, Burkea africana* and *Diplorynchus condylocarpon*. Differences in species composition, diversity and structure occur at the local scale.
Pennington et al., 2018	The African miombo woodlands that have traditionally been termed 'forests', are better regarded as savannas than dry forests. They have an open structure with a grassy ground layer and regularly burn.
Ribeiro et al., 2020b	Miombo woodlands are defined by low tree diversity with a majority of tree species belonging to the genera *Brachystegia*, *Isoberlinia* and/or *Julbernardia*. After the three dominant species, the other frequent vegetation categories are 1) *Hymenocardia*/*Uapaca* miombo, 2) *Diplorhynchus* miombo, and 3) *Combretum* miombo. The geographic distribution of these units is intermingled. Areas of intergradation are usually ecotones that occur both at local and regional scales.

Gumbo & Dumas-Johansen, 2021	Over the last 40 years, it is the uniformity of the dominance of genera *Brachystegia*, *Julbernardia* and *Isoberlinia* that best determine the description of miombo. In addition, the existence of species from any two of the three genera may help determine whether is wet or dry miombo.

The soils supporting miombo are typically nutrient-poor, acidic, and low in organic matter and exchangeable bases (Frost, 1996; Chidumayo, 1997; Mendelsohn & Martins, 2018). Infiltration and percolation rates are generally high (Ribeiro et al., 2020b). Miombo woodlands are shaped by a tropical climate with a distinct wet and dry season (Chidumayo, 1997; Ribeiro et al., 2020b). Annual rainfall ranges between 600 and 1500 mm (Malmer, 2007).

Despite their low productivity, miombo ecosystems harbour high levels of species and genetic diversity (Ribeiro et al., 2015). However, anthropogenic pressures can impact their integrity. Drivers of landscape change include agricultural expansion, population growth, urbanization, infrastructure development, woodfuel demand in urban areas, resettlement due to political reasons or conflict, and extractive industries (Campbell & Byron, 1996; Chidumayo, 1997; Frost, 1996; IPBES, 2018b). Small-scale shifting cultivation, whilst traditionally reversible and spatially diffuse, has increasingly led to permanent land conversion as farmers transition to sedentary or market-oriented agriculture (Zulu et al., 2020; Marchant et al., 2018).

An estimated 61–91% of miombo woodlands experience some form of degradation (Sileshi et al., 2007), and undisturbed woodlands are now rare (Misana et al., 1996). Woodland clearance has direct implications for biodiversity, soil conservation, and the ability of local communities to sustain their livelihoods, especially under growing climatic stress (Campbell & Byron, 1996).

Globally, only 31% of miombo woodlands are under some form of protection (IUCN and UNEP-WCMC, 2019). In Angola, where miombo woodlands are the dominant woodland type covering over 60% of the territory (Malmer et al., 2007; WBG-ENR, 2019), only 6% are formally protected. Southeast Angola, which includes extensive miombo woodlands, remains one of the least studied ecosystems and it is not under formal protection. It is here that initiatives, such as those led by the Wild Bird Trust with the National Geographic Society, are beginning to collect ecological data with the aim to develop conservation strategies. As research and conservation efforts intensify in southeast Angola, understanding the complex socio-ecological dynamics of miombo ecosystems, especially their responses to fire and human use in general, will be essential for sustaining both biodiversity and rural livelihoods.

1.4 Angola

1.4.1 Setting the context: generalities of Angola

Angola is a rich country in terms of history, culture, natural resources and biodiversity, that has undergone long periods of political instability. In 1961 a war against the Portuguese regime began, and in 1975 the country gained its independence. However, towards the end of the independence war, differences among national groups (motivated in part by ethnic tensions and in part by international interests) were difficult to reconcile and soon after the independence war ended, a 27-year civil war unfolded (World Bank, 2019). At its end, the civil war displaced over four million people and took the lives of up to a million people (Beaumont, 2023). The conflict also had large negative effects in the environment and in wildlife populations (Breytenbach, 2001). Almost two decades after the end of the war, Angola remains one of the most heavily landmine-contaminated countries in the world (Vandome, 2019). The legacy of the conflict continues to shape the country's social, political and economic dynamics.

Angola has 18 provinces, and its population is concentrated in only five provinces. 53% of the population lives in Luanda, Huila, Benguela, Huambo and Cuanza-Sul (Instituto Nacional de Estatística, 2018) where wealth and development are concentrated. Around 32% of the population is considered to live under poverty (poverty defined as 'anyone living on less than $2.15 a day'; World Bank, 2020a). Although many rural regions in Angola remained remote and sparsely inhabited during the war (Zweede et al., 2006), about 37% of the population currently live in these areas, where poverty is more pronounced (Oglethorpe et al., 2018; World Bank, 2019). In rural areas, subsistence agriculture, charcoal production, and fishing provide the main livelihood for most people, although in urban centres half of Angola’s food is imported (Oglethorpe et al., 2018). Rural municipalities have not been able to keep pace with demand for basic services, such as health and education (Pröpper et al., 2015). Angolan population has a strong dependence on natural resources including wood and wildlife products (Oglethorpe et al., 2018), and around 80% of the population depends on tree biomass to meet their energy and livelihood needs (World Bank, 2019). The reliance on tree biomass underscores the critical role of land and resource access in sustaining livelihoods.

Angola’s biological diversity is one of the richest in Africa. Angola occupies 4% of the terrestrial area of Africa, yet it possesses one of the highest diversity of biomes in the continent and is second to South Africa in terms of the number of ecoregions found within its borders (Huntley & Ferrand, 2019). Climatic diversity in combination with soil ecological variability contributes to the formation of bioclimatic zones that produce a range of vegetation from dense tropical forests to deserts, and provide habitat for a high level of biological diversity (CBD, 2024). This rich ecological variation is reflected in Angola’s extensive woodland system which covers 46% of the country (World Bank Group, 2024). Among these, miombo has been identified as the dominant type of woodland (Malmer, 2007).

However, Angola’s deforestation rate is estimated at 0.4% per year (CBD, 2024). Wooded ecosystems are under threat from increasing charcoal production and clearing for agriculture (Chiteculo et al., 2018) whilst conservation areas (13 in total) represent 6.6% of the country’s surface. Angola accounts for 17% of the Kavango-Zambezi Trans-Frontier Conservation Area, the largest in the continent (Vandome, 2019).

Angola is one of the countries in southern Africa with the fewest scientific studies, particularly on wooded ecosystems, the dominant ecosystems in the country (David et al., 2022; Huntley & Ferrand, 2019). As Angola gradually rebuilds peace and stability, research opportunities are reopening. However, the legacy of colonialism continues to influence various aspects of Angolan life, including negative perceptions of local peoples’ interactions with vegetation. Moreover, whilst national and international pressures to address environmental uncertainties (e.g., climate change and deforestation) are pushing for formal conservation mechanisms, the country still falls behind other African countries in this regard. Meanwhile, rapid land use change and land-use intensification post-civil war are contributing to habitat degradation and loss, further complicating conservation efforts.

1.4.2 Current vegetation maps of Angola

To date, several vegetation maps of Angola have been produced, each employing different classification systems and spatial resolutions. Despite these differences, most agree in identifying southeast Angola as being predominantly covered by miombo woodlands and savanna ecosystems (Figures 1.1, 1.2 and 1.3).

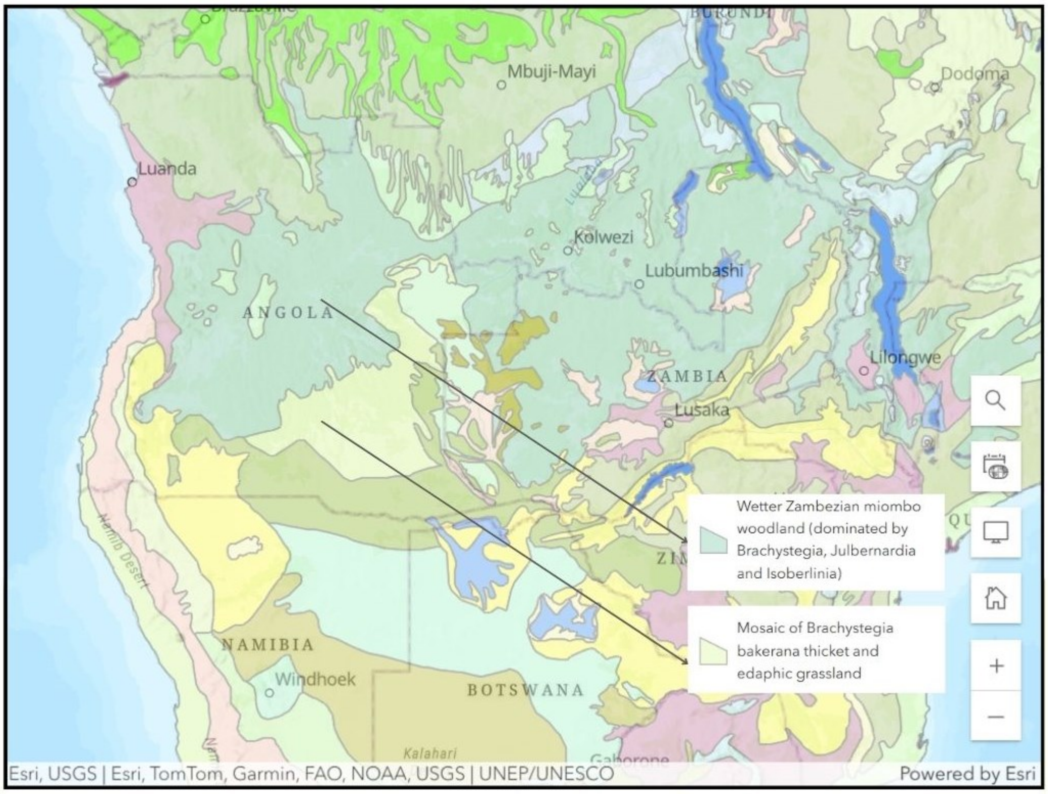

Figure 1.1. Whites' (1983) floristic regions and mapping units of Africa. Angola falls within the Zambezian regional centre of endemism

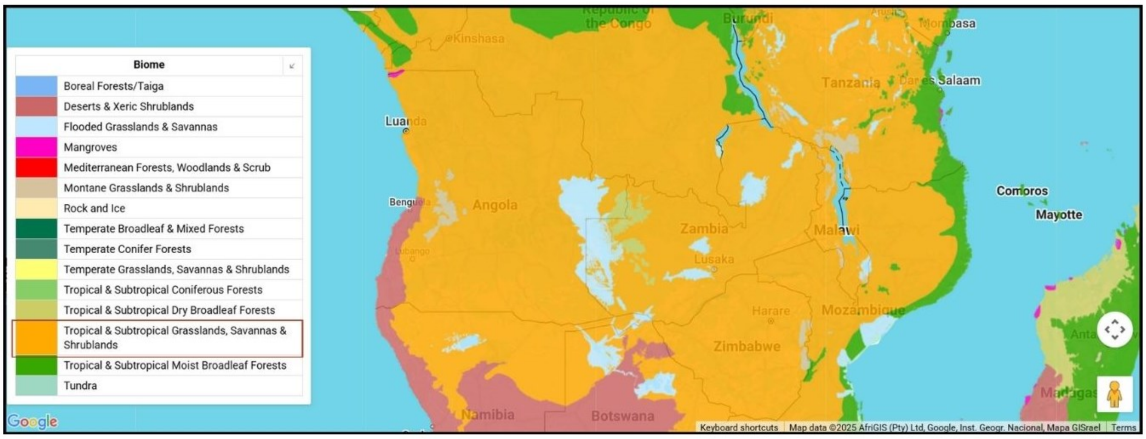

Figure 1.2. Olson et al. (2001) maps of terrestrial biomes in Angola. Angola is shown as predominantly a tropical and subtropical grassland, savanna and shrubland.

Figure 1.3. Dinerstein et al. (2017) & Burgess et al. (2004), maps of ecoregions of Angola, where southeast Angola falls under the miombo woodland classification.

1.4.3 Climate patterns in Angola

Angola experiences a strongly seasonal tropical climate, shaped by both latitude and altitude. The rainy season, lasting from October to May, coincides with the hottest period of the year, with average temperatures between 22–23°C (World Bank, 2025). The dry season, known as *cacimbo*, spans from June to September and is the coolest period, with temperatures averaging 18–20°C (Huntley et al., 2019a). Rainfall varies geographically, decreasing from northeast to southwest. Altitude further regulates both temperature and precipitation, leading to cooler and wetter conditions in highland areas (Huntley et al., 2019a; World Bank, 2025). Data on extreme minimum temperatures and frost occurrence remain scarce, limiting the understanding of climatic influences on vegetation (Zigelski et al., 2019). Temperature factors, along with fire and herbivory, are critical in shaping the floristic composition and structure of Angola's ecosystems (Zigelski et al., 2019; Huntley et al., 2019a).

Angola is increasingly vulnerable to climate change, facing more frequent and severe hazards, particularly flooding and droughts, which have been the most common natural disasters between 1980 and 2020 (World Bank, 2025). The southern region has experienced some of the worst droughts in decades (Correia et al., 2025). Recent climate analyses show a warming trend (Pinto et al., 2023; Carvalho et al., 2017), with projections of more frequent, prolonged, and intense heatwaves and a rise in both maximum and minimum temperatures across the country (Soares et al., 2024). Rainfall is expected to decrease overall, particularly in the southern region, with rainfall reductions of up to 300 mm (Carvalho et al., 2017), whilst the number of consecutive dry days is projected to increase, especially in the northeast (Correia et al., 2025). Additionally, the number of days above 30°C is expected to increase (Pinto et al., 2023).

Angola is considered highly vulnerable to climate change due to a combination of high climate variability, widespread poverty, weak infrastructure, and low adaptive capacity (Soares et al., 2024). These factors make the country vulnerable to extreme heat, droughts, and changing rainfall patterns, with possible repercussions on health, food security, water resources, and ecosystems (Correia et al., 2025; Pinto et al., 2023). Such climate trends also threaten Angola's agricultural sector, which accounts for the livelihood of the majority of the population (Soares et al., 2024). The poorest populations are particularly at risk due to their greater exposure and their limited capacity to adapt (Climate Watch, 2024).

1.4.4 Colonial and postcolonial history of Angola: land governance

Land plays a central role in Angola's political, economic, social, and cultural life (Pacheco, 2004). Although recent years have seen signs of power decentralisation (Oglethorpe et al., 2018), the country's land tenure system remains highly centralised and strongly influenced by its colonial and socialist legacies (Carranza & Treakle, 2014; Satgé & Castro, 2022). The Land Law (Lei das Terras, 2004) reserves all permanent land tenure rights to the state (Zweede et al., 2006), reflecting a continuation of state control over land. Whilst most rural land is held under customary arrangements, customary law is not recognised in statutory frameworks, resulting in significant tenure insecurity (Pröpper et al., 2015). For many Angolan ethnic groups, land has historically been regarded as sacred and communal, an understanding that contrasts with colonial systems based on legal title and commodification (Carranza & Treakle, 2014). Local communities retain access rights to forest resources for subsistence, though these do not extend to formal commercial use (World Bank, 2019).

Before European colonization, land governance in Angola was rooted in customary tenure, managed locally by kin-based authorities. These systems varied regionally and reflected strong relationships between communities and their land (Satgé & Castro, 2022). Portuguese colonial involvement in Angola began in the 1500s, primarily to support the slave trade, but from 1838, land policies increasingly dispossessed Angolans of their land, undermining customary rights and transferring ownership from local communities to settlers and making customary tenure legally irrelevant (Chikohomero & Modupe, 2018). In 1907, the establishment of reserves pushed rural populations onto marginal lands, and later large-scale settler plantations dominated, backed by regulatory frameworks that excluded customary land ownership (Satgé & Castro, 2022; Carranza & Treakle, 2014). During the war of independence, this pattern intensified, when forced relocation displaced rural populations from their ancestral lands, further disrupting traditional ties to territories and reinforcing colonial control (Satgé & Castro, 2022).

After independence in 1975, attempts to centralise power and establish a socialist state enabled the government to assert control over privately own properties (Ercolessi, 2011). However, the civil war (1975–2002) meant that land policy was not a priority, and efforts to address colonial injustices were restricted. The war displaced over four million people, destroyed infrastructure and land records, and left a great extension of rural land unsafe due to landmines (Satgé & Castro, 2022; Chikohomero & Modupe, 2018). However, in the central highlands and southeast Angola, the collapse of formal state institutions allowed customary tenure systems to persist (Foley, 2007).

In 1992, Angola passed a Land Law that attempted to formalize land tenure by introducing the concept of *usucapião* (beneficial occupation) and by recognising diverse tenure forms (Satgé & Castro, 2022). However, a centralised orientation was maintained, requiring land to be used for national development, and failing to address informal urban settlements, communal land, and the legal status of customary authorities (Satgé & Castro, 2022; Foley, 2007). During the transition to a market economy in the 1990s, large areas of former colonial and state farms were privatized, often benefiting political and military elites (Foley, 2007; Birmingham, 2015). Meanwhile, land continued to change ownership through informal transactions, abandonment, illegal occupation, or inheritance, leading to overlapping statutory and customary claims and complicating legitimate ownership (Foley, 2007). Although independence enabled some families to reclaim ancestral land, rural areas remained marginalised by urban development policies and weak legal recognition of customary practices (Satgé & Castro, 2022).

The 2004, Land Law marked a turning point in Angola's land governance, aiming to formalize tenure systems, promote economic development, and recognise customary rights (Foley, 2007). Whilst it reiterated state ownership of all land, it also acknowledged the role of *sobas* (traditional authorities) in rural land management (Chikohomero & Modupe, 2018; Satgé & Castro, 2022). Despite these legal reforms, implementation has remained weak. Most rural land continues to be accessed informally through customary inheritance, social relations, and allocation by *sobas*, often without formal documentation (Carranza & Treakle, 2014). Although the 2010 Constitution affirmed customary land rights, tenure insecurity persists due to the lack of demarcation, legal recognition, and institutional support (Satgé & Castro, 2022; Foley, 2007).

In southeast of Angola, customary systems are still important, especially since state administrations are weak or nearly absent, and village elders typically allocate land to local residents. However, this customary system lacks formal legal recognition, leaving communities vulnerable to expropriation and allowing the state to retain the right to reallocate land for development (Foley, 2007). For instance, in the country over 300 land reserves (areas of land formally designated by the state for specific uses like forestry or agriculture) have been declared, and many of them overlap with customary territories (Satgé & Castro, 2022; Pacheco, 2004). Overall, weak formal institutions have left traditional authorities to fill governance gaps, but their norms often diverge from statutory law. Without alignment between legal frameworks and customary practices, as well as a focus on equitable access and tenure security for vulnerable rural populations, land-related tensions are likely to persist (Foley, 2007; Chikohomero & Modupe, 2018).

1.4.5 Conservation in Angola

Formal conservation was not a widespread concern in Angola until colonial times. During the colonial administration, emblematic species such as the Giant Sable Antelope and *Welwitschia mirabilis* received protection, and the first protected areas in the form of National Parks and Game Reserves in the country came in 1936 (Huntley et al., 2019b). However, during the civil war wildlife populations greatly decreased and Angola's national parks were severely impacted (CBD, 2024). By 1988, the IUCN listed Angola's entire protected area network as threatened (Russo et al., 2022). In the early 2000s, the National Biodiversity Strategy and Action Plan was created, and the network of protected areas expanded to 115 000 km^2 (Figure 1.4), supported by the Convention on Biological Diversity (CBD, 2010). Today, most protected areas continue to face significant challenges, including limited funding, weak technical capacity, and a shortage of trained staff (Oglethorpe et al., 2018; African Development Bank Group, 2009). Currently, Angola has 14 protected areas, with one in Moxico province: Cameia National Park.

Since the start of the civil war, hunting for bushmeat has been a major driver of wildlife population declines, alongside the illegal trade in wildlife products such as ivory, rhino horn, and teak (Huntley et al., 2019b). Whilst illegal wildlife trade has been relatively well documented, a much larger and unmonitored trade in timber has surged in past years (Huntley et al, 2019b). In response to the global collapse of oil prices, Angola issued decrees in 2016 that opened large parts of the country to timber concessions, many granted to international companies (African Development Bank Group, 2009). This has resulted in accelerated timber extraction and has led to extensive deforestation (Mendelsohn, 2019). Although land transformation and deforestation may now be the most significant drivers of biodiversity loss in Angola, their impacts remain unquantified (Huntley et al, 2019b).

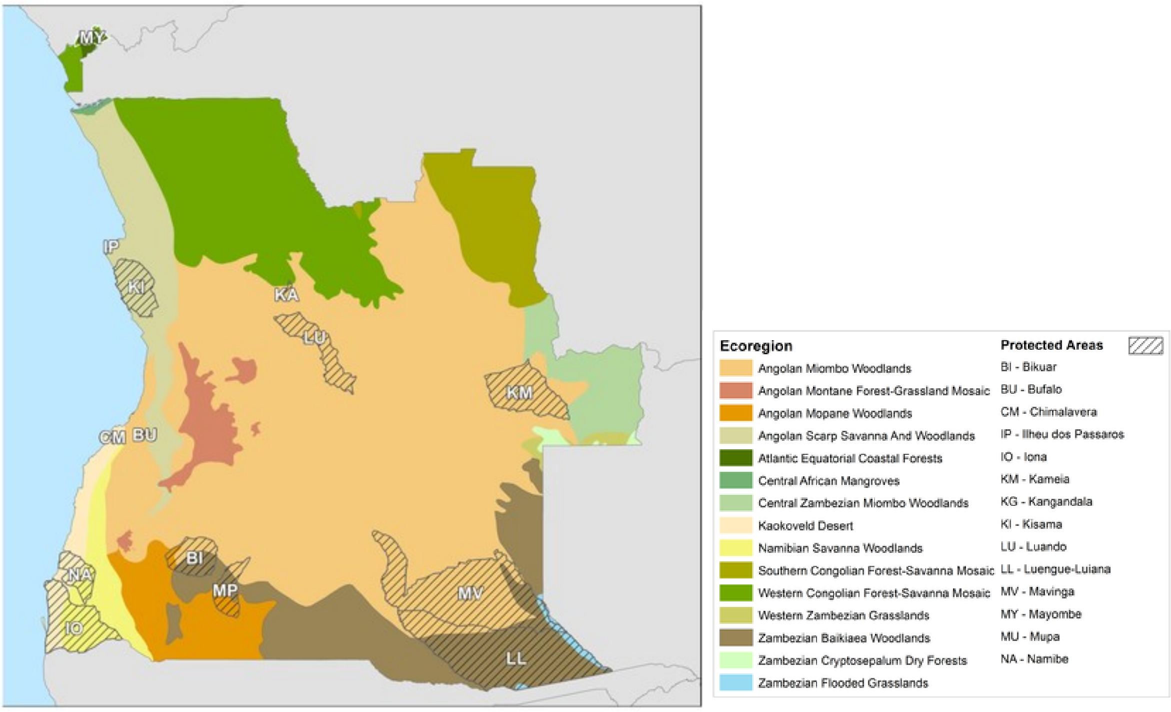

Figure 1.4. Protected areas in Angola (Olson et al., 2001).

According to some scholars, and in line with international conservation targets, a key conservation priority in Angola is to expand the country's protected areas and to secure protection for its critically endangered biodiversity hotspots, including the escarpment forests, central highlands, and northern border regions, (Russo et al., 2022; Huntley et al., 2019b). However, protecting biodiversity cannot be isolated from its socio-ecological context. Conservation and research must engage with the human dimensions that shape ecological outcomes. Understanding socio-economic drivers such as the transition from subsistence to cash economies, the bushmeat trade, slash-and-burn agriculture, charcoal production, and nomadic pastoralism is essential (Russo et al., 2019). As I have mentioned above, these efforts should incorporate local knowledge into management and research. At a broader scale, updating Angola's vegetation maps is essential for informed land-use planning and conservation (Russo et al., 2019; Huntley et al., 2019b). Expanding partnerships with institutions involved in biodiversity research and conservation can strengthen conservation efforts as well (Russo et al., 2022).

Angola's conservation efforts are supported by regulatory frameworks, including the Environmental Law, the Forest and Wildlife Law, the Environmental Conservation Areas Act, and the National Biodiversity Strategy and Action Plan (2019–2025). Although Angola has established a legal framework for conservation, it has historically overlooked community rights to wildlife and cultural heritage (Russo et al., 2022). Recent legislation, such as the Environmental Conservation Areas Act and the Biodiversity Strategy (2019–2025), has begun to address this by promoting community participation and identifying priority areas for protected area expansion, including in Moxico. However, the implementation of these initiatives is constrained by limited regulatory support for community-based management, institutional weaknesses, and gaps in ecological knowledge (Oglethorpe et al., 2018; Russo et al., 2022). The implementation of these rights is further complicated by persistent gender inequities, limiting women's participation in natural resource governance (Oglethorpe et al., 2018; Russo et al., 2022).

1.4.6 Current role of the state in resource management

The Angolan state retains centralized authority over natural resource management through the Ministry of Agriculture and Forestry (Ministério da Agricultura e Florestas) and the Ministry of Environment (Ministério do Ambiente). These institutions are responsible for establishing legal frameworks, issuing resource extraction licenses, and overseeing forest and biodiversity conservation (Ministério do Ambiente, 2025). However, in practice, the state's presence in rural and remote areas is often limited due to historical legacies of conflict, institutional weaknesses, and logistical constraints (African Development Bank Group, 2009; Oglethorpe et al., 2018).

The Law on Forests and Wildlife (2017) outlines the principles for sustainable forest and wildlife management. It recognises subsistence and communal forest use as free and exempt from permits, including small-scale extraction for subsistence activities. The Law also introduces the concept of ‘community forests’, enabling local management of forests on communal lands, though these are not yet operational. Pilot efforts are underway in Moxico and Cuando Cubango (Russo et al., 2022). Although Angola has 18 forest reserves (six in Moxico, covering 865,000 ha) these date back to the colonial era, and no new reserves have been formally added since (SARDC, SADC & IUCN, 1994).

1.4.7 Customary rules, traditional beliefs and natural resource governance in Angola

Despite a legal framework that allocates land ownership to the state, customary rules and traditional authorities remain central to natural resource governance in Angola, particularly in rural areas where formal state presence is limited and where rural communities remain highly dependent on natural resources for their livelihoods (UNDP, 2017). Customary systems of governance are embedded in cultural understandings of nature and historically, Angolan communities have managed resources through a combination of customary rules, religious beliefs, and moral obligations that link people to the land (Satgé & Castro, 2022). Such beliefs inform practices around subsistence use and communal access, forming longstanding systems of community-based natural resource management (Oglethorpe et al., 2018).

In such systems, *sobas* (traditional leaders) play a key role in land allocation, resolving disputes, coordinating local communities, and overseeing the use of natural resources (Russo et al., 2022). Importantly, their authority is recognised in Angola’s 2010 Constitution and supported by the National Policy on Forests, Wildlife, and Conservation Areas, which emphasizes community involvement in natural resource management and poverty alleviation through sustainable use.

However, customary institutions and belief systems have been weakened by colonial land expropriation, war and displacement, population growth, and expanding market access (Foley, 2007). Many communities were displaced during Angola’s conflict, and although subsistence activities have resumed under traditional authorities in many areas, the loss of traditional control mechanisms has created vulnerabilities, especially where new commercial pressures (e.g., charcoal, bushmeat, wildlife trade) have emerged (Oglethorpe et al., 2018). In some areas, *sobas* continue to play an effective role in regulating access and managing community resources, whilst in others, customary rules have not proved adequate against external pressures, weakening communal authority. Overall, Angola's traditional governance systems reflect a dynamic interplay between cultural beliefs, customary practices, and state regulations. Recognising customary practices is crucial for fostering inclusive and sustainable resource management in the country.

1.4.8 Fire in Angola

Approximately 70% of the global burned area occurs in Africa (Van der Werf et al., 2010; Giglio et al., 2013) and within Southern Africa, Angola, Zambia, and Mozambique experience the highest fire activity (Archibald et al, 2010). Remote sensing studies suggest that nearly 50% of Angola's surface area burns every two years during the dry season between May and October, with notable spatial and temporal variation (Archibald et al., 2010; Stellmes et al., 2013), and with most fires being anthropogenic (Catarino et al., 2020). Despite growing interest, research on Angola's fire ecology remains limited due to decades of conflict, landmine contamination, and inaccessibility (Huntley & Ferrand, 2019). Moreover, the social dimensions of fire management remain poorly understood and represent a critical research gap (Loft et al., 2024).

In the southeast highlands of Moxico, fire regimes diverge from national patterns. Here, dense woodlands often experience low fire frequencies, with some areas remaining unburned for several years (Lourenço et al., 2023), or with as little as 10% of the region burning in a 10-year period (Stellmes et al., 2013). However, recent observations indicate that fire intensity may be increasing in these areas, with Moxico showing an upward trend (Catarino et al., 2020). At the same time, in some forest-savanna transition zones, fire recurrence appears to be decreasing due to policy, migration, and cultural change (Quissindo, 2021). Whilst such shifts may appear beneficial in terms of reducing burnt resources, they can lead to vegetation changes or degradation if they undermine local knowledge systems and management practices.

Uses of fire in Angola

In Angola, most fire is deeply embedded in subsistence and livelihood strategies, including agricultural practices, hunting, cattle grazing, harvesting of natural resources (e.g., caterpillars and honey), pest control, and clearing around villages (Nieman et al., 2024; Meller et al., 2022; Eriksen, 2007; Shaffer et al., 2010). Fire is also used in cultural and spiritual rituals (Quissindo, 2021). In Angola, fire regimes are also closely tied to population dynamics. Population growth, increased demand for forest resources, and shifting cultivation practices intensify fire pressure, particularly in savannas and along forest edges where vegetation becomes more flammable (Catarino et al., 2020; Powell et al., 2023). In rural areas, where external support is limited and subsistence needs are high, fire remains the most economical and accessible land management tool (Catarino et al., 2020). In the miombo woodlands shifting cultivation is widely practiced due to poor, sandy soils with low water retention, limited access to fertilizers or modern techniques, and variable rainfall, and in this context, cutting and burning vegetation (slash and burn) helps prepare fields and restore soil nutrients (Wallenfang et al., 2015).

The timing and type of fires reflect land management objectives. Grasslands are typically burned in the early dry season (June–July) to facilitate hunting or clear village surroundings, whilst woodlands are burned later (August–September) to prepare agricultural fields (Meller et al., 2022; Schneibel et al., 2013; Catarino et al., 2020). Late-season fires, often more intense due to drier fuels, can escape control and affect large areas (Govender et al., 2006; Laris et al., 2017).

Whilst fire has historically been used sustainably in many parts of Angola, recent shifts, driven by demographic change, climate variability, rural depopulation, and fire suppression policies, have disrupted long-standing fire regimes which can threaten biodiversity and woodland structure (Powell et al., 2023; Archibald, 2016). Indeed, there is a global trend of declining subsistence-oriented fire use and increasing market-oriented fire practices (Smith et al., 2024).

Despite its utility, fire has often been negatively portrayed, particularly in conservation and policy narratives. This negative framing likely originated in colonial times, where fire was seen as destructive of forests valued by colonial governments (Rodriguez et al., 2013; Mistry et al., 2016; Rodriguez, 2007; Laris & Wardell, 2006). These perspectives shaped fire suppression policies that persist today (Laris, 2002; Eriksen, 2007). As a result, younger generations in many parts of the world often lack experience with traditional fire use and are more inclined to favour fire suppression (Mistry et al., 2005; Rodriguez et al., 2013; Martínez-Torres et al., 2016; Copes-Gerbitz et al., 2021). Furthermore, bias against local fire knowledge persists in academic and policy circles (Bowman, 1998; Shaffer, 2010). Despite such perspectives, many traditional fire regimes are based on deep ecological understanding and involve early dry season burns, selective late burning, and the intentional preservation of unburned patches, strategies that contribute to fire resilience and ecological health (Laris, 2002; Christianson, 2015). But the loss of local ecological knowledge related to fire complicates effective landscape management. In southeast Angola, many communities use fire knowledge to manage the landscape, however, prolonged periods of conflict along with colonial-rooted negative narratives around fires have disrupted local fire practices.

1.4.9 Southeast Angola: Ecological importance

Southeast Angola, one of the country's least populated and most rural areas (World Bank, 2020b), is notable for its putatively undisturbed natural landscapes (Pröpper et al., 2015; Zweede et al., 2006). This area is crucial for the health of water systems in south-central Africa, as their landscapes are sources and tributaries for some of southern Africa's most important rivers. These rivers include the Upper Zambezi, which feeds Victoria Falls among several other important conservation areas; the Cuando, which feeds the Linyanti wetlands in Namibia and Botswana; and together with the Cubango river, feed into the Okavango Delta in Botswana (Vandome, 2019).

I conducted my study in southeast of Angola, in the highlands that are mostly in the Moxico province with a smaller portion in the Bié and Cuando Cubango provinces. The Moxico province has an estimated population of 935 649 inhabitants (Instituto Nacional de Estatística, 2014), with the lowest population density of the country at 0.3 person/km^2. The work I conducted in the ground was done in the Luchaze municipality in the Moxico province, which has only 1.8% of the total Moxico population. Remote sensing analysis in this thesis included the whole area of the highlands (red polygon in Figure 1.5).

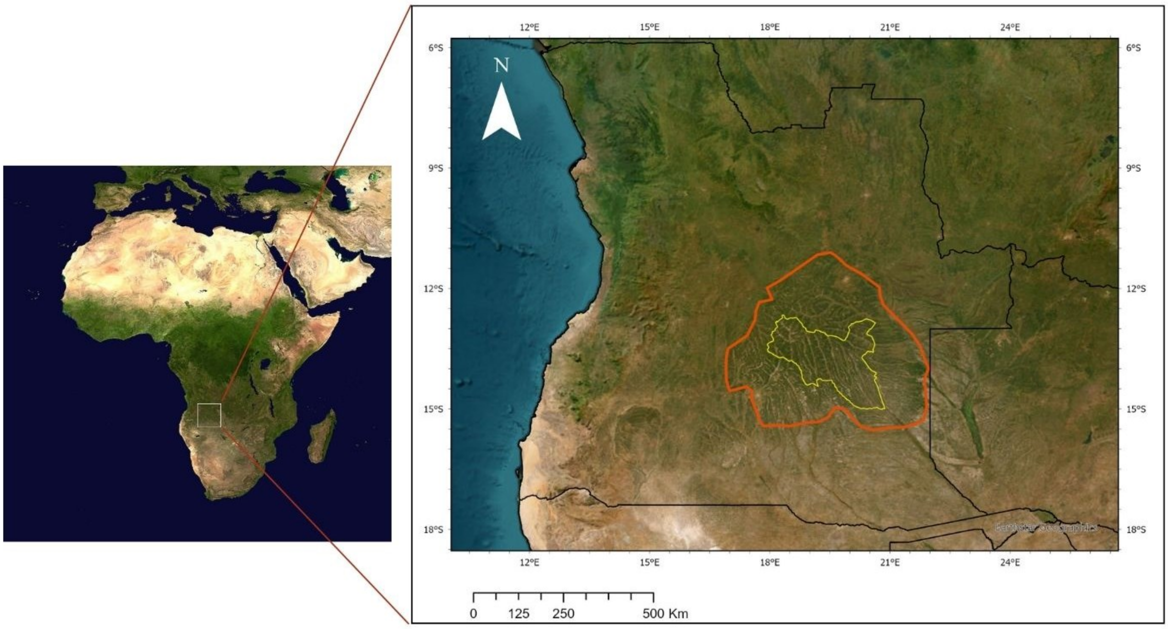

Figure 1.5. Study area in Southeast Angola. Highlands of Moxico in red polygon and Luchaze municipality in yellow polygon.

The region features what has been termed one of the 'largest contiguous area of miombo woodland in Africa' (NGOWP, 2017) and which has remained largely undisturbed due to past conflicts. Soils are nutrient poor (mostly Arenosols and Ferrasols), and highly sandy (>60%), resulting in low agricultural potential (Mendelsohn & Martins, 2018). Despite the nutrient-poor habitats leading to low animal densities, these landscapes are important for endangered animal species (e.g., African wild dog, wattled crane and African skimmer), birds, invertebrates, fish, plants, including geoxyles or underground trees (NGOWP, 2017; Mendelsohn & Martins, 2018). Southeast Angola's rich natural landscapes and key water systems underscore its ecological importance and make the area a prime candidate for conservation measures (Andrews et al., 2024); however, the region is still underexplored and has remained understudied from a Western scientific perspective (Goyder & Gonçalves, 2019; Lautenschläger et al., 2022).

1.4.10 Life in the southeast

Southeast Angola is largely disconnected from markets and urban centres, and lacks communication infrastructure (NGOWP, 2017). Rural life is organised around villages, which consist of closely related families in smaller settlements and more diverse relationships in larger ones (Mendelsohn & Martins, 2018). Fewer than 4% of households have access to improved water supplies, over 30% of adults are illiterate, and there is no electricity infrastructure (Pröpper et al., 2015). Whilst the largest villages have schools and some clinics, most children are involved in household chores rather than formal education. Health care is limited, with communities relying on traditional medicine (NGOWP, 2017).

Local communities practice shifting cultivation due to the low-nutrient landscape (NGOWP, 2017; Pröpper et al., 2015). This method represents the most viable and cost-effective means to grow foods, especially given the limited access to markets, which leaves few alternatives to improve land productivity. Cassava, millet, and corn are staple crops, and wild fruits are consumed when available (Pröpper et al., 2015). Fishing and agriculture are mainly for subsistence, whilst bushmeat, cassava flour, and honey are trade products and important income sources. Wood and to a much lesser degree charcoal (mainly in the agricultural frontier towards the west of my study area) are the primary fuel sources (NGOWP, 2017). Other products harvested from the woodlands, such as building materials and medicinal plants, are also integral to local well-being and income generation (Campbell & Byron, 1996).

1.4.11 Southeast Angola: socio-politics

Angola's civil war heavily affected remote rural areas with limited government presence. The southeast was among the most affected by the conflict, and it is still the most heavily mined area in the country (Vandome, 2019). By 2018, Moxico province was estimated to have 150-200 minefields, making it the second most heavily mined province after Cuando Cubango.

Moxico was a stronghold for the UNITA (National Union for the Total Independence of Angola) led by Jonas Savimbi, which battled the MPLA (Popular Movement for the Liberation of Angola) for over two decades until the war ended in 2002 (World Peace Foundation, 2015). Since then, the MPLA has maintained control of the national government.

The southeast of the country, marked by poor roads and reliance on low-productivity agriculture, held valuable natural resources for war purposes such as timber, diamonds, and wildlife, and the fight for control over these resources significantly fuelled the conflict (SAHO, 2015). Moreover, the limited provision of social services, weak justice systems, lack of public investment and slow economic growth in this remote area, likely played a motivating role for the rural population to oppose the national government, or at least to not resist the opposition. This, alongside ethnic tensions (SAHO, 2015), were important factors in the geography and dynamic of the civil war in the southeast. Most villages in the region were vacated during the conflict and residents only began returning in 2002 after the war ended (NGOWP, 2017). Many local peoples in my study area played direct roles in the conflict, serving as combatants, nurses, and carriers, which profoundly impacted their livelihoods.

To date, southeast Angola remains marginalised due to past political affiliations during the war (Brinkman & Alessi, 2009). This marginalisation has resulted in minimal infrastructural development, limiting scientific research and reinforcing the region’s remoteness (Andrews et al., 2024). Despite the end of the conflict, the legacy of war persists through destroyed infrastructure, displaced populations, returning refugees, economic hardship, and landmines (Zweede et al., 2006).

1.5 Data collection methods

1.5.1 The case study approach as a way to understand human-wooded ecosystem interactions

The choice of my methods was based on two justifications. The first one is methodological. I employed a mixed methods approach through multiple case studies. A ‘case study’ approach involves the study of an issue (human-wooded ecosystems interactions) explored through one or more cases (six villages) within a bounded system (the highlands in the southeast) (Creswell, 2013). Focusing on a few villages allowed me to gain a deep and context-specific understanding of the relationship between humans and wooded ecosystems and to identify the local practices and conditions (cultural, social, environmental, and ecological) that influence wooded ecosystems (Yin, 2014; Creswell, 2013). The second reason pertains to the logistics of the work. The study area is difficult to access, heavily mined, distances are large, and moving around always requires time and a vehicle. Given these constraints, and the need to ensure both depth of engagement and personal safety, I decided to focus on a smaller number of sites. A multiple case study approach therefore allowed for in-depth fieldwork within the limits of time, resources, and security. As mentioned previously, I based my work on the understanding of woodlands as socio-ecological systems by studying the resource system (woodlands) and the resource users (local peoples). I trust that a case study approach employing quantitative and qualitative data provided appropriate methods to gain insights into the complexity of these dynamics.

However, I acknowledge that a case study approach with six villages has limitations on the research questions that can be addressed. For instance, if more villages were included in this work, I could have gained a better understanding of the human-wooded ecosystems interactions based on geographical and environmental gradients (for example, understand the effect of the slightly higher rainfall zone of the villages in the north in human-woodland interactions). But during the work I learned that in terms of socio-demographics, economics, politics and culture, these villages were similar, including the configuration of their surrounding landscapes, and for my research questions, their similarities were more important than their differences. These similarities allowed me to treat each case study as sampling units of a broader landscape, and with caution, helped me envision that, given that most of the people in the highlands are of similar ethic origin and share a common culture, livelihoods and history, I could picture human-wooded ecosystem interactions being similar across the landscape. Although how generalisable the results are in the broader human-wooded ecosystems context depends on many variables (Flyvbjerg, 2006), I believe the knowledge gained through this approach is still valuable in the decision and policy making processes for the conservation of this area.

1.5.2 Social science approaches

The purpose of using social science approaches was to gain a deep understanding of the landscape based on local knowledge. Social science helped me understand that the way local peoples perceived the landscape is as important as the physical configuration (based on ecological criteria), since knowledge guides local choices and uses of the vegetation. Also, since I had limited time and scope, local knowledge helped me gain a much broader understanding of the ecology and dynamics of the vegetation through time and space (Berkes, 2012). For this, I employed four main methods: participatory mapping, semi-structured interviews, transect walks and rapid surveys. The details of these methods are presented in Chapters 2 and 4, but here I will present a justification for their use.

Participatory methods and transect walks

Participatory mapping, countermapping or indigenous mapping, terms often used as synonyms, is a practice that provides an alternative to conventional cartography by allowing local communities to represent their lands and resources based on their own social, cultural, and ecological perspectives (Young & Gilmore, 2017). This method addresses the historical marginalisation inherent in conventional maps by incorporating elements often omitted, such as traditional land boundaries, resource management practices, and sacred areas (Berkes et al. 2000; Rainforest Foundation, 2015). By empowering communities to visualize their own territories, participatory mapping enhances local land-use planning and decision-making, and helps reinforce cultural identities (Brown & Kytta, 2014; Herlihy & Knapp, 2003). This approach reveals complex human-wooded ecosystems relationships that conventional methods may overlook.

Transect walks involve walking (and discussing) with local peoples through their land. This practice provides a spatially grounded, real time and first-hand understanding of how local communities interact with and manage their surroundings. It also facilitates direct observation of ecological and social variables such as tree species, land use practices (e.g., agriculture, fire use, harvesting), and cultural sites, all of which can offer insights into how humans shape and are shaped by wooded ecosystems. Transect walks also encourage community participation, as key informants guide the walk. Similarly, the use of interviews and surveys were a mean to provide space for local knowledge to define landscapes and to co-produce the knowledge generated through this study.

1.5.3 Ecology methods: involving local peoples in the process of surveying vegetation

The specific methods for surveying vegetation are detailed in Chapter 3. The data collection and analyses were supported by the Socio-Ecological Observatory for Studying African Woodlands network (SEOSAW partnership, 2021), a network of scientists that study the ecological response of woodlands to global change through the use of vegetation monitoring plots. However, I believe it is crucial to emphasise the significance of involving local resource users in the data collection process, since their unique knowledge and insights are invaluable. For each vegetation plot surveyed, every walk in nature, and every landscape visited, I was accompanied by one or two local collaborators. Their presence was essential not only for safety, due to their expert spatial knowledge and ability to identify signs of danger like lion tracks, venomous snakes, or poisonous plants, but also for their deep understanding of the social and ecological dynamics in the environment. They effortlessly answered every question I asked about the environment, enriching my knowledge and enhancing my research. Including local peoples in the research process is not just about adding valuable insights; it also promotes that the research is inclusive and participatory, giving space to their voices, perspectives, and claims to their land.

1.5.4 Spatial analyses: recognising local knowledge

Remote sensing is a powerful tool for studying human-wooded ecosystems interactions. It offers broad spatial and temporal coverage (David et al., 2022) and provides data at resolutions that would be logistically challenging to achieve with conventional survey methods alone (Pritchard et al., 2021). However, despite its strengths, remote sensing has limitations. Vegetation classifications based on remote sensing often simplify landscapes, unifying diverse ecosystems into standard categories that may not fully capture local variation (Edney, 1997). This can lead to distortions in how landscapes are represented and managed (Monmonier, 1996). The classification systems created through remote sensing are often imposed by centralised authorities, which can reinforce power imbalances and perpetuate state control over land (Robbins & Maddock, 2000), and which might result in unfair outcomes for marginalised peoples (Pritchard et al., 2021). To avoid these downsides, an alternative is to combine remote sensing with ground-based methods. The latter can enrich the remotely sensed data, bringing in local perspectives and knowledge that are often missed in remote sensing. Together, they provide a more comprehensive and accurate understanding of human-wooded ecosystems interactions.

1.5.5 Mixed methods approach, data triangulation and bridging knowledge systems

Mixed methods research integrates both qualitative and quantitative approaches to provide a comprehensive understanding of a phenomenon. By combining both approaches, various dimensions and complexities of the subject of study can be made visible, offering deeper insights from multiple perspectives (Creswell, 2007). Mixed methods research offers the potential of greater strength for a study than either qualitative or quantitative research by itself (Creswell & Clark, 2017). Moreover, approaching problems from different epistemological or conceptual viewpoints can aid in thinking more widely and creatively about research issues (Nightingale, 2016).

The rationale behind the use of mixed methods approach in this study is that human-wooded ecosystems are too complex to be studied through only one method and one conceptualisation. The way issues are framed and conceptualised plays a critical role in shaping the methodologies applied to study research questions. These methodologies, in turn, influence the data collected. Consequently, different framings, epistemologies, and methodological approaches can yield distinct yet complementary perspectives, enriching our overall understanding of the subject of study (Nightingale, 2016).

For this study, a sequential mixed methods approach was employed. This means that qualitative data collection took place first, then quantitative data collection, and in some cases qualitative data collection again to explore new insights gained from the data analysis process. I used data triangulation to analyse my results, drawing on multiple sources and methods to develop more comprehensive insights into landscapes, vegetation and fire. Specifically, I employed both complementary and convergent triangulation (Nightingale, 2020). Complementary triangulation allowed me to bring together the different methods (participatory maps, transect walks, surveys, semi-structured interviews, vegetation plots, and remote sensing), to develop more comprehensive insights into vegetation and fire use. Convergent (and divergent) triangulation enabled comparison across methods to confirm or contrast findings, thereby strengthening the robustness of my conclusions (Nightingale, 2016; Nightingale, 2020; Nemarundwe & Richards, 2002). Throughout the analysis, I also discussed interpretations with collaborators and continuously reassessed my findings in light of field observations and lived experiences.

To document LEK, I started by spending significant time with local communities to build trust. I conducted regular visits over the course of almost four years. Rather than approaching LEK as a simple set of factual ecological observations, I recognised that it also encompasses ethical values, cultural meanings, and alternative epistemologies (Usher, 2000; Houde, 2007). The methodology was therefore designed to be participatory, inclusive, and collaborative, involving ongoing dialogue with knowledge holders at different stages of the research. This implied respecting local protocols, giving regular feedback, and discussing interpretations of the data, especially where conflicting views emerged (Molnár & Babai, 2021). LEK holders were treated as active participants and experts, rather than as passive informants (Charnley et al., 2007).

1.5.6 Decolonising research

In terms of the role of decolonising methods in my work, I aimed to create space for local voices and epistemologies through participatory methodologies (Zavala, 2013; Datta, 2018), placing an emphasis on local perspectives and knowledges (MacLean et al., 2022; Igwe et al., 2022). Decolonising methodologies require ongoing self-reflection, recognition of researcher privileges, acknowledgment of participants' contributions and co-ownership of research outcomes, and interrogating who benefits from the research outcomes (Keikelame & Swartz, 2019; Molnár & Babai, 2021; Datta, 2018).

Interestingly, during my research I realised that at least in ecological sciences, researchers often lack training in culturally appropriate practices, including engagement with community protocols and benefit-sharing (Datta, 2018). Whilst one may not fully achieve the ideals of decolonising methodology, striving toward them by implementing culturally sensitive and ethically grounded strategies is crucial (Datta, 2018).

1.6 Fieldwork and site selection

1.6.1 Time spent in the field

My fieldwork spanned from November 2021 to July 2024. In total, I visited the field six times, with some longer trips (up to three months) and others shorter (one month). Each field visit had its own objective, although data collection methods often overlapped (e.g., whilst asking about vegetation uses, the fire topic would come up, so then I would record this data for the chapter related to fire). Figure 1.6 shows the organisation of my work in Angola.

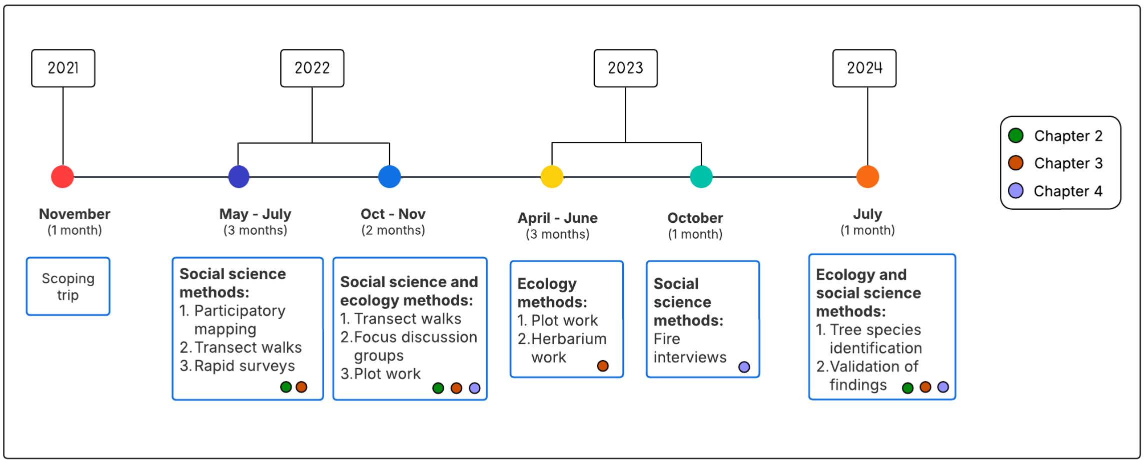

Figure 1.6. Fieldwork overview: time spent in the field and objective of each visit.

1.6.2 Collaboration with National Geographic Okavango Wilderness Project (NGOWP)

My collaboration with NGOWP emerged from an agreement between my academic supervisors and the project leadership. At the time, NGOWP was actively seeking students to carry out scientific work in the region, given the scarcity of data in the area. Whilst the project's initial interest was mostly on mapping vegetation through a combination of remote sensing and fieldwork, they were supportive when my focus shifted toward investigating human–nature relationships in the landscape. I was lucky to have the freedom to design and conduct my research, with the commitment to abide to local cultural norms. Nonetheless, I regularly consulted with Angolan project leaders to ensure feasibility and appropriateness. Accessing the field required joining NGOWP expeditions, as field logistics in southeast Angola are complex and costly. Once on site, I was typically accompanied by one to three local assistants and had a vehicle available to travel between villages, allowing me to spend extended periods in each location as needed. In return, I agreed to share non-sensitive findings with NGOWP, with appropriate confidentiality protocols, so that my work might contribute to their broader conservation planning efforts.

1.6.3 Village choice

Villages were selected in collaboration with NGOWP, prioritising communities where the project had already established relationships and where local authorities were supportive. These communities were situated near the main road, ensuring logistical feasibility, but were also geographically dispersed, allowing me to work across a broader portion of the landscape whilst maintaining access and safety. I acknowledge potential biases in the selection of villages, particularly the possibility that prior engagement with NGOWP may have shaped community perceptions, especially regarding ecology, fire and conservation, themes that align with the focus of this thesis. However, given the logistical and safety challenges of conducting independent research in this region, partnering with NGOWP provided critical access that would have otherwise been unattainable. Considering how understudied this area is, I believe the insights gained remain valuable and contribute meaningfully to broader understandings of human–environment interactions.

Given Angola's history of conflict, the presence of landmines was an important consideration during fieldwork, and the village selection also considered the risks in terms of landmines. Fortunately, detailed maps indicating mined areas are available for most of the country. In this region, landmines are primarily concentrated around bridges and larger towns. Upon my arrival, I was shown areas near my field sites identified as potentially hazardous, which I strictly avoided. Most importantly, local collaborators were deeply knowledgeable about safe routes and locations, and they played a key role in guiding me safely through the landscape.

1.7 Suitability of southeast Angola as a study case

Because of its characteristics, southeast Angola offers a unique context for investigating the interactions between local knowledge, ecological processes, and fire dynamics. The region's ecological importance, coupled with the high dependency of local communities on natural resources, minimal state presence, and limited infrastructural development, creates a setting in which human-environment relationships are primarily governed by customary practices rather than formal governance. This distinctive setting, along with the scarcity of scientific information on the region, offers an exceptional opportunity to study socio-ecological systems with relatively little external influence. Furthermore, among the few major shocks to have affected the region in recent decades, the civil war stands out as the most consequential. I therefore viewed this as an opportunity to investigate the impact of the conflict on fire regimes, a topic that remains minimally explored in the literature. In sum, the combination of ecology, fire use, historical legacies, and data gaps makes southeast Angola an ideal site to investigate the aims of this thesis: understanding how ecological dynamics are shaped through the interplay of local knowledge, scientific knowledge, and human-environment interactions.

1.8 The study site

1.8.1 Personal descriptions of social and cultural dynamics in my study cases

The following accounts are descriptions of my study area, the highlands of Moxico in the southeast of Angola, based on my daily informal interactions with local peoples (well aware of the influence my position on these perceptions), which I hope will help set the context and explain my interpretations of the data. The NGOWP has worked with 29 villages in the highlands and although I only worked in six, I was able to visit other villages and gain insights from them as well. I conducted my work in the villages of Sete, Sapele, Samununga, Sassungu, Sayoswa and Tempué (Figure 1.7).

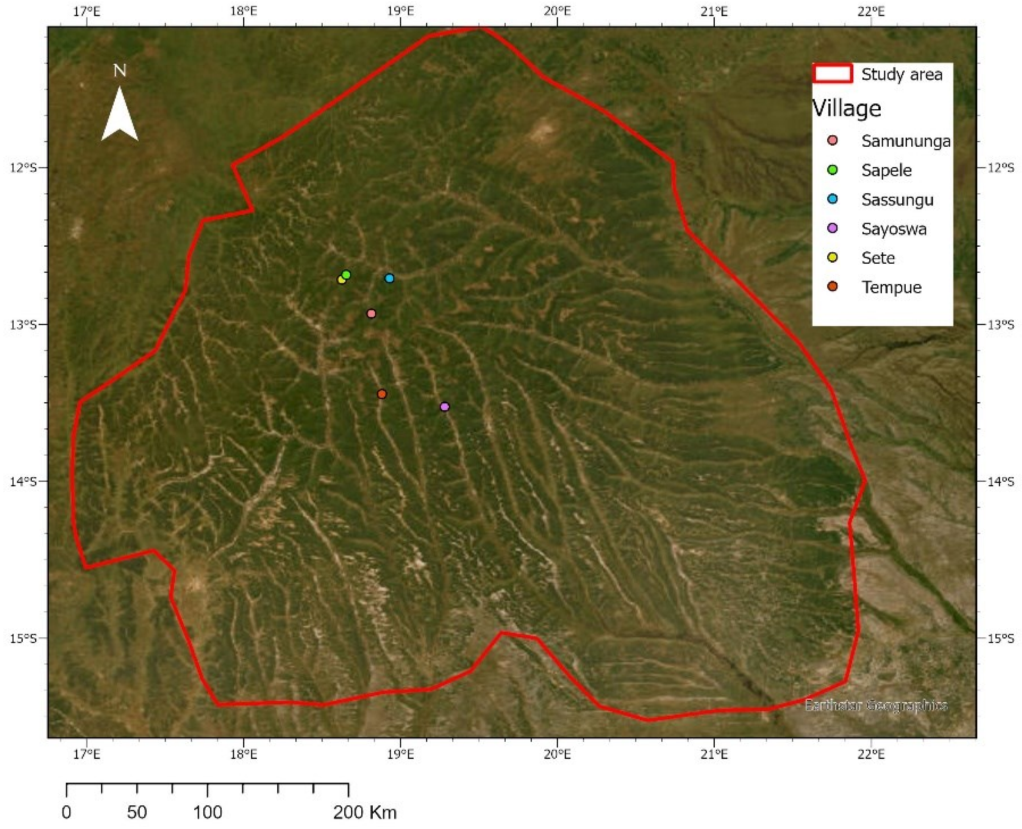

Figure 1.7. Villages included in my study

Livelihoods in these highlands are completely dependent on natural resources. The landscape consists of gently rolling, large hills, with denser vegetation often found at mid and high elevations, whilst grasslands and rivers lie at the valley bottoms. There are many communities established in these highlands, with no official numbers recorded. Villages are usually located at mid elevations, providing convenient access to rivers whilst offering protection from floods. Meanwhile, the nearby hilltops, rich in woody resources and where people prefer to cultivate, are also close (Figure 1.8). Villages are similar in socio-demographic, cultural, economic, and political dynamics. However, Tempué, the largest village I studied, is a 'comuna' rather than a village, meaning that several villages occur within the same territory, with each having their own local authority. For practical purposes, and because my work was mostly related to spatial and ecological dynamics surrounding human settlements, I treated Tempué as a single village in this study. Tempué used to be a Portuguese base during colonial times, where they harvested valuable woods, the main being *Guibourtia coleosperma*. For this reason, of all the villages where I worked, Tempué was the only one that had concrete buildings (although old and mostly uninhabited), a clinic, and three schools. In addition, the basecamp of the NGOWP is located in the outskirts of Tempué, and thus, it was logistically easier to work there.

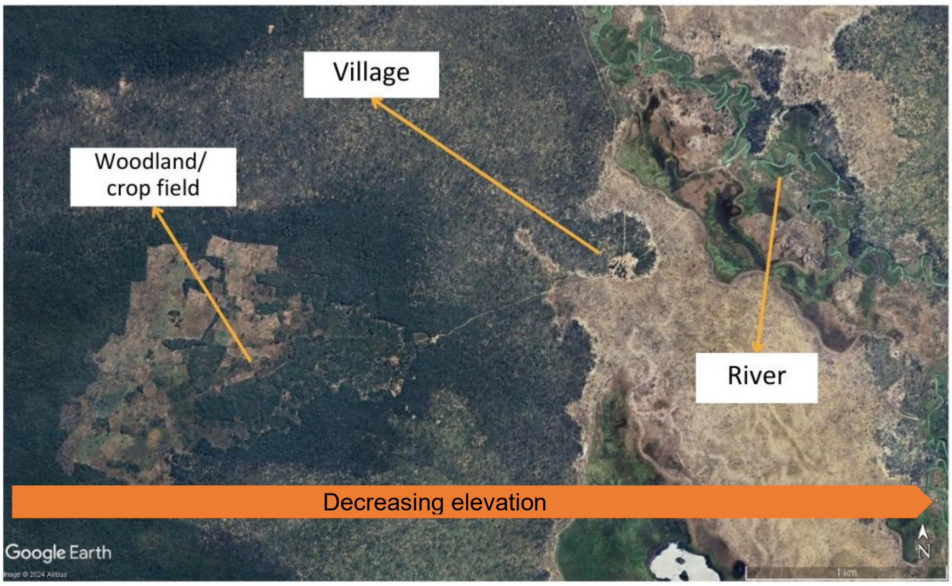

Figure 1.8. Typical village location in the landscape, situated at mid elevations, between rivers in the lowlands and forests in the highlands.

Residents in the villages belong mostly to two ethnic groups, Luchaze (within the broader *Ngangela* ethnic group) and *Tchokwé*. Villages in the south of the study area, Tempué and Sayoswa have mostly Luchaze people and Samununga, Sassungu, Sete and Sapele have a mix of both. The mix of people from different ethnic groups did not seem to result in conflicts based on ethnicity. None of the villages have access to urban markets within walking distance. Most villages require a walk of 2-3 days if not more (e.g., for Sayoswa and Tempué) to access urban markets (although Tempué, Sete and Samununga have a small shop with basic products). However, there are trucks with *candongueiros* or traders, that drive by occasionally and people can pay to be transported to markets, or sell their produce to the *candongueiros*, mainly honey, corn, cassava and beans.

Socio-political organisation is based on a tribal structure. Villages are led by the local authority, the *soba*, a role often reserved for and inherited by one of the eldest, male members of the communities. A council comprised of the eldest men of the community advise the *soba* and regularly meet to discuss communal issues. Most villages are predominantly made up of family members which inherit territories delineated by kinship ties.

Governance over natural resources is not strict, and burning someone else's crop may be the only instance with imposed consequences for poor management (for example, replacing lost crops). Pressure on natural resources is not apparent since people only take what they can cut and use (cutting is with axes, there is no machinery other than hand tools), because the effort of cutting too big or too many trees might outweigh the benefits. Although there is not an evident consciousness around the management of natural resources (as per the Western view of sustainable management use), local peoples possess an understanding of the interdependencies within nature, and therefore, natural resources are highly valued.

Small scale shifting agriculture is the main livelihood activity, with cassava, corn, pearl millet and beans as the main crops. Locations for shifting agriculture are up to the individual to choose. Agriculture fields are the only instance where, for a time period, land is owned by the individual rather than by the community (*de facto* rules). Crop fields are abandoned after three to five years of cultivation, when they are then left to fallow, taking at least 20-30 years to regenerate. A small fraction of local residents has vegetable gardens by the rivers, called *nacas*, which provide garlic, onion, carrots and cabbage for a few months per year. Fire is an essential tool to manage the landscape, particularly for shifting agriculture, although it also serves many other purposes.

Honey production is another key activity for livelihoods. Most of the production of honey is done using traditional beehives, constructed with the bark of tree species such as *Baphia spp*., *Uvaria angolensis*, *Julbernardia paniculata*, *Pteleopsis anisoptera*, and *Brachystegia spp*. Beehives are placed strategically in trees that can support them and at a height where they avoid fire. There are two harvesting seasons for honey, April, when *Julbernardia paniculata* is the main flowering source, and September, when *Cryptosepalum exfoliatum*, *Erythrophleum africanum* and *Brachystegia spp*. are some of the main sources. In general, tree species of *Julbernardia paniculata*, *Cryptosepalum exfoliatum*, *Erythrophleum africanum*, *Brachystegia bakeriana*, B. *longifolia* (restricted to villages in the north), and *Burkea africana* are of particular abundance in this area.

Hunting is another important livelihood activity. The main species targeted are wild pigs and small antelope since the landscape does not have high populations of larger animals. Although hunting for commercial purposes is forbidden in Angola, in this area hunting is still practiced both for self-consumption and for selling in markets. Lastly, collection of wild fruits, mushrooms, and medicinal plants are important activities that support communities. The use of timber and non-timber forest products for firewood, construction, furniture and tools is also important. Livestock is found in villages in small quantities, primarily goats, chicken and pigs. Livestock are often consumed for special occasions or are traded for other goods.

Most villages have churches and schools, managed by the communities. Only Tempué has a clinical health facility, but services offered are not regular. Sete has a nurse (trained during the civil war) that is also a traditional healer, and villagers from across the area travel to see him. Teachers are sent from urban centres but most often schools do not have teachers, so children miss school regularly. Religion plays an important part of the social life in the villages. Rather than replacing traditional religious practices, most churches follow a blending of Christian and traditional beliefs.

In terms of ecology, local peoples possess deep knowledge regarding the vegetation in the landscape. They have different names for the different types of vegetation. The same applies for fire use, as local peoples use fire based on knowledge that has been passed through generations. More details of vegetation and fire are presented in the empirical chapters.

1.9 Ethics

Ethical research in cross-cultural contexts requires a conscious and reflexive approach through the whole research process, including theory and fieldwork. Researchers must acknowledge how their position in the research affects the relationships they build, their access to data, the questions they ask and their interpretations (Gupta & Kelly, 2014; Sandoval et al., 2016; Diver & Higgins, 2014; Staddon, 2022). Ethical engagement also requires acknowledging the limitations of one's own training and the constraints imposed by the academic systems in which researchers operate (Diver & Higgins, 2014). Academic institutions often fall short in equipping researchers to engage meaningfully with community concerns, cultural practices, or the complexities encountered during fieldwork (Datta, 2018). Embracing these challenges and committing to grounded approaches is a key step towards ethical practices, which are in line with decolonising research.

Actively including voices that are often excluded and shifting from viewing participants merely as data sources to recognising them as experts and collaborators in the co-production of knowledge are also steps for ethical engagement (Udah, 2024). Ethical research also requires care, reciprocity, honesty, accountability, humility, respect and a commitment to listen, all of these grounded in the recognition that our knowledge is partial, situated, and never neutral (Staddon, 2014; Staddon et al., 2023; Shanley & Laird, 2002; Datta, 2018).

1.9.1 Positionality

My initial approaches to study wooded ecosystems in southeast Angola from a purely ecological lens were influenced by my past experience in the natural sciences. As a trained biologist used to framing research questions from a quantitative approach, the ecological lens made sense to me. However, for a long time I had been intrigued by rural livelihoods and their relationship with the environment. Soon after I visited my study site for the first time, I realised that the questions I wanted to ask required more than quantitative approaches. Somewhere then, wooded ecosystems stopped being my sole interest, and 'populated wooded ecosystems' (wooded ecosystems with humans inhabiting them) became my main interest. Although my initial idea was that both methodologies had the same weight, after spending prolonged times with the communities I became more aware of the value of social science research and in some cases, it became my main method whilst I used ecological methods to complement what people shared with me (what Creswell, 2013 calls concurrent *embedded strategy*, where more emphasis is placed on either quantitative or qualitative methods, with the other approach serving as a secondary strategy that is *embedded* within the primary one). But spending time with local peoples meant that I needed to be aware of what type of relationships I established with them and the position where I stood in this context as a researcher. Acknowledging one's positionality means recognising how the researcher's social and personal context, such as class, gender, ethnicity, and lived experience, influences every stage of the research process (Sandoval et al., 2016; Diver & Higgins, 2014). Positionality plays a fundamental role in shaping not only the framing of research questions but also the interpretation of knowledge (Staddon, 2022; Saif et al., 2024).

I am aware that my personal and professional experiences affected my position and interpretation of the learnings from this study. I acknowledge that my role as a researcher situated me in a position of power, potentially affecting the data collection process (for example, due to the often external negative perception about customary fire use, respondents might have felt restricted about sharing how they use fire). The reality in the study area differed from my reality (country of origin, socio-economic status, access to goods and services, formal education, etc.) thus, influencing my understanding of local human-nature relationships. Because of this, I paid attention to the power imbalances in my interactions with respondents, produced by past and present contexts. Colonialism is still a very fresh memory in Angola and modern manifestations of colonialism are still evident. Because these power imbalances could create discomfort with the respondents, before starting my data collection process I spent time with the communities to try to create trust. I shared aspects of my daily life in hopes of finding points of similarities that would help us feel less like strangers (whilst remaining conscious that these do not erase the structural inequalities embedded in research encounters; Staddon, 2022). I looked for informal spaces to share with local peoples and to give space for questions. I visited church services, I washed in the river with other village women, I shared wild foods with local peoples, and I attended a wedding and a funeral. Although I did not plan these, rather they happened naturally, these shared experiences helped me build trust and familiarity. As Gupta and Kelly (2014) argue, fieldwork often develops with emotional complexity, requiring researchers to be responsive to informal and unstructured interactions that can be as meaningful as formal interviews. And at some point, I shifted from being a complete unknown outsider, to a known outsider or a partial, temporary 'insider'.

Moreover, I provided descriptions of the project at the beginning of the data collection and information on how the data was going to be used. I gave space for questions and concerns, and I made sure people knew that they had the choice to participate or not. In cases where the data collection methods took longer than 30 min, I offered soap and salt as a way to thank them for their time (as these are highly valued goods), and for people who spent the whole day supporting me, I paid a daily fee established by the NGOWP. Lastly, in the hopes to produce a fair and accurate representation of the communities' knowledges and interactions with vegetation and fire, I would often check the interpretations I drew from the data with the communities, recognising that knowledge is co-produced and that my interpretations were limited by my positionality (Staddon, 2022; Saif et al., 2024). Thinking reflexively about my positionality also encouraged me to actively make space for different ways of knowing, hoping to challenge dominant knowledge frameworks and bring more inclusive forms of scholarship into academic spaces (Staddon, 2022; Saif et al., 2024).

1.9.2 Working with local research collaborators

Although citizen science and the role of paraecologists (local researchers trained through experience rather than formal education, Silvertown, 2009; Janzen, 2004; Schmiedel et al., 2016) have received growing attention in ecological research, there remains limited focus on the nuanced, everyday relationships between researchers and local collaborators, especially in studies using mixed methods to examine human–environment interactions (Pritchard, 2017). Relationships with local collaborators, therefore, also require ethical reflexivity. Local collaborators play a crucial role in mediating access, interpreting context, and building trust. Their knowledge of local norms allows for smoother interactions with participants and facilitates building trust with respondents, and they are often best positioned to identify which field sites are safe and appropriate for research.

In my case, the research collaborators: Fabio Quintas, Eduardo Fernando, Joao 'Ifafe', and Andre Linhango, were inhabitants of the communities where I worked, who because of their job as traders or nurses, have learned Portuguese; thus, one of the main types of support they provided me with was translating. Their role in my research was fundamental, whether in the process of gaining trust with the communities and explaining my objectives to village residents, or by explaining to me what the participants' answers, and the many expressions they use in the local languages, meant to my research interests. Spending time with them and creating trust was also essential to overcome tensions created by my positionality, and their presence also helped to mediate the power asymmetries inherent in my role as a foreign researcher.

1.9.3 Giving back

During this work, I continuously questioned myself about the research I wanted to conduct. I rejected the idea of doing extractive research, and I felt I could have a small but positive impact on this place. But soon I realised that postgraduate research, at least at the Ph.D. level, is rarely done to effect immediate positive change. Student-researchers might not do 'action research' because we often do not know enough about the local needs, or do not have time, resources or the experience, and lack the power or position to trigger change.

Whilst conducting my work, local peoples often asked me how it would benefit them. They said they are tired of people coming to take data and not returning. Indeed, it is hard to explain the immediate benefits of much of the research at the Ph.D. level, or at least of mine.

Nonetheless, I became deeply engaged with my project, but I admit that the benefits to the local communities might not be easy to detect in the short term. Thus, I asked my interviewees what I could do to ‘give back’ to them.

The question of “giving back” is deeply interconnected with issues of positionality, reflexivity, and power relations during fieldwork (Staddon, 2014; Gupta & Kelly, 2014). Researchers often enter communities with advantages like funding and institutional support, yet they rely entirely on the time, care, and knowledge of local residents to carry out their work (Diver & Higgins, 2014). Despite this dependence, there is limited guidance on how to engage in meaningful, ethical reciprocity (Gupta & Kelly, 2014). As Staddon (2014) points out, there are no universal set of protocols that can prepare us for the ethical challenges during fieldwork, but recognising that these dilemmas exist is an important first step.

Therefore, I asked what they thought was a fair exchange, trusting in the value of listening to what people want and need without me trying to decide what is best, as a means of building something that felt reciprocal. There were many things they wanted and needed, but I could not help with all of their needs. They wanted more teachers for their schools, or even schools since there are no schools in all communities; they wanted health facilities with nurses and doctors, and they wanted roads improved so they can access markets and cities. They wanted footballs so they can play. They also needed medicines. Out of all of the things they asked for, I believe medicines were the one I could help with, and so that is what I gave (with the support of many kind people from all over the world who donated through a virtual funding campaign). This was a small, simple act that will not change their lives considerably nor provide long-term benefits, but maybe it will provide relief when women are in labour, when children are going through malaria or when the elder cannot stand the pain of their knees from walking for days. And maybe they will remember that we came to their land to learn and appreciate them because we care for them.

Giving back in fieldwork is dynamic and ongoing, it requires involvement, commitment, presence, empathy, and a conscious navigation of the power dynamics embedded in everyday life (Gupta & Kelly, 2014; Diver & Higgins, 2014). Giving back can also involve participatory research design, collaborative activities, or feedback mechanisms (Yanou et al., 2023; Diver & Higgins, 2014). Importantly, giving back is not one-way, researchers also receive in many ways, through generosity, insight, time, hospitality, and trust (Diver & Higgins, 2014). And we may not be able to reciprocate equally, but acknowledging the inequality of the exchange and being humble about it, can open space for more just relationships between researchers and local collaborators.

I trust we need to work towards the creation of horizontal relationships between researchers from institutions in 'high income' countries and people in 'low income' nations, where we genuinely listen and show that we care and respect them beyond a transactional relationship. As researchers, we should strive to create a pathway for solidarity, opportunity and transformation with people who we work with. These places have a long memory of extraction and plundering, and we have an opportunity to do differently.

To conclude this section, I wish to give full credit to the holders of the knowledge shared in this work. Whilst I take responsibility for the interpretations presented, the knowledge itself belongs to the Luchaze and Tchokwe peoples, who generously and patiently shared with me valuable aspects of their culture, history, and daily lives. Throughout this thesis, I often use the term 'I' to describe the actions taken to complete the research, not to claim ownership of the knowledge, but to assume responsibility for how it is represented. In many instances, 'we' would be more accurate, reflecting the collaborative nature of this work. Hence, I fully acknowledge the many individuals who actively participated and were central to this study. I hope this work contributes to the safeguarding of their knowledges and helps reinforce their cultural identities and connections to their living place, and helps bring visibility to their right to the land.

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Chapter 2. The value of participatory methods in classifying woodland types in Southeast Angola

Abstract

Remote sensing is a useful tool for the classification of vegetation in ecological sciences, and maps based on remote sensing methods are often employed to guide conservation interventions. However, when maps fail to account for the socio-ecological complexity of landscapes, they risk undermining local livelihoods by imposing external perspectives. For this reason, it is unclear whether relying solely on large-scale data and non-contextualised methods is effective and equitable for ecosystem conservation at the local scale. This chapter aims to explore the classification of vegetation based on local knowledge in the highlands of southeast Angola, emphasizing the limitations of conventional mapping methods for representing lived landscapes. This region, one of the most remote and isolated of Angola, is known for having some of the best-preserved woodlands in Africa, also playing a critical role in maintaining Southern Africa's water systems. The region is an ideal candidate for conservation interventions but the impact of top-down conservation approaches on local communities is yet to be explored. I first used unsupervised remote sensing to classify vegetation in southeast Angola, and then I used participatory mapping along with transect walks and surveys in five rural villages to include local knowledge into a supervised woodland classification. The results revealed that local peoples possess detailed spatial knowledge, reflected in a classification system of five different woodland and two grassland types. The vegetation types are differentiated by the density of vegetation, their fire regimes and the uses of each, yet local peoples do not make a clear distinction between vegetation class and use. My findings suggest that bridging remote sensing and ground-based methods provides an integral understanding of the landscape. Moreover, conservation initiatives are likely to be more effective when they consider local knowledge and land management practices, rather than imposing classifications. To ensure successful conservation efforts in the highlands of Moxico, it is critical to consider local contexts and include the viewpoints of land users.

2.1 Introduction

The use of remote sensing to map and classify landscapes has proved to be a useful tool for the management of ecosystems, the monitoring of forests and the conservation of habitats (David et al., 2022). These technologies have made data available at spatial and temporal resolutions that are logistically challenging with ‘conventional’ survey methods alone (Pritchard et al., 2021). However, the effectiveness of relying exclusively on large-scale data products and non-contextualised methods for ecosystem conservation at a local scale remains unclear.

The sole reliance on satellite data for land classification can lack local meaning, resulting in simplified representations and uniform territories (Bennet et al., 2022; Monmonier, 1996; Robbins & Maddock, 2000). Rather than being neutral, top-down, technology-driven mapping approaches can delegitimise local knowledge systems and local control over resource management, exacerbating political tensions by reinforcing external narratives (Ramirez-Gomez et al., 2015; Robbins, 2003). When land interventions are grounded on imposed classifications, the distribution of land-derived benefits can perpetuate existing disparities (Meyfroidt et al., 2022). Furthermore, fixed land cover types often shape how landscapes are evaluated and managed (Latour, 1987), sometimes resulting in *reverse adaptation*, where ecosystems are shaped to fit imposed categories (Veregin, 1995; Robbins & Maddock, 2000).

Fixed land classifications often prioritise potential land productivity for activities like crop cultivation and timber extraction, whilst overlooking essential and traditional land uses that sustain livelihoods, such as wild food gathering, grazing, medicinal plant use, and the harvesting of non-timber forest products (Robbins & Maddock, 2000). These classifications also tend to ignore the multifunctionality of the land, as local communities often rely on the same land cover to provide multiple services and fulfil overlapping needs (Otte et al., 2007). In ecology, remote sensing classifications typically rely on floristic composition and vegetation structure (Schulz et al., 2019). For conservation purposes, satellite data frequently assesses biophysical features like forest cover, forest change, and ecosystem fragmentation (Hernando et al., 2017; Blackman, 2013; Corbane et al., 2015). Thus, the values assigned to the land by conventional ecological and conservation approaches may not align with those of local communities. These approaches tend to emphasise single functions, which can create tensions between conservation priorities and the diverse livelihood needs of local peoples.

Furthermore, many current remote sensing products still lack the spatial resolution necessary to answer ‘why’ questions related to landscapes, limiting their utility for social science research (Zhu et al., 2022). A more nuanced understanding emerges from bridging social science data with remote sensing, allowing for deeper insights into land-use dynamics and human-environment interactions. Foundational work such as *People and Pixels* (Liverman, 1998) has emphasized the need to connect satellite-based observations with situated, place-based knowledge to address sustainability, livelihoods, and conservation challenges. Yet, interdisciplinary collaboration remains challenging, since social scientists must engage with the predictive aspirations of natural science, whilst remote sensing scientists must accept the contextual, non-deterministic nature of human decision-making (Liverman & Cuesta, 2008; Rindfuss et al., 2004). A critical, reflexive and ethical approach to mapping that embraces these tensions is essential for more equitable and effective ecology and conservation research.

For effective conservation interventions at the local scale, it is essential to consider the process of developing land classifications, the entities responsible for their production, and their impacts on local livelihoods. At the local scale, cultures with strong connections to their land often possess intricate systems for classifying habitats, ecosystems, and landscapes based on local ecological knowledge and the associated uses and values (Berkes et al., 1998; Duvall, 2008; Levinson, 2008; Shepard et al., 2001). This knowledge, passed down through generations, is interactive and adaptive, reflecting both ecological knowledge and cultural practices (McCall & Minang, 2005; Schulz et al., 2019; Tengö et al., 2014). Developed over long time frames and with fine spatial detail, local ecological knowledge often enables communities to manage their lands in ways that are compatible with, and frequently enhance, biodiversity conservation (Schulz et al., 2019; Tengö et al., 2014; Garnett et al., 2018). Therefore, incorporating local perspectives into land classifications for conservation can significantly enhance the effectiveness of conservation interventions.

Inclusive mapping processes that attempt to capture local knowledges of the landscape have been developed as a counterapproach to conventional land classification systems. Participatory mapping, countermapping, or indigenous mapping, terms often used interchangeably, is a practice that recognises that conventional maps have historically marginalised alternative views of the world and in response, attempts to give voice to those views through the production of new maps based on local knowledge and grassroots approaches (Brown & Kyttä, 2014; Corbett, 2009; Young & Gilmore, 2017; Dunn, 2007). This practice recognises that local communities possess great and detailed knowledge of their land and resources, which can be effectively represented geographically. Participatory maps often include information omitted from official maps such as customary land boundaries, traditional and natural resource use and management practices, sacred areas, social, cultural and historical knowledge, demography, ethno-linguistic groups, among other locally relevant information (Corbett, 2009; Rainforest Foundation, 2015).

By combining detailed insights from participatory maps with scientific methods like remote sensing, conservation efforts can gain a richer, more accurate understanding of landscape dynamics that leverages the strengths of both local knowledge and scientific analysis, also recognising local peoples as knowledge holders (Agrawal, 1995; Berkes, 2012; Ogunbameru & Muller, 1996). Scientists are often able to monitor variables difficult to detect through direct observation and relate them to landscape processes; however, their methods may be limited at comprehending complex socio-ecological interrelations (Bond et al., 2003). Conversely, local peoples can describe socio-ecological processes qualitatively and provide a historical perspective based on intergenerational knowledge transfer (Chalmers & Fabricius, 2007).

Bridging diverse knowledge systems may also serve as a reference for comparison, dialogue, and an evaluation of scientific knowledge through field validation (Robbins, 2003). Moreover, when the power and legitimacy of diverse knowledge systems is acknowledged (i.e., by scientists and policy makers), space to foster conservation partnerships with local peoples is created, whilst adapting conservation measures to local contexts thereby increasing their local acceptance (Chapin et al., 2005). In addition, by making visible how land is used locally, more effective and just conservation approaches can be conceived.

Southeast Angola contains some of Africa's largest and least disturbed areas of miombo woodlands. This region is crucial in sustaining the water systems of south-central Africa, serving as sources and tributaries for key rivers that support biodiversity and people downstream, including the Upper Zambezi, the Cuando, and the Cubango, the latter two of which feed into the Okavango Delta in Botswana (Vandome, 2019). The region is home to communities whose livelihoods depend on subsistence agriculture and natural resources. Because of its ecological value, this area holds a high conservation value but the impacts of conservation interventions for local livelihoods have yet to be assessed. By comparing local and remote classifications, this work fills an empirical and methodological gap as it shows how participatory methods can complement satellite-based approaches to produce more meaningful, nuanced, and equitable representations of landscapes, particularly in an isolated, post-conflict context with weak institutional presence, conditions that can amplify the risks of externally imposed conservation. Moreover, this work offers a model for how similar approaches can be applied in other data-poor regions facing the pressures of conservation. In this way, this chapter hopefully contributes not only to the southeast Angola context, but to a growing body of work seeking to rethink mapping from the ground up.

My overall goal for this study was to explore the value of local knowledge in mapping vegetation and the potential implications of the different mapping approaches for conservation. I aimed to answer the following research questions: 1) What are the locally perceived land covers?, 2) How do local land classifications compare to remote sensing classifications?, and 3) What are the uses and preferences of each vegetation class for local livelihoods? To achieve my goals, I contrasted remote sensing analysis with participatory methods to classify wooded areas. The participatory methods aimed to capture not only biogeophysical information of the landscape but also uses and preferences of the vegetation based on local knowledge.

2.2 Methods

2.2.1 Study area

I approached this work as a multiple case study, developed in five communities in southeast Angola, in the highlands of Moxico province (although a small portion extends to the provinces of Bié and Cuando Cubango). The communities there are mostly of Luchaze and Tchokwé ethnic groups. Most of the population of Moxico is situated in the capital Luena, and the highlands have some of the lowest populations of the country, at 0.3 persons/km^2 (INE, 2014). The highlands of Moxico lie in one of the most isolated and remote areas of Angola, and the sandy roads and dense vegetation make access difficult. According to Angolan Law (Lei de Terras, 2004), land belongs to the state, but the state respects the rights held by rural communities, including those based on customary use.

The study area has a hilly topography, with woodlands and forest at higher elevations and rivers and grasslands at lower elevations (Figure 2.1). Previous land classifications of the area have mapped various vegetation classes such as peatland, miombo woodland, and valley and upland grasslands (Burgess et al., 2004; Lourenco et al., 2023; White, 1983). Wooded areas are dominated by common miombo species; *Brachystegia spp*. and *Julbernardia paniculata* in open woodlands, as well as *Cryptosepalum exfoliatum spp*. in denser vegetation formations. Lower elevation areas are dominated by rivers surrounded by *Loudetia spp*., grasslands and peatlands, with open savannas dominated by trees of *Burkea africana* and *Terminalia brachystemma* (Goyder et al., 2018; pers. obs.). These landscapes are habitat to important endangered animal species (i.e., African wild dog, wattled crane and African skimmer), plants, including underground trees, birds, invertebrates, and fish, among others (NGOWP, 2017).

Climate in the area is seasonal with high temperatures and wet conditions during the summer and low temperatures and dry conditions during the winter. The rainy season extends from mid-October to the end of April, and the dry season starts in May and lasts until mid- October. Mean daily temperature ranges from 10°C to 28°C (USGS, 2020) and rainfall in the area averages 1030mm ± 100mm (mean SD) per year (Funk et al., 2015). Elevation ranges from 1220 to 1580 masl (CSP, 2024). The entire study area comprises 184 220 km^2. Communities in the region depend mainly on agriculture, honey production, hunting, and collection of different woods and non-timber forest products for subsistence as well as for income generation.

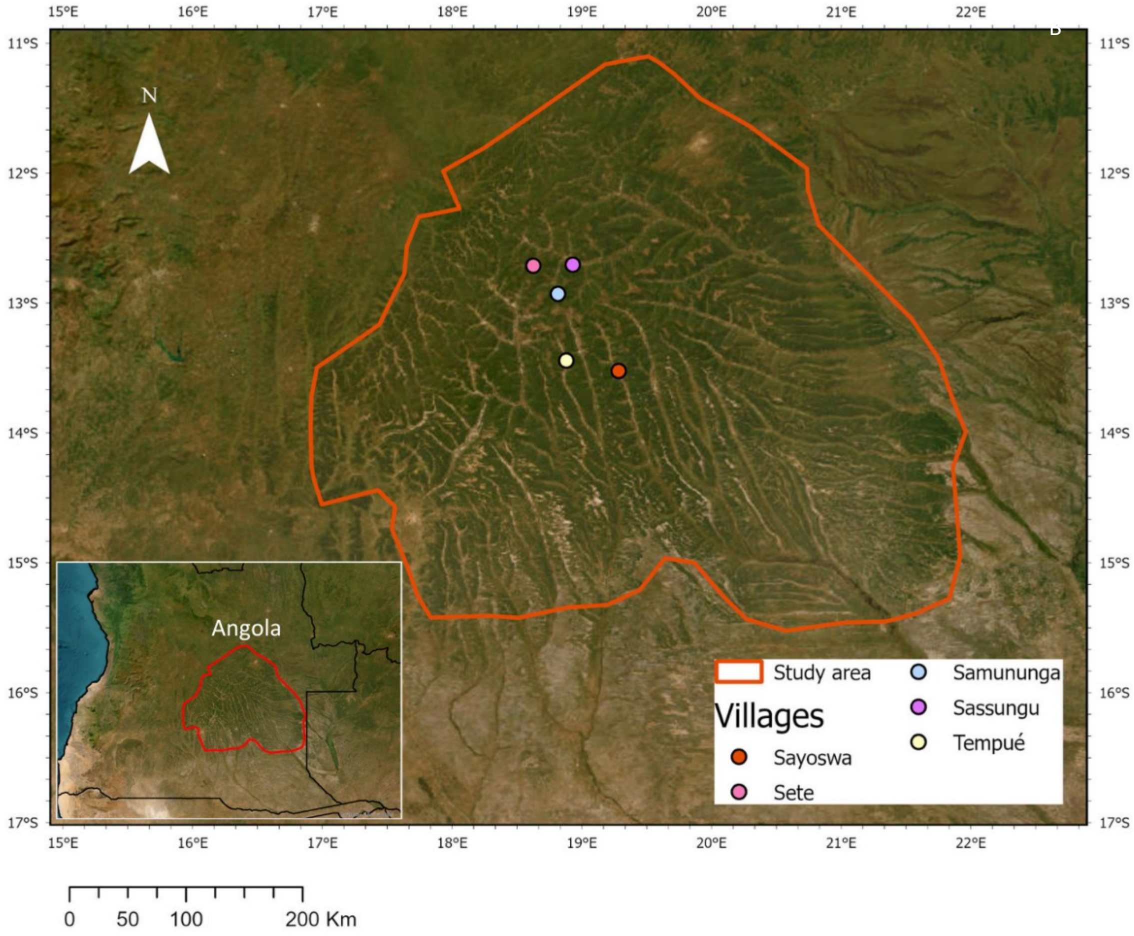


Figure 2.1. Area of study in east Angola (left lower corner) and communities where work was undertaken (bigger map). Map from Google Earth.

2.2.2 Data collection and analyses

Fieldwork took place intermittently from November 2021 to June 2023, for a total of 6 months. The work aimed to identify what are the major vegetation types according to local peoples, how are these used and where do they occur.

Research question 1. Local classification of vegetation

To address the first research question, I used a participatory mapping approach (Chambers, 2006; Cochrane & Corbett, 2020; McCall, 2004) combined with discussion groups. Participatory methods were carried in the villages of Sayoswa, Tempué, Sassungu, Samununga and Sete (Figure 2.1). All work was undertaken with the support of a local collaborator/translator. Rather than a temporal and methodological linear approach, my methods were iterative.

To achieve this objective, I conducted discussion groups/participatory mapping activities across the five communities. Groups of people were interviewed using semi-structured interviews with the objective of producing a map resulting from the discussion. Groups of no more than eight people were planned for, to ensure participation of all (Krueger & Casey, 2015; Lowery & Morse, 2009), although sometimes more people joined. Males and females were separated to avoid male dominance. People were also grouped according to their ages (<25, >25 to <50, and > 50 years old). The main objective of this method was to gain insights into the group knowledges of the vegetation types around their land, with corresponding descriptions. The importance of vegetation types, intensity of use, management, and governance were also discussed. For the sampling, although I aimed for a random stratified sampling (Shively, 2011), I adjusted to local norms (being guided by decolonising research principles) and people's availability. For this process, my local collaborator, which was also a member of the community, helped us bring together a group of people within the desired strata (e.g., men or women, young or elder), as random as he possibly could by walking in different directions across the village and inviting those who he encountered.

In total, I led 20 discussion groups, comprising 12 male and eight female sessions. Eight groups were of people less than 25 years old, seven groups comprised people between 25 and 50 years old and four groups comprised people older than 50 years old. Participants were experienced in various subsistence activities, since individuals typically engage in multiple activities rather than specializing in a single one.

To create the maps, I used a white paper board and markers of different colours. The group drew the rivers first as a way to locate themselves in the board. They located the village relative to where the river was and from there they marked where different vegetation types were located. Most participants were somehow intimidated with the use of paper and markers. Thus, for the most part they would point and describe and I would mark what they were describing on the paper. I double checked with them if what they were saying was fairly represented on the paper (Tobias, 2000). We also used the ground to show landscape features (Corbett, 2009), which they felt more comfortable with. Since I needed to save these maps for later analyses, I used simultaneously the ground and the boards for data collection, annotating the names of the vegetation types and further descriptions, including which places were used for which activities and which resources were offered by each place (Schrekenberg et al, 2016). The questions I used to lead this activity can be found in Appendix A1.1a.

Research question 2. Remote sensing and local classification

To address the second research question, I created two types of maps, one with only the inputs from satellite-derived data layers (an unsupervised classification) which provided me with large-scale, replicable coverage of the landscape, and helped in detecting broad patterns in vegetation cover (Rogan & Chen, 2004; Foody, 2003). I then created a second map using the same data layers, but with additional ground-based observations of vegetation types derived from the local classification (a supervised classification).

The vegetation classifications were executed with inputs (bands B2, B3, B4, B5, B6, B7, B8, B11) from 20 m resolution imagery from Sentinel-2 dataset (ESA, 2023) using Google Earth Engine (GEE). I used imagery acquired during the dry season of 2022 (May to October) since the cloud coverage is lower during this time. This season also offered greater visual contrast among vegetation types, enhancing distinctions between evergreen forests and deciduous woodlands that are less apparent in wet season imagery. For the unsupervised maps, I used a *K-means* clustering approach as this does not require prior knowledge of the classes. I set the number of classes to be the same as documented during my fieldwork (five classes, numbered from 0-4). In addition to Sentinel satellite imagery, I used the following three data layers, since local peoples pointed at these data as important when differentiating vegetation types:

- *Fire layer:* I used MODIS (MODIS/061/MCD64A1; Giglio et al., 2021) Burned Area data acquired from GEE from 2000 to 2022. This product has a resolution of 500 meters and is a monthly product. I identified pixels burned in each image within the study area (the product classifies a pixel as fully burned, even if only a portion burned). I then assigned binary values; 1 to years that had burned pixels and 0 to years that had unburned pixels. I then summed the number of times a pixel burned from 2000 to 2022.
- *Vegetation density:* I used the Normalised Difference of Vegetation Index (NDVI) as a proxy for vegetation density (Mitchard & Flintrop, 2013) from Sentinel-2 dataset (COPERNICUS/S2_SR_HARMONIZED, ESA, 2023) using the differences among Bands 4 (red) and 8 (near-infrared).
- *Topographic position index:* I used the Shuttle Radar Topographic Mission (SRTM) data set to add a precomputed index of the relative topographic position of each pixel (TPI) (CSP/ERGo/1_0/Global/ SRTM_Mtpi; CSP, 2024) within the study area. TPI is a relative measure of the position of a specific point in relation to the position of its surroundings.

For the supervised classification, I used a random forest model with the same Sentinel and additional data layers used for the unsupervised classification, in addition to the ground-based geo-referenced observations of vegetation class, obtained during fieldwork whilst moving around the landscape (between villages or whilst collecting qualitative data, and based on local classifications of the vegetation). Using a handheld GPS (Garmin GPSmap 62), I recorded the geographic coordinates of 342 locations with the presence of a local resident indicating which vegetation type that place corresponded to. I then used the points as training data for a supervised classification. The amount of data points varied across vegetation classes (since the data collection was opportunistic; meaning that rather than looking for certain vegetation types, I recorded the types that I found as I moved through the landscape). The number of points for each vegetation type were: 81 for savannas, 76 for shrublands, 57 for dense woodlands, and 115 points for open woodlands (which included miombo and open woodlands). Data points for grasslands were added visually using Google Earth since this land cover is important and common in the landscape, but points for grassland were not collected using the ground-based method previously mentioned (as fieldwork focused on wooded areas). However, based on fieldwork conducted after initial Google Earth observations, I am confident that grasslands can be correctly assigned from Google Earth imagery. For the supervised classification, I used 70% of the data points for training and 30% of the points for validation through a confusion matrix.

For the mapping, I grouped open woodlands and miombo woodlands into the 'open woodland' classification as well as the two grassland types into a single class (as they often occur adjacent to each other), because I did not have enough ground truth data to keep them as separate categories, and because the share structural similarities.

To compare both classifications (supervised and unsupervised), I conducted two analyses. First, I performed a Sankey analysis by turning the unsupervised and supervised maps into data frames (using the Raster package v.3.6-26*;* Hijmans, 2023, in R studio). I then merged both data frames based on the pixel ID and assessed which classes had a correspondence. Unsupervised classes were coloured with the class that had the highest correspondence to the classes in the supervised classification. New colours in the unsupervised classification were added if a class corresponded to several different classes in the supervised classification, and when an existing colour from the supervised classification was already used for an unsupervised class.

Second, I produced boxplots to assess the fire count, NDVI and TPI of each class for both classifications, using GEE to compare attributes among classification methods. For this purpose, I created random points across the classifications and extracted the values of the variables previously mentioned for each data point (using the function *Extract values to points* from *ArcGIS Pro* v.3.1.3.). Fire patterns were analysed using a Wilcoxon sign rank test (due to a non-normal distribution of linear model residuals) and TPI and NDVI through linear models using R Statistical Environment *Rstudio* v.4.3.*2* (R Core Team, 2019).

Research question 3. Uses and preferences of vegetation classes

To address the third research question, I used two data collection methods complementary to the participatory mapping activity to understand the use and values of the different vegetation classes. These methods, rooted in participatory rural appraisal techniques (Chambers, 1994), allow for efficient, community-based data collection that support local voices in defining resource use, land types, and environmental nuances. Their flexibility makes them ideal for triangulating with other methods. The methods were:

A) *Transect walks* (Olson et al., 2016): Walks around the landscape took place with 17 key informants (local residents who have developed knowledge around the uses and characteristics of the landscape; Jagger & Angelsen, 2011). I carried out ten walks with individuals younger than 25 years old, and seven walks with individuals between 25 and 50 years old, totalling 15 men and two women (as women often did not have time available). In most cases, the key informants were appointed by the *soba*, in accordance with local protocols and in line with principles of decolonising research methodologies (Datta, 2018). I asked the *soba* to identify someone with strong knowledge of the landscape and the various types of vegetation. At other times, community members suggested key informants, as individuals with expertise in specific areas are well known within the community. These walks, lasting between two to four hours, extended in multiple directions from each village. The direction was determined by the key informant. During each walk, we visited multiple types of vegetation, sometimes as many as five or six with each key informant. In total, I surveyed 13 shrublands, 11 open savannas, 10 miombo woodlands, 14 dense woodlands, and 7 grasslands. Once a vegetation class was reached, I conducted a semi-structured interview with questions about the differences among vegetation, uses, common tree species, and management. I also recorded the geographic coordinates of each place visited.

B) *Rapid surveys*: I interviewed 114 people individually. I used a stratified random sampling method (Shively, 2011). The strata chosen were inhabitants of the village and people old enough to independently perform activities in the landscape. After asking permission from the *soba* to walk around the community to survey people, I

> would walk randomly in different directions and ask whomever I encountered, who met the sampling requirements, if I could conduct rapid surveys. Limitations on the randomness of the respondents were present since social dynamics often require local authorities to indicate who will be interviewed. 55% of my interviewees were men and 45% women, whilst 29% were youth, 47% middle aged and 24% elder (for more detailed demographics of the respondents see Appendix A1.1b). I used a structured closed-end rapid survey (20-30 min) to gather information regarding vegetation uses (Jagger & Angelsen, 2011). This involved using a digital map on a tablet where people would point out the location where they performed subsistence activities and based on their responses, I attached qualitative data to those places using *ArcGIS Field Maps* v24.1.1. I recorded vegetation uses, resources, tree species, animals found, and management of these. Questions for the interview and survey can be found in Appendix A1.1a.

To analyse the qualitative data, I used a thematic inductive coding approach (i.e., themes were established after starting the data collection rather than beforehand) (Thomas, 2006), to identify the main vegetation classes reported by local inhabitants. These included: i) Dense woodlands, ii) Miombo woodlands, iii) Open woodlands, iv) Shrublands, v) Savannas, and vi) Grasslands. Afterwards, attributes were assigned to each theme, including a) general descriptions, b) activities/actual uses/preferred uses, c) animal species found, d) tree species found, e) management, and f) perceived importance for subsistence.

I employed triangulation by bringing together data from participatory mapping, transect walks, and rapid surveys, methods that together contributed to both complementary and convergent triangulation (Nemarundwe & Richards, 2002; Nightingale, 2016). Complementary triangulation allowed each method to offer distinct insights into vegetation types and landscape features, and overall helped me create a broader understanding of vegetation in the region (than each method alone). Convergent triangulation enabled the comparison of responses across methods to confirm information. I performed this triangulation separately for each community and by gender and age group, allowing me to identify patterns and divergences: a) among respondents within a village regarding the same vegetation class, b) across different vegetation types, c) between villages, d) among men and women, and e) among youths and elders. However, I focused mostly on the convergences of such separation rather than the divergences (as the convergences were more). This task contributed to comprehensive descriptions of local vegetation classes and to mapping their spatial distribution. Qualitative data were coded and analysed in *Nvivo* v.12 (QSR International, 2018), further supporting systematic cross-checking across data sources. During the research process, I used principles from decolonising research methods to conduct my work. This included recognising local peoples as owners of the knowledge produced (Datta, 2018), and conducting research based in reciprocity, humility, respect and active listening (Staddon, 2014; Staddon et al., 2023; Shanley & Laird, 2002; Datta, 2018).

Activities, uses and preference of the vegetation types

Using rapid surveys, I ranked identified vegetation uses on an ordinal scale (from 1-5) based on the frequency a given activity was mentioned within each vegetation type (for example, how many times agriculture was the response when asked about the use of dense woodlands). I then compared the results with data from transect walks and participatory mapping. Afterwards, I combined the frequency of responses for each activity, and assigned the value 1st to the vegetation type that was mentioned more often for all the livelihood activities combined and the 5th to the one mentioned the least. Vegetation classes not used for the main livelihood uses were not included in the ranking (for example agriculture in open savannas). The uses mapped were eight: i) agriculture, ii) honey production, iii) hunting, iv) collection of wild foods, v) collection of firewood, vi) wood harvesting for construction, tools and artefacts, vii) grasses for practical uses, and viii) medicine collection. Even though I only mapped four wooded vegetation types, for the qualitative descriptions I separated miombo and the second type of open woodlands (*Chipapa*), since although these were structurally and floristically similar (and thus mapped together), they had different uses. However, as previously explained, for the map of uses the second type of open woodland, *Chipapa*, was not included (and thus, the ranking for the mapping was 1-4).

Furthermore, data analyses highlighted in some cases contrasting results between the preferred uses of the vegetation and their actual use (explored through the question: which places are more important and which are less important for you?). I thus asked respondents to identify their preferred vegetation classes for each livelihood activity. For example, people might prefer dense vegetation for agriculture but that might be far, so they could mostly use open areas because they are more accessible. I used the same method as above to identify the most preferred vegetation class for each activity (I asked which was the preferred vegetation type, for example, for honey production, and I assigned the highest value from 1-5 to the vegetation that was mentioned the most). Then, I added the total number of times that a vegetation class was preferred for any given activity (for example, summing the times dense woodlands were preferred for agriculture + honey production + hunting, etc.), and ordered the vegetation types from most preference for all subsistence activities combined to the lowest one with the least preferences. This map helped visualize the contrasts among land uses and preferences which can aid in the understanding of the factors that shape decisions over land use, including future scenarios (for example, the preferred land covers can be targeted if the availability of the current land used was to change). For this map, the 'other' open woodland (*Chipapa*) was also not included.

2.3 Results

2.3.1 Main vegetation types based on local knowledge

Qualitative descriptions of vegetation types according to local knowledge

Local peoples identify five different wooded vegetation types and two grassland types in this area. I assigned English names to each, based on my translations and which, to a certain degree, correspond to names used in the southern African woodland literature (Campbell, 1996; Chidumayo, 1997). The following classification and descriptions are based on local ecological knowledge.

Dense woodlands: *Lihumbu* in the local language Luchaze

Local peoples describe this vegetation as having high stem density, with a diversity of tree sizes (height and diameter), but dominated by small diameter stems. The soil surface is covered by mosses with few or no grasses and abundant shrubs. Some local peoples classify this as two types, a denser one (*Lihumbu*) and a less dense one (*Liunda*). *Cryptosepalum exfoliatum pseudotaxus* is the most common tree species, but *Burkea africana*, *Dyospiros pseudomelix* subsp. *brevicalix, Brachystegia bakeriana, B. spiciformis,* and *Landolphya camtoloba* are also common. Agriculture, collection of wild foods (particularly mushrooms) and building materials, hunting and honey production are some of the most important activities performed here. This is one of the most important sites for agriculture, where they can grow a variety of crops like corn, pearl millet (where it grows better than in any other vegetation type), cassava, and beans. Gazelle and guineafowl might be animals exclusive to this vegetation, but wild pigs and monkeys are also found. These woodlands rarely burn, except when cleared for cultivation or accidentally, when only the edges are affected, mostly from fires from clearing nearby areas for agriculture. People cut trees mainly to clear for agriculture and for materials for construction, as trees are straight and with small diameters.

Miombo woodlands: *Nkangala* in the local language Luchaze

Local peoples describe this vegetation as being open with tall, thick trees. Although vegetation here is less dense than dense woodlands, stem density is still high, and the vegetation gets denser the further it is from rivers. Grasses and shrubs are present in the understorey. *Julbernardia paniculata* was identified as the dominant species, and although some patches are dominated by *Brachystegia spiciformis* too, that species is also notably absent in some areas. *Julbernardia paniculata, Brachystegia bakeriana*, and *B. spiciformis* reach their largest relative size in this vegetation. Other common species found are *Erythrophleum africanum*, *Parinari curaterifolia* and *Guibourtia coleosperma*. Agriculture, honey production, hunting and wild food collection are some of the most important activities performed here. Respondents said this vegetation is the best place to grow cassava. Sable antelope, wild pigs, deer, monkeys, and lions are some of the animals found here, although Sete and Samununga report a scarcity of animals for hunting. People intentionally burn patches of this vegetation to clear land for agriculture and to drive away snakes, as well as to hunt or to improve visibility. However, these woodlands are not burned every year (but every 2-3 years), nor is every patch burned at the same time. Fires used for the harvesting of honey can also spill over and accidentally burn these areas, yet larger trees seem to be fire resistant.

Shrublands: *Chitete* in the local language Luchaze

These are described as having abundant shrub cover and a few large trees, although the shrub cover and size is variable. Grasses are present but abundance is variable. The species dominating this vegetation tends to be *Brachystegia bakeriana,* although here it is more often a shrub than a tree. Other common species are *Monotes spp*., *Erythrophleum africanum*, *Burkea africana*, *Guibourtia coleosperma*, *Julbernardia paniculata*, and *Brachystegia longifolia.* Firewood collection is one of the main activities performed here, but collection of medicines and wild foods is also important. Hunting and placement of beehives can be undertaken here, but this is not the preferred place for these activities. Deer, rodents and wild pigs are hunted here. These woodlands are burned to clear the understorey (which makes it easier to walk through and less risky in terms of snakes) and to stimulate the growth of wild foods and new leaves. Some people reported difficulties finding enough firewood, resulting in having to travel larger distances or needing to find other vegetation to collect.

Open savannas: *Chana* in the local language Luchaze

These are described as having an understorey dominated by grasses of different species (but mainly *Loudetia spp*.), some shrubs and scattered small trees. Open savannas are often found near the riverbank but there are also savannas at high elevations. Open savannas at different elevations differ in stem density, with lower density near riverbanks. *Burkea africana* often dominates this vegetation when it is by the river, but *Erythrophleum africanum, Pterocarups angolensis, Terminalia brachystemma, Strychnos spp., Monotes spp.,* and *Dyplorynchus condilocarpon* are also found here. Wild food collection is one of the main activities performed here, although medicine, grass collection, and hunting are important too. Wild pigs, hares, rabbits, and rodents are commonly hunted here. Insects important for wild honey production are found in the herbaceous layer. Termite mounds, useful for construction bricks and for animal traps are also common in this type of vegetation. Open savannas are reported to be one of the covers that burn the most, although most of the burning occurs intentionally early in the dry season. The reason for burning is to stimulate wild fruit and young leaves/grass production for human consumption and to attract animals for hunting, as well as to drive away snakes.

Open woodlands: *Chipapa* in the local language Luchaze

These are open wooded areas, and some describe them as a mix between miombo and savannas. Some report these places as being former dense woodlands, but because of intense fires, they have turned into this vegetation type. Others say that these have always existed as they are. These do not occur near the rivers but always in the middle of dense or miombo woodlands. Trees are big and tall but not too abundant, with many grasses and shrubs. Tree species common here are *Hymenocardia acida, Dialum englerianum, Burkea africana, Guibourtia coleosperma, Diplorhynchus condylocarpon, Erythrophleum africanum,* and *Monotes spp*. Bracken is abundant in the understorey. Local peoples can obtain a few wild foods, medicines and materials for construction here, and they can hunt and place beehives, but other places are preferred for these activities. Animals like deer and wild pigs are hunted here. This land cover burns heavily and often every year, and fires frequently get to it from burning nearby crop fields.

Grasslands: two types, *Chizansa* and *Chimpoka* in the local language Luchaze

Grasslands tend to be mostly adjacent to the rivers (and have no trees). Although *Loudetia spp*. are the most common, this vegetation has other grasses of different size and type. Grasslands are widely used for the collection of grasses for ceilings, walls and brooms. Local peoples classify two types of grassland depending on the dominant grass species and the proximity to rivers. *Chizansa* occurs in lowlands by rivers and *Chimpoka* in higher grounds, but always close to rivers. Soils in grasslands are wet and fertile and people use them to grow vegetables such as cabbage, carrots and onions. Fires are reported to get to grasslands either accidentally from other places or intentionally to prepare soil for vegetable gardens.

Other features of the land

Local peoples also mentioned other features to describe the geography of the landscape, such as lowlands or thickets (Table 2.1). These are not necessarily different vegetation classes but areas or features within the vegetation classes mentioned above.

Table 2.1. Physical features of the land described by local inhabitants of southeast Angola

Local name	Description	Proposed scientific classification
Mumbuakusa/ Hipukusa	Areas with shrubs and thick vegetation, in the middle of two types of vegetation	Thicket in transition zones
Mingulunga	Low areas in the landscape, often by waterbodies and peatlands	Lowland/ valley of catena
Mapela	Areas with no trees, no grasses, only sand	Sand plain

2.3.2 Comparison between supervised and unsupervised vegetation classification

The two methods to classify vegetation revealed important differences. Each approach showed different land cover diversity at different catenal positions. Notably, unsupervised maps (with classes 0-4) do not differentiate dense woodlands from open woodlands (Figure 2.2a and 2.3b), but this same classification displayed a higher number of covers in open lowland areas (Figure 2.3d). When looking at the correspondence among classes from both mapping approaches (Figure 2.4), 99% of the dense woodland matched class 0 in the unsupervised map. However, dense woodlands made up only 35% of class 0. Meanwhile 61% of the open woodlands were also classified within class 0 in the unsupervised approach. Indeed, each vegetation type from the supervised classification contained a portion mapped as class 0 in the unsupervised classification, with approximately 50% of savannas and grasslands, and 25% of shrublands falling into this category. A portion of shrublands and savannas fell into all five vegetation classes in the unsupervised classification. Moreover, the supervised classification revealed an 88% accuracy in the validation process.

To further assess the differences among mapping approaches, I looked at fire, NDVI and TPI of each class on both approaches (Figure 2.5). Based on NDVI only, the unsupervised classification revealed five distinct vegetation classes whereas the supervised classification revealed three (Figure 2.5a and 2.5b). For TPI, the supervised classification differentiated open and dense woodlands at higher TPI than grasslands and shrubland (Figure 2.5c and 2.5d), whereas the unsupervised classification did not differentiate vegetation classes based on TPI.

Moreover, the unsupervised classification resulted in three distinct fire counts, whilst the supervised classification identified four, allowing for a differentiation in fire frequency among open woodlands, dense woodlands, savannas, and grasslands (Figure 2.5e and 2.5f). In the unsupervised classification, class 0 had the lowest fire count, averaging 1.6 fires over the past 23 years. This partially aligns with fire counts in dense woodlands. However, in the unsupervised classification, dense and open woodlands are combined in class 0, which has the lowest fire count, yet open woodlands are also included in classes 1 and 3, which experience fire counts up to five times higher than dense woodlands. In contrast, savannas, which had the highest fire count in the supervised classification, averaging 13.3 fires over the same period, are also distributed across class 0 which has the lowest fire count. For an unsupervised classification with no fire, NDVI or TPI layers, see Appendix A.1.2.

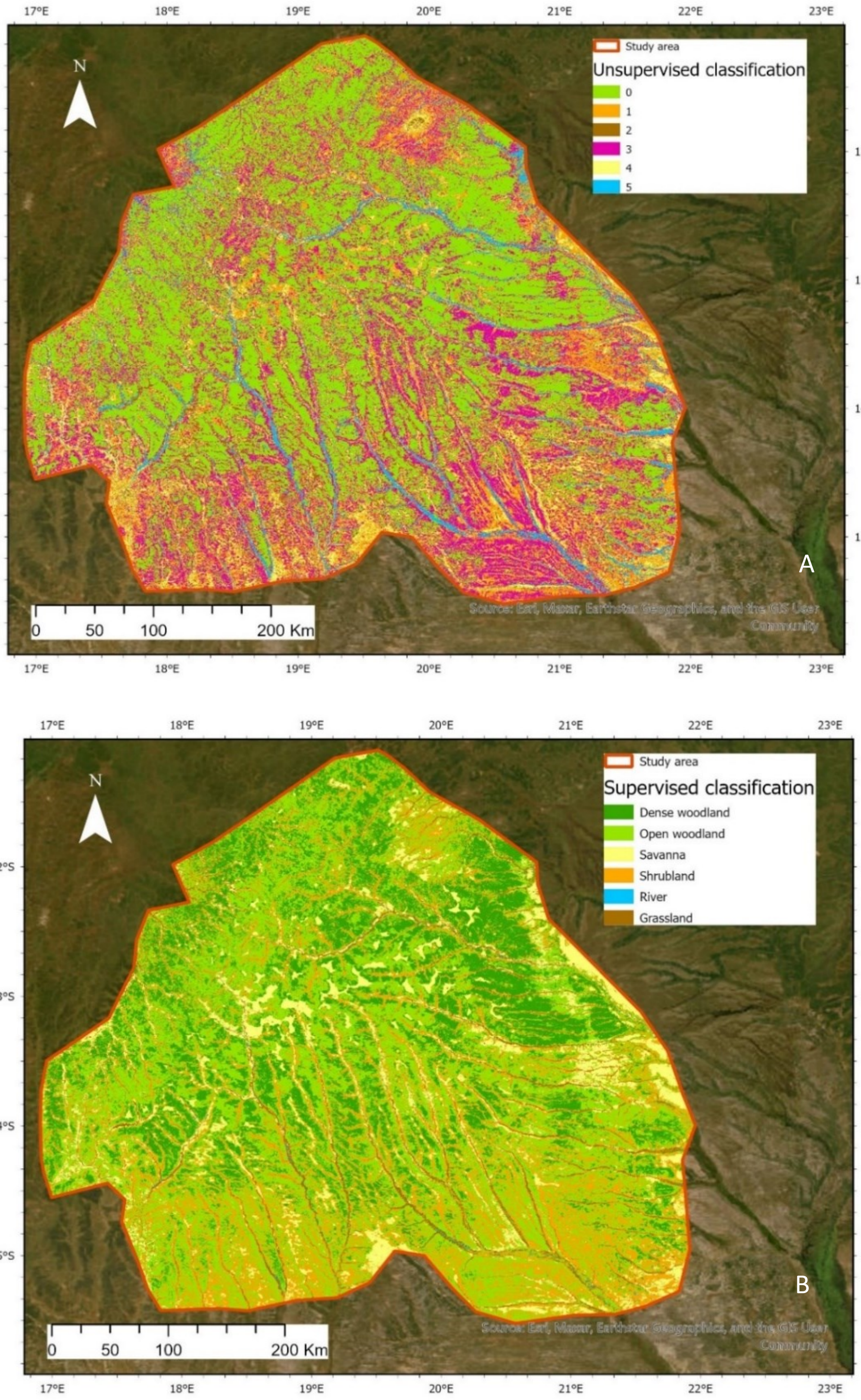


Figure 2.2. A) Unsupervised vegetation cover classification of the region of study with five classes (to match the five vegetation types described by local peoples). B) Supervised classification using data points collected on the field based on local classifications of the vegetation, with an 88% validation accuracy (using 70% of data points for training and 30% for validation). Both classifications used Sentinel-2 data (USGS, 2021), fire (burn count; MODIS; Giglio et al., 2021) and topography data (CSP, 2024).

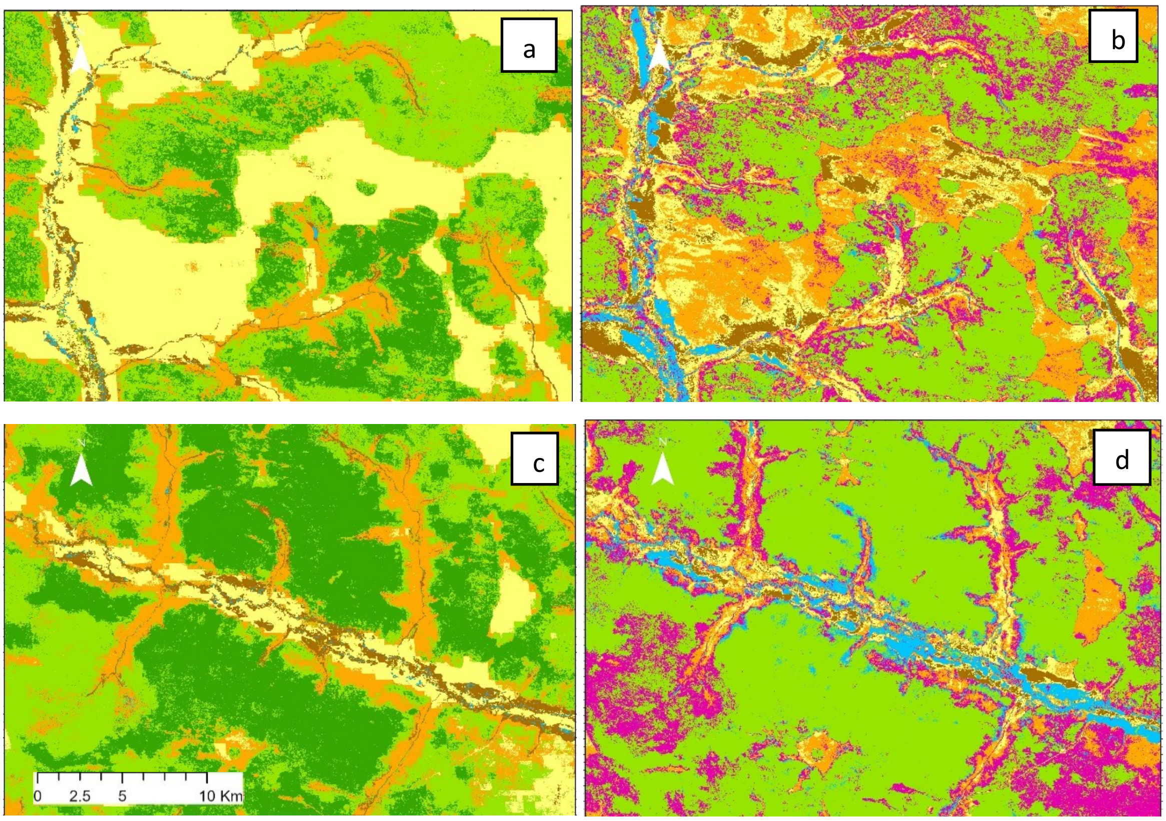


Figure 2.3. Insets from random places in the supervised and unsupervised classifications, where a) supervised classifications distinguish dense woodlands from open woodlands when compared to the b) unsupervised classification and, c) supervised classification reflects less vegetation covers in savannas and shrublands than d) unsupervised classifications.

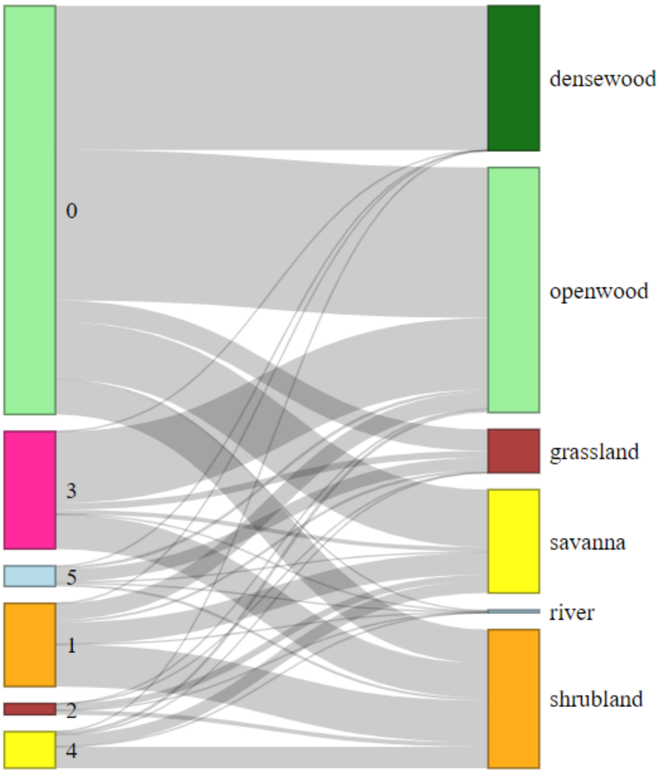
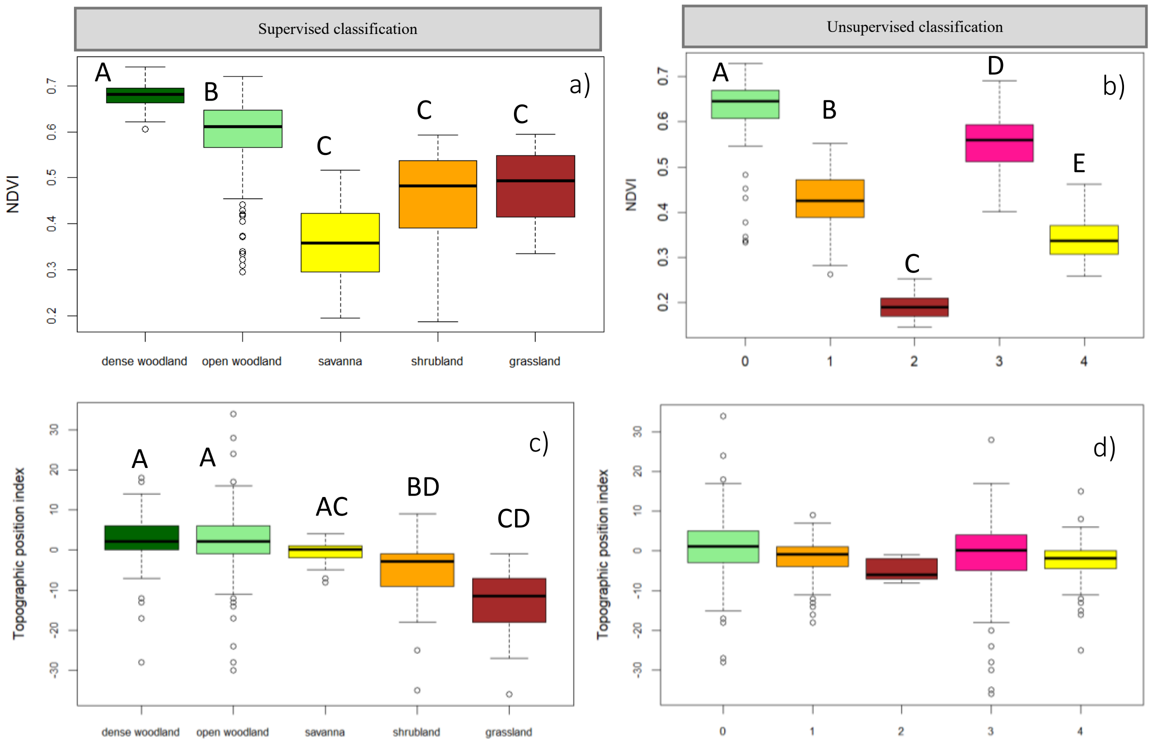


Figure 2.4. Sankey diagram comparing the unsupervised classification to the supervised classification (for bar graphs representing this correspondence see Appendix 1.3).



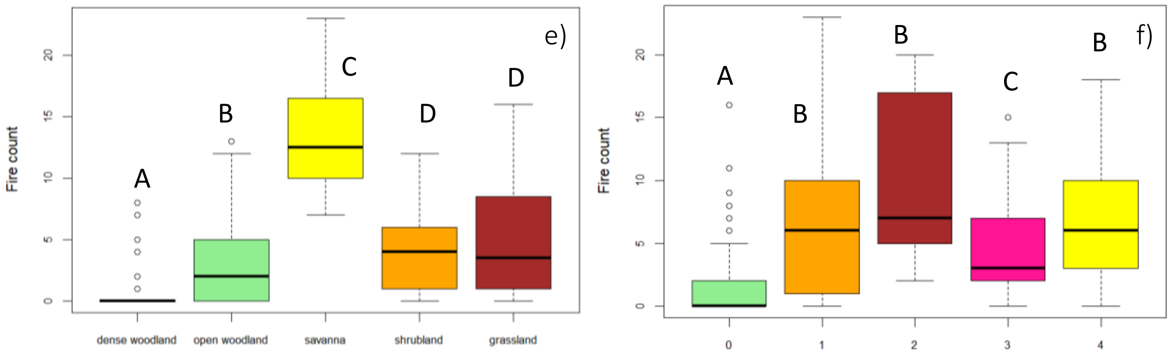


Figure 2.5. NDVI (Sentinel-2; ESA, 2023), TPI (STRM; CSP, 2024) and fire counts (during the last 23 years, maximum value of 1 per year; MODIS, burned area product; Giglio et al., 2021); of the supervised (a, c, e) and unsupervised classifications (b, d, f) respectively. Letters above boxes mean significant differences among classes. Same letters mean no statistical significance between the classes.

2.3.3 Uses of the vegetation

Different vegetation classes are used for different purposes across the region, and most have multiple uses. Dense woodlands are most used for agriculture, wood harvesting and collection of wild foods, whilst savannas are most used for collection of grasses and wild foods (Table 2.2). Although the presence of plant species or other products (i.e., mushrooms) or features (i.e., soil fertility) are important, there might be other factors that determine which places are most used. In general, miombo woodlands, followed by dense woodlands are the most used (Figure 2.6). The resources in the area are mainly used for agriculture, wood harvesting, honey production, hunting, collection of wild foods, firewood, and medicines. Agriculture might be the activity that causes the greatest change in the landscape since it requires vegetation clearing and burning. Maps displaying the most to least used vegetation presented by subsistence activity can be found in Appendix A1.4.

Table 2.2. Vegetation types from most used (1˚) to least used (5 ˚) for different productive and cultural activities

Use	Agriculture	Hunting	Honey production	Firewood collection	Wild foods collection	Wood for construction, tools and artefacts	Grasses for construction and artefacts	Medicines
1˚	Dense woodland	Miombo woodland	Miombo woodland	Shrubland	Savanna, Miombo woodland, Dense woodland	Dense woodland, Miombo woodland	Savanna	Shrubland

2 °	Miombo woodland	Dense woodland	Dense woodland	Miombo woodland	Shrubland	Shrubland	Grassland	Miombo woodland, Dense woodland, Savanna
3 °	Grassland	Shrubland Savanna	Shrubland	Dense woodland	Open woodland	Savanna	Miombo woodland, Dense woodland	Open woodland
4 °	Shrubland	Open woodland	Savanna	Savanna Open woodland		Open woodland	Shrubland	
5 °			Open woodland					

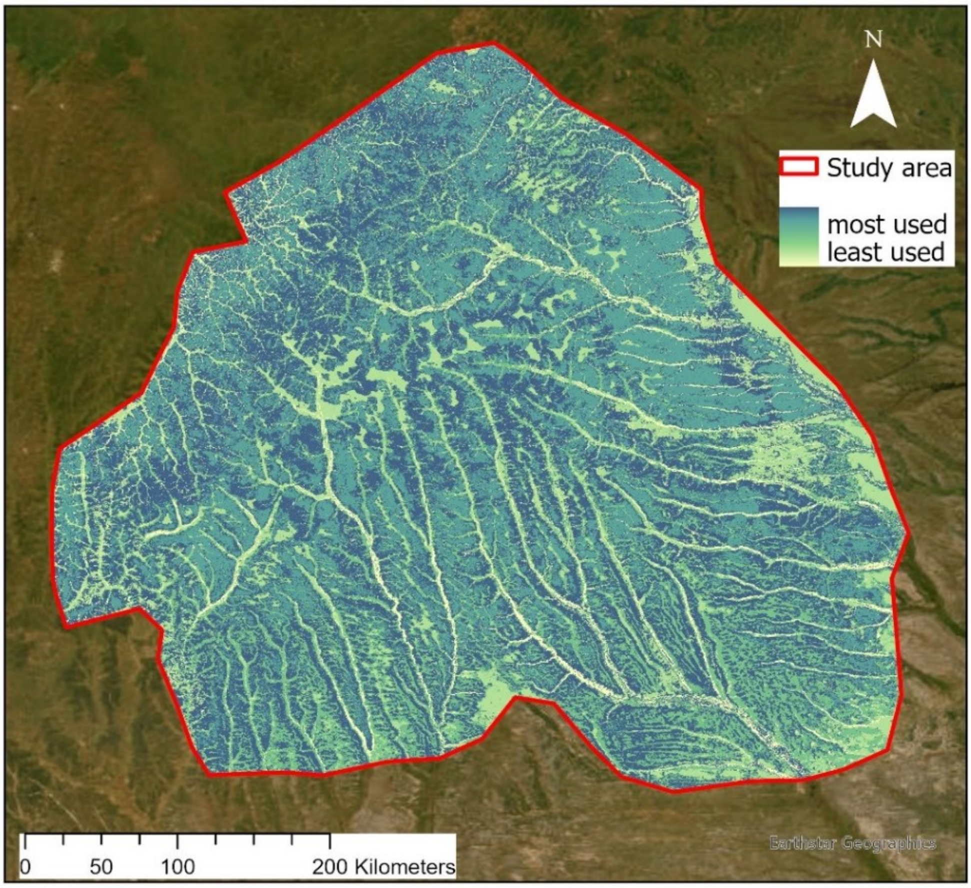


Figure 2.6. Map representing the sum of values (on a scale of 1-4) assigned to least to most used vegetation cover for all subsistence activities combined. Highest values represent the vegetation that are most used and lowest the ones least used. Miombo woodlands are the most used and grasslands the least.

2.3.4 Multiple uses and preferred vegetation classes

Vegetation types in this region are multifunctional, this means that they are used for multiple activities, products, values and services. For example, people have the choice to collect wild foods from either savannas or miombo. However, although most vegetation covers can be used for most activities, not all are preferred for all activities (Table 2.3). For example, savannas and shrublands can be used for up to six activities but they are only preferred for collecting wild foods and medicines respectively. Likewise, open woodlands are useful for six activities but preferred for none of the activities. Dense and miombo woodlands are used for all the main activities and also preferred for several (Figure 2.7), such as agriculture and honey production respectively. Thus, there is not always a direct relationship between which places are more used for certain activities and which ones are preferred for that activity.

Table 2.3. Preferred vegetation types for different productive and cultural activities in the region of study. Dense woodlands have the highest number of preferred uses, followed by miombo woodlands. *Green colour indicates the preferred class for that activity. ‘x’ means that the vegetation class is not used for that activity. The preference score is obtained adding how many times that vegetation class is preferred.

	Agriculture	Honey	Hunting	Wild food	Wood (construction, artefacts, tools)	Firewood	Medicine	Grass collection	Total uses	Pref. score
Dense wood	yes	yes	yes	yes	yes	yes	yes	no	7	4
Miombo wood	yes	yes	yes	yes	yes	yes	yes	yes	8	3
Open wood	no	yes	yes	yes	yes	yes	yes	yes	6	0
Shrub	no	yes	yes	yes	yes	yes	yes	yes	6	1
Savanna	no	yes	yes	yes	yes	yes	yes	yes	6	2
Grassland	yes	no	no	no	no	no	yes	yes	2	1

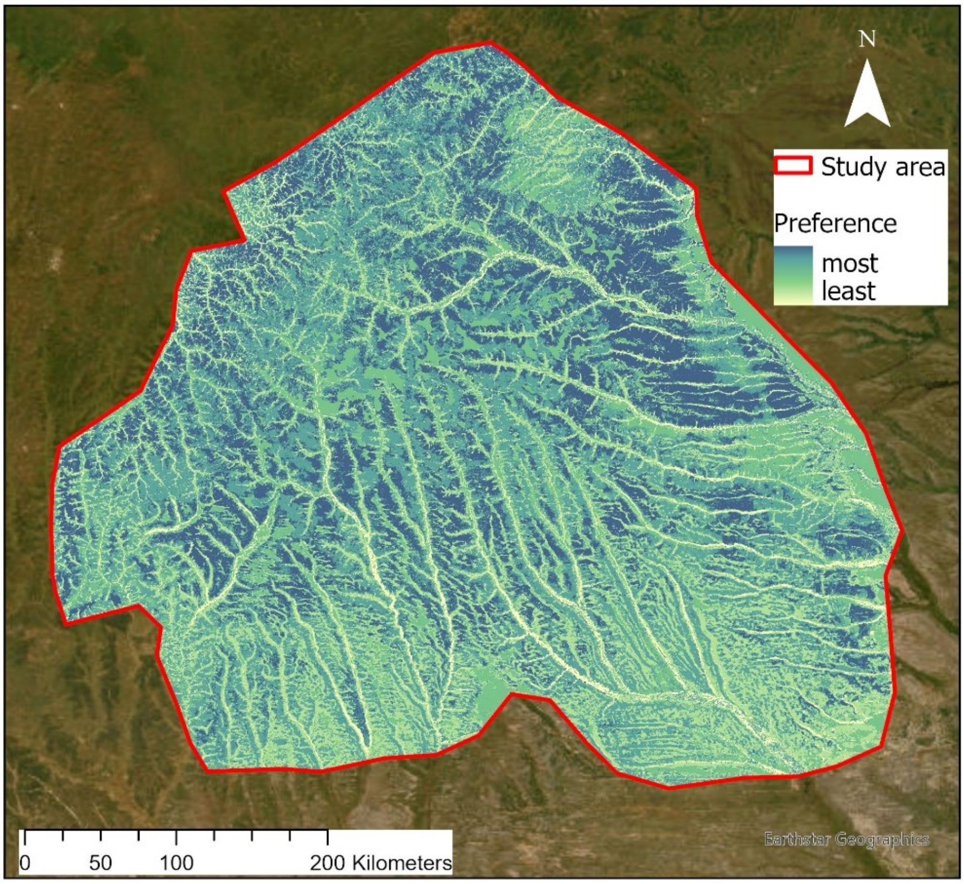


Figure 2.7. Vegetation classes with the highest to lowest number of preferences for productive and cultural activities (scale 1-4). Dense woodlands have the highest value being the place where four activities are preferred to be conducted.

Preferred land covers for agriculture varied across communities based on multiple factors. Dense woodlands were generally preferred for their fertile soils, ideal for cassava cultivation, a staple crop. However, proximity to villages also influenced choices. Sayoswa and Samununga primarily used and preferred dense woodlands, which were nearby, whilst Tempué and Sete preferred nearby miombo woodlands despite their less fertile soils. Effort to prepare fields was another consideration. Whilst dense woodlands have higher stem density, their smaller trees make land preparation easier. Additionally, the availability of suitable land close to villages played an important role in vegetation choice. For example, Sayoswa uses nearby dense woodlands, whilst Tempué, lacking accessible dense woodlands, prioritises miombo for its multiple benefits.

Preferences were also influenced by factors beyond resources, including socio-demographic variables like gender, reflecting the complexity of land use and preference decisions. For example, women more frequently discussed and drew shrublands during participatory mapping exercises. Men, on the other hand, spoke little of them, and some did not even mention shrublands. Rather, men spent more time speaking about more distant woodlands. In terms of age, I did not find considerable differences in the type knowledge shared by the youth compared to knowledge held by the elders, however the elder were able to share more details regarding changes in vegetation from past to present times. Examples of the results for the participatory mapping method are shown in Figure 2.8.

Figure 2.8. Participatory maps showing multiples of resources and uses of the different types of vegetation.

2.4 Discussion

My results suggest that participatory methods capture rich and important information about landscapes and livelihoods in southeast Angola. Through local ecological knowledge (LEK), I learned that local peoples identify five woodland types and two grassland types. Their differences reside in the tree species found on each, tree density, fire regimes, and uses. The gaps between supervised and unsupervised classifications in my study illustrate the shortcomings of conventional mapping methods and the advantages of an inclusive, ground-based approach. Centring the delineation of the landscape on local ecological knowledge is fundamental to capture features of the landscape useful for scientific land classification. Using LEK in combination with satellite data therefore offers a deeper understanding of the vegetation in the region than remote sense mapping alone. Furthermore, rather than seeing landscapes as physical units, understanding them as socio-ecological systems could foster a more holistic view of landscape dynamics (Lambin et al., 2006).

Remote sensing and participatory methods for the classification of vegetation

In this study, dense and open woodlands were, to an extent, classified under the same cover when using satellite data only. As revealed by local knowledge, these two vegetation covers have different fire regimes and uses. Merging them could therefore result in homogenized management approaches that can threaten the ecological diversity of the landscape.

Moreover, local insights on fire regimes, topography, and vegetation density proved particularly valuable for distinguishing among different types of woodlands. This highlights the potential for bridging local knowledge with remote sensing analyses to enrich our understanding of landscape patterns and processes and to aid in the production of scientific knowledge and ultimately, improving the mapping process (Sandbrook et al., 2023; Schleicher et al., 2019). In parallel, inclusive methods can support the shift to decolonising conservation by placing local voices and epistemologies at the centre of the research process (Smith, 2012; Yanou et al., 2023).

This study also highlights that unsupervised maps do not make evident aspects of vegetation important for livelihoods, particularly in terms of use like the collection of non-timber forest products (e.g., mushrooms, grasses, and medicines) not necessarily linked to forest structure but nonetheless important.

Vegetation use and cover

My results show that whilst each vegetation type is used for main specific purposes, several activities (such as wild food gathering), take place across multiple vegetation classes, demonstrating the landscape's multifunctionality, as noted in other African contexts (Roth, 2009; Cumming & Lynam, 1997). Having alternative places for the most important livelihood activities (i.e., agriculture and honey production) provides a safety net for local peoples and translates into less pressure on only one type of vegetation. Thus, a landscape that supports diverse uses, under sustainable management conditions, might remain compatible with conservation objectives. The value of this landscape thus, lies not just in specific vegetation types, but in the diversity of vegetation types and resources it offers, a diversity that is important from both a conservation and a social justice perspective.

Furthermore, I found that local peoples perceive vegetation type and its use as inherently connected, rather than as separate categories. From a socio-ecological perspective, vegetation classification and its practical uses in rural contexts managed locally, are often indistinguishable, reflecting an integrated view of the landscape (Robbins & Maddock, 2000). Given the strong link between vegetation use and type, the understanding of their relationship benefited in this study from an approach that linked social data to remote sensing and geographical information (Fox et al., 2003). This approach allowed me to interpret vegetation types in the context of their physical and ecological features with relation to their uses by local communities (Walsh & Crews-Meyer, 2002). Furthermore, by merging use and class, a visualization of who might deserve rights over the land can become visible (Robbins & Maddock, 2000). An ethical approach to conservation is not only a matter of human rights, but also a pragmatic and effective strategy for environmental protection (Domínguez & Luoma, 2020).

Participatory methods support the understanding of the motivations behind resource use and preference, which can be relevant to conservation approaches that seek to regulate resource use. In this case, the choice and preference for which place to use might be linked to reasons beyond the availability of resources, such as the cost associated to their collection (i.e., distance to the site, Lynam et al., 2004) or who is collecting (i.e., gender) and under which conditions (i.e., time limited). Gender, along season and the quality and quantity of available resources have been observed to be significant variables in the spatiality of productive activities in rural landscapes (Roth, 2009; Pritchard et al., 2019). In my study site, I observed that women and men focused on different places. For example, women spoke more frequently about shrublands, which reflects their daily involvement in firewood collection and their movement within the immediate landscape, which gives them detailed local knowledge of nearby areas. In contrast, men tend to travel greater distances for hunting, fishing, and honey production. As a result, they often have a broader spatial understanding of the wider landscape beyond the immediate village surroundings.

The configuration of the immediate landscape also played an important role in the assessment of services provided by the vegetation and in what was used by local peoples. For example, depending on what was around each village, the chosen vegetation type for agriculture differed, which might mean that the targeted vegetation cover for agricultural conversion depends on its distance from the village (Fagerholm et al., 2012). In addition, I found that local peoples in this study use resources in an area around the village of about 105 to 490 km^2 for a village of about 300-2000 people. This range is similar to that observed in other parts of southern Africa (Cumming & Lynam, 1997).

Notably, in some cases the most used vegetation covers were not the most valued by people. These types of subtleties might only be identified through ground-based methods that capture complex multi-dimensional insights about socio-ecological landscapes. Furthermore, preference is not the only determinant of use or appreciation. Vegetation that might be seen as of ‘low’ forestry value, namely open savannas with little or no tree cover, still play an important role for rural livelihoods by providing wild foods and hunting grounds. The ability of households to utilise resources from systems with low or no biomass also contributes to their economic resilience, demonstrating that high biomass woodlands are not the only providers of environmental products and services (Pritchard et al, 2019), even when conservation highly values tree cover. To achieve socially equitable conservation outcomes, it is then crucial to incorporate the diverse values that local communities attribute to nature (Pritchard et al., 2019; Schleicher et al., 2019).

Participatory methods and its role in conservation

Conventional mapping exercises can have concrete impacts on local communities and the environment, particularly when shaped by colonial legacies that continue to devalue local land-use systems in favour of Western ideals of productivity (Dominguez & Luoma, 2020). These approaches often reproduce a colonial worldview that separates people from place

(Muller et al., 2019), undermining local livelihoods and cultural practices, and may lead to the infringement of communities' rights to land and resources (Schleicher et al., 2019).

Conservation-driven classifications, often based on ecological metrics such as canopy density, carbon stocks, or biodiversity, tend to prioritize dense or tall-structured woodlands as areas of high conservation value (Schulz et al., 2019; Hernando et al., 2017; Blackman, 2013; Corbane et al., 2015), whilst such resources might also be highly relevant for local livelihoods. The overlap between conservation priorities and local resource use might then create tensions (Shackeroff & Campbell, 2007; Berkes, 2012; Lynam et al., 2004). In southeast Angola, places with high ecological value, such as dense woodlands, are also highly valued by local communities. Yet, instead of viewing local use as a threat, I argue that local communities often act as stewards of these areas precisely because of the importance to their livelihoods. In this context, use does not equal degradation, and may, in fact, support sustainable management. Imposing top-down conservation approaches without recognising the role of local communities in sustainably managing the land, could then have adverse effects for local communities (Barnes et al., 2023). Indeed, evidence from similar contexts show that forest loss can be significantly lower on locally managed lands compared to those governed by centralised conservation schemes (Yanou et al., 2023). Worldwide many local communities have been effective in engaging in sustainable practices to maintain vegetation diversity and ecosystem health, since that ensures that ecosystems continue to meet their needs (Pratzer et al., 2023).

Recommendations

Conservation goals are not politically neutral; rather, they carry substantial social, distributive, and justice implications (Meyfroidt et al., 2022). Actively involving local communities through participatory methods in the definition of their territories can enhance the fairness and effectiveness of conservation, fostering dialogue and collaboration that leads to more equitable outcomes (Sandbrook et al., 2023; Schleicher et al., 2019).

If conservation initiatives are to be implemented in the highlands of Moxico, it is critical to consider LEK, with respect, reciprocity, and humility, as well as to question the assumptions over what is the ideal landscape and according to whom (Pritchard et al., 2021; Wyborn & Evans, 2021). Participatory maps can represent a vehicle for the communication of local eco-spatial information and a mechanism through which marginalised groups can advocate for the recognition of customary land rights (Corbett, 2009). Ultimately, projects that align with local peoples' preferences, and that are implemented through inclusive management, and promote sustainable resource use, rather than enforcing strict protection of biological resources or top-down interventions, are more likely to empower local peoples as well as encourage cultural and livelihood benefits, leading to positive conservation and social outcomes (Löfqvist et al., 2023; Oldekop et al., 2016).

Limitations: to map or not to map?

Like any research approach, mapping may not fully capture local knowledges and realities, as certain human dimensions are difficult to represent spatially or quantify in numerical terms (Malavasi, 2020; Wyborn & Evans, 2021). Indeed, the main challenge I encountered was the difficulty of translating qualitative data into maps. A great amount of what I learned through this study was not easily displayed in a spatial data layer. Also, boundaries in the vegetation classification system of local peoples were sometimes fuzzy, as previously reported in local land classification systems (McCall & Dunn, 2012). This can reflect the dynamic nature of human-environment interactions, and the difficult task of fitting nature within human-made classification systems (Robbins & Maddock, 2000). Seldomly do experiential spatialities fit into models with static boundaries, thus, an integral representation of how people interact and experience space requires moving towards mapping that shows dynamism (Roth, 2009). This opens an epistemological question: to what extent is it possible to map living spatial knowledge? Or is it inevitable that, one of their most important characteristics, their dynamism, might get lost in mapping'?

In addition, bridging LEK with Western management systems risks oversimplifying local knowledge and reinforcing existing power imbalances. Thus, it is essential to address these power dynamics in the research and conservation arena (Albuquerque et al., 2021; Houde, 2007). Moreover, considering issues of intellectual property rights also need careful consideration since sharing spatial data can risk enabling land dispossession of marginalised groups (Bohensky & Maru, 2011; Barber & Jackson, 2015).

Lastly, it is important to recognise that the local descriptions of the vegetation might only be an approximation or simplification of the diversity of local knowledges. How many and which classes of vegetation exist in the landscape is arbitrary, as it relates to the purpose of the classification. Maps are selective, they represent a particular way of looking at the world, and they often do not display all there is to know about any given place (Malavasi, 2020). In this study, when comparing participatory maps produced by different groups for the same village as well as among groups of different villages, maps varied, possibly a result of personal experiences, gender, and occupation, among other factors difficult to represent on a map. Moreover, local knowledge is not 'fixed', as there might be contrasting views not only between local and scientific knowledge but also between various local knowledges (Andolina et al., 2009; Gilmore & Young, 2012). To produce maps, I relied on averages or median values, but the produced maps are not always fair at portraying variability within the same class that is expressed by individual or collective experiences.

2.5 Conclusion

The use of remote sensing to map and classify the land has proved to be a useful tool in ecology and forestry, but this method might simplify reality and only display features important for top-down conservation, namely woodland structure or forest change. The use of participatory methods to understand local classifications of the vegetation can enhance conventional mapping which in turn can serve as a means for inclusive rights-based conservation. Bridging remote sensing with LEK can support the production of maps that portray physical, social and cultural values that people attach to socio-ecological landscapes.

In this study, local peoples revealed a classification of the vegetation that included five different woodland types besides grasslands and rivers. Vegetation types in this region are distinguished not only by their unique fire regimes, vegetation density and topographic positions, but also by specific uses and products each provides to local communities. For them, vegetation types and their uses are closely interconnected rather than seen as separate categories. When uses of the vegetation are acknowledged and considered into mapping processes, locally relevant social aspects of the landscape can be identified, along with a visualization of who might deserve rights over the land. In this case, a socio-ecological framework approach enabled a better understanding of landscapes as complex systems of interactions between human societies and the environment. Furthermore, centring local knowledges and uses of vegetation is essential for the co-development of just, inclusive and effective conservation plans. However, an effective recognition of the sovereignty of local peoples in conservation means challenging existing power structures (Muller et al., 2019).

Overall, these findings contribute to conservation science by advocating for ground-based, context-sensitive mapping approaches through the bridging of scientific and local knowledge systems. In the process, these findings support decolonising methodologies by positioning LEK as central to understanding and classifying socio-ecological systems.

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Chapter 3. Exploring Angola’s dry forests: a floristic analysis of wooded vegetation in the southeast

Abstract

Around 40% of Africa is dominated by tropical woody vegetation, and different terms have long been used to classify such vegetation. Miombo has been recognised as the most extensive tropical woodland in Africa, but definitions of miombo are broad and often overlap with definitions of savannas and forests. Angola, one of the countries in the miombo region, contains woody vegetation that covers 60% of the country and miombo has been identified as the dominant vegetation type. However, local peoples reported diverse vegetation types in places that have previously been mapped as miombo woodlands. This chapter explores the ecology of woodlands in southeast Angola, a region that has been touted as containing one of the largest and least disturbed blocks of miombo in the world. This study aimed to test the current classification of the region as a homogeneous miombo woodland. By establishing 26 vegetation sampling plots and integrating local ecological knowledge and floristic analyses, I identified five distinct woodland formations, including a rare dry forest dominated by *Cryptosepalum exfoliatum pseudotaxus*, revealing overlaps between local and scientific vegetation classifications. Such vegetation types differ in floristic and structural metrics. Furthermore, floristic comparisons with plots across the broader region, including in the Democratic Republic of Congo, Namibia, and Zambia, revealed that the study area's vegetation matches various non-miombo vegetation types. In particular, the *Cryptosepalum*-dominated plots floristically align with Zambezian dry evergreen forests. This forest type differs significantly from typical miombo woodlands in composition and structure, prompting a re-evaluation of Angolan vegetation maps and highlighting the need to include evergreen dry forests in maps of Angola, which have previously only been mapped in western Zambia. Accurate vegetation classification is essential for effective management and conservation, as these landscapes support both biodiversity and vulnerable human populations.

3.1 Introduction

Around 40% of Africa is dominated by tropical woody vegetation (Mayaux et al., 2004). Different and overlapping categories have long been used to classify such vegetation (Richards et al., 1940), including terms like savanna, woodland, thicket, shrubland and dry forest. Dry forests and woodlands have been defined as vegetation dominated primarily by trees, where the canopy covers more than 10 % of the ground surface, occurring in climates with a dry season of three months or more (FAO, 2000). These types of vegetation are found in 31 countries in western, eastern and southern Africa, being the dominant vegetation in the majority of these countries. They cover approximately 17.3 million km^2 and are inhabited by over 500 million people (Chidumayo & Gumbo, 2010). Within dry forests and woodlands, miombo has been recognised as the most extensive tropical woodland in Africa (FAO, 2012; Frost, 1996).

Miombo ecosystems, a type of savanna, spread across seven countries in southern Africa, covering an estimated 1.9 million km^2 and are home to nearly 250 million people (Ribeiro et al., 2020a). Miombo lays in the transition between closed rain forest in central Africa and open woodlands or savannas of southern Africa (Malaisse, 1993). Fabaceae tree species, particularly the Detarioid genera *Brachystegia*, *Julbernardia* and *Isoberlinia* dominate miombo woodlands, a feature that distinguishes them from other African woody formations (Frost, 1996; Ribeiro et al., 2015). However, miombo ecosystems are diverse and these genera might not be representative of all miombo ecosystems (Banda et al., 2008; Mwakalukwa et al., 2014).

Miombo woodlands can be homogenous over large areas or show high physiognomic variation, particularly in terms of tree density and canopy cover, with such variations potentially related to disturbance (Ribeiro et al., 2015). Miombo woodlands can also be interspersed with other vegetation types such as mopane woodlands, *dambos* (grassy areas with seasonally waterlogged forests), dry forests, deciduous, semideciduous and evergreen forests (Campbell et al., 2007; Chidumayo & Gumbo, 2010; Oliveras & Malhi, 2016). Miombo woodland structure and floristics are strongly influenced by multiple factors, particularly plant available moisture, plant available nutrients, fire and herbivory (Mistry, 2014).

Miombo woodlands have been described as a plagioclimax ecosystem or the sub-climax to evergreen or semi-evergreen forests, with this sub-climax state maintained by frequent fires, human use and herbivory (Freson et al., 1974; Lawton, 1978; Morris, 1970). Others have described it as a closed deciduous woodland within the spectrum of savanna ecosystems (Walker, 1981). Miombo has also been termed a moist-dystrophic savanna (Huntley, 1982) and a pyric savanna (Lehmann et al., 2022), with a history of adaptation to fire reflected in the presence of fire tolerant tree species and a flammable grassy understorey (Ratnam et al., 2011). In the literature, terms used for miombo range from open grassland to bushland, woodland, thicket or closed canopy forest (Banda et al., 2008; Frost, 1996; Malmer, 2007).

In general, the terminology used to describe African vegetation is based in different approaches, and there is not a universally accepted classification system but instead different descriptions with different criteria. This can lead to misunderstanding and mismanagement of tropical vegetation.

Along with the discrepancies regarding miombo woodland definitions and classification, miombo ecology studies have focused mostly on dry miombo and on describing species composition and structure within protected areas, as well as areas where cultivation is not occurring (Jew et al., 2016). Moreover, changes to the miombo woodlands or the actual coverage of miombo have not been thoroughly investigated (Gumbo & Dumas-Johansen, 2021; Zulu et al., 2020). Research in miombo ecology in Southern Africa has been concentrated in the central and eastern parts of the miombo region, particularly in Tanzania, Mozambique, Democratic Republic of Congo, Zimbabwe and Zambia.

Angola is one of the countries in Southern Africa with the fewest scientific studies regarding dry forests and woodlands (David et al., 2022). Angola is also the region’s least inventoried country for plants, with significant gaps in knowledge about species composition, plant diversity, and vegetation patterns, particularly in the southeast (Goyder et al., 2018; Goyder

& Gonçalves, 2019; Lautenschläger et al., 2022; Revermann et al., 2017). Much of the available information about Angola's plant and woodland ecology has been derived from botanical studies conducted during colonial times or, more recently, from remote sensing data (Chisingui et al., 2018). When ground-based sampling has been conducted, it has not focused on the southeast (see Catarino et al., 2020; Godlee et al., 2020; Revermann et al., 2017; Schneibel et al., 2018).

Angola's woody vegetation covers 60% of the country (World Bank, 2019) and miombo has been identified as the dominant vegetation type (covering 570 000 km^2; Malmer, 2007; Loft et al., 2024, Burgess et al., 2004; White, 1983). However, vegetation patterns in Angola are complex, and there have been many vegetation classifications over time. For instance, Gossweiler and Mendonça (1939) identified 19 vegetation units (Revermann & Finckh, 2019), and later, Barbosa mapped 32 vegetation units (1970). Even though in these classifications miombo predominates, discrepancies exist among them.

At the same time Angola faces significant changes in its woody cover, losing 500 000 hectares per year with a net annual change of −0.8% (World Bank, 2019). Indeed, Angola holds the world's highest annual rate of cropland expansion into woody ecosystems (Estes et al., 2016). These dynamics underscore the importance of improving our understanding of Angola's vegetation to balance conservation and land-use demands amidst ecological transformations.

But the level of transformation is not uniform across the country. The highlands of southeast Angola are among the country's best-preserved woodlands and most isolated regions (Pröpper et al., 2015; Zweede et al., 2006). Much of southeast Angola has been marginalised, possibly due to political affiliations during the civil war (Brinkman & Alessi, 2009), which reflects in little infrastructural development and a lack of accessibility for scientific studies. However, these limitations have also been important to maintain much of the region's 'remoteness' and 'intactness' (Andrews et al., 2024). Currently, several communities reside in the region, and appear to use resources sustainably.

The woodlands of southeast Angola are part of the Central Zambezian miombo ecoregion (Barbosa, 1970; Burgess et al., 2004), described in the literature as being dominated by wet miombo (Burges et al., 2004), with a small patch of Zambezian evergreen forest on the border with Zambia (Barbosa, 1970; Lautenschläger et al., 2022). However, recent studies reveal a widely variable fire regime in these woodlands, with some areas experiencing little to no burning over the past 23 years (Lourenco et al., 2023). Given that fire is generally considered to be a characteristic feature of miombo ecosystems (Chidumayo, 1997a; Puyravaud et al., 1995), the absence of fire in some areas challenge the notion of this region as a homogeneous miombo landscape.

The woodlands in southeast Angola are crucial for the health of southern Africa's water systems, particularly for the Okavango Delta where the Cuito-Cubango and Cuando rivers originate, as well as for the Zambezi River basin. The region is also essential in supporting rural livelihoods by contributing to food security and providing a wide variety of ecosystem services (Campbell et al., 2007; Chidumayo & Gumbo, 2010; Gumbo & Dumas-Johansen, 2021). The ecological and social relevance, along with its remoteness, makes the highlands of southeast Angola a priority for conservation efforts (Andrews et al., 2024). However, significant knowledge gaps concerning the region's ecology represent a challenge to effectively plan, manage and monitor these ecosystems based on their unique characteristics.

My goal in this study is to improve the understanding of vegetation in the poorly known region of the highlands of southeast Angola, which has been touted as 'one of the largest remaining intact miombo woodlands on the continent' (NGWOP, 2017, p.7). Since the knowledge gap about the ecology of this area is significant, I aim to engage local knowledge holders in the process. I aim to address the following research questions: 1) What are the main vegetation types found in the highlands of southeast Angola, and how do they differ in terms of floristic composition and structure?, and 2) How do the vegetation types in southeast Angola compare floristically with woodland and forest types in neighbouring countries? To answer these questions, I aim to characterise the main vegetation types based on ground-based ecological surveys, specifically in terms of floristics and structure. Then, I strive to floristically compare the vegetation types present in the region with vegetation across neighbouring countries, to understand where this vegetation sits within broader classification schemes.

Parallel to ecological surveys, this study draws on local ecological knowledge (LEK) to help identify, describe, and contextualise local vegetation types, which can help us to identify key variables not captured in scientific assessments of the vegetation in this area (Brook & McLachlan, 2008; Gadgil et al., 2003). Complementing and contrasting LEK with scientific ecological knowledge can enrich our understanding of the vegetation in this area and support more grounded conservation decisions (Albuquerque et al., 2021). Moreover, incorporating LEK ensures that the study reflects local realities and strengthens the relevance of ecological research to the people who depend on these landscapes.

3.2 Methods

3.2.1 Study area

This study was developed in the highlands of Moxico province in southeast Angola (Figure 3.1). The highlands are dominated by woody vegetation at higher elevations, and rivers and grasslands at lower elevations.

Climate in the study area is seasonal with high temperatures and rainy conditions during the summer and low temperatures and dry conditions during the winter. The rainy season goes from mid-October to the end of April, whilst the dry season starts in May and lasts until mid-October. Temperature ranges from 10°C to 28°C (USGS, 2020) and annual rainfall averages 1030mm ± 100mm (mean ± S.D.) (Funk et al., 2015). Elevation varies from 1220 to 1580 masl (USGS, 2020). Communities in the region depend mainly on agriculture, honey production, hunting, and collection of different woods and non-timber forest products for subsistence as well as for income generation.

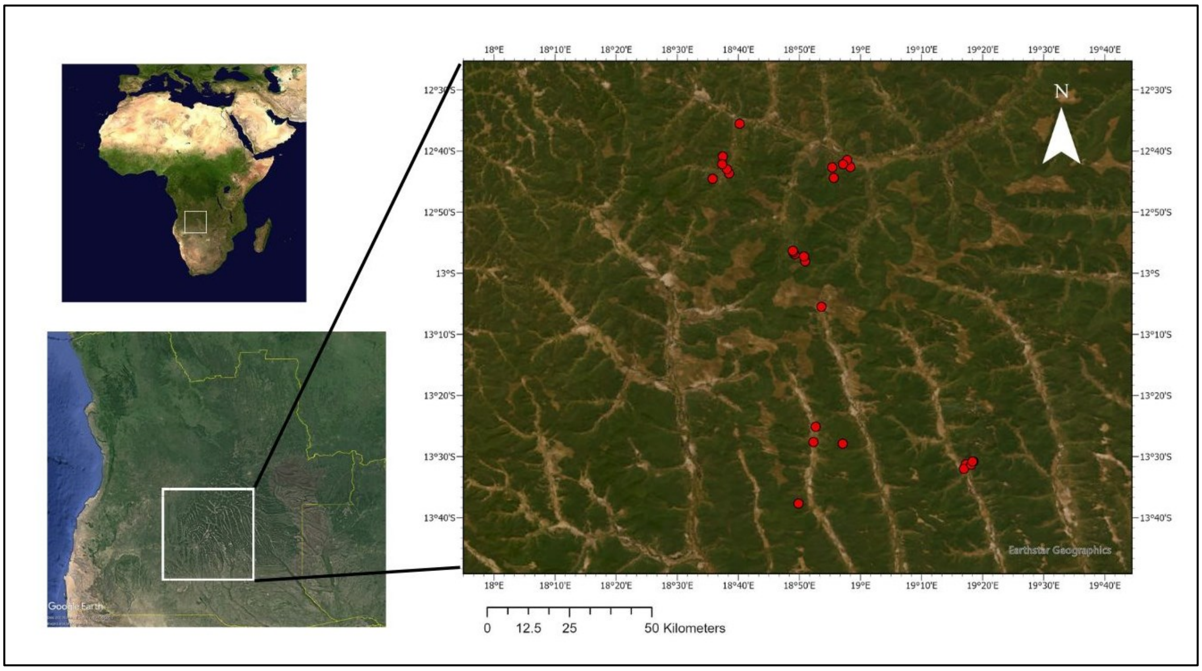

Figure 3.1. The highlands of Moxico in southeast Angola, with the panel on the right showing the location of plots (red points) within the area of study. Within the panel, low elevation areas along rivers are brown, reflecting low tree cover compared to higher elevation interfluves.

3.2.2 Data collection

Research question 1. Ecological surveys: Plot data collection

I used the SEOSAW protocol (SEOSAW Field Manual v3.5) developed by the SEOSAW network (SEOSAW, 2022) for inventorying woody vegetation with plots (Godlee et al., 2020; Gonçalves et al., 2017). Using the SEOSAW protocol allowed my data to be more readily comparable to other data (e.g., across the broader region). Plots were established in five vegetation types identified through local classifications (described in Chapter 2), so that I could compare western scientific classifications with local ones. I assigned English names to the different vegetation types that correspond, to the best extent possible, to standard names in the literature (Chidumayo, 1997b; Richards et al., 1940). The woody vegetations according to local peoples were: a) open savannas (dominated by grasses with scattered trees), b) shrublands (dominated by shrubs with scattered trees and variable grass cover), c) miombo woodlands (dominated by trees of the *Brachystegia* and *Julbernardia* genera with variable grass cover), d) open woodlands (dominated by trees of other genera and with high grass cover), and e) dense woodlands (dominated by *Cryptosepalum spp.* with little to no grass cover). I sampled twenty-six 50x50 m plots in the study area (Figure 3.1), a choice to balance between sample number and sampling sufficiency per sample (i.e., plots were small enough so that I would have enough plot data points to analyse in a comparative manner). Sampling was stratified by vegetation type: dense woodlands (5 plots), miombo woodlands (5 plots), open woodlands (4 plots), shrublands (5 plots), and open savannas (7 plots) (the differences in total plots were due to time constraints). Plots were established in areas accessible from local villages whilst spatially dispersed to sample all the vegetation types. Within each plot, every tree stem ≥ 5 cm diameter at breast height (DBH, at 1.3 m height above the ground) was sampled. For each tree stem the species and stem diameter were recorded. For trees with multiple stems, each stem ≥5 cm stem diameter was recorded. Tree species were identified based on their vernacular names with the help of local peoples, and scientific names were later determined using several field guides (Coates Palgrave, 2003; Smith & Allen, 2004; van Wyk & van Wyk, 2014). I took one voucher specimen of each tree species found in the field to the Lubango herbarium (LUBA), in Huila Province, Angola, for confirmation of identification, and vouchers are held there. Species identification was challenging since I was not familiar with plant species in Angola, and because of limited availability of floristic references for this region. To overcome this, I spent time with the herbarium collections and consulted experts in the floristics of the region (Francisco Maiato, Ruth Francisco, and David Goyder).

I also recorded grass, shrub (woody plants shorter than 1.3 m, including tree saplings) and canopy cover, visually estimating how much of the plot was covered by each of these (% of the plot, from 0-100). Other characteristics of the plots were recorded such as elevation, the number of termite mounds and the number of stumps in each plot, the latter as an indicator of human use (Tripathi et al., 2019; Furukawa et al., 2011). In this region, two things readily show human use, fire and stumps. Because dense woodlands do not burn, cut stems (i.e., stumps) is the one disturbance that can occur across all vegetation types and that can be a sign of human use. Fire data, including fire scars, were not measured because of time constraints and because the focus was on vegetation structure and floristics.

I also analysed soil samples from each plot to understand the relationship between soil characteristics and vegetation types. Different soil parameters can influence plant growth and community composition, and gaining knowledge about soils helps contextualize the floristic and structural differences observed in the vegetation (Frost, 1996). The analyses consisted of bulked samples collected at six random points within each plot. Samples were taken from 0-30 cm depth with a 6 cm diameter soil corer. All core samples were air dried and large materials (e.g., roots and big rocks) were removed. 100 g of dry soil of each sample were sent to the Laboratories at the School of Geography from the University of Leeds, to quantify the following variables: soil texture (proportion of sand, silt and clay), pH (pH H_2O and pH KCl), carbon, nitrogen, magnesium, calcium, aluminium, sodium, potassium, and cation exchange capacity (CEC). Texture was obtained by treating the soil with a dispersant agent, then blending, sieving into sand (0.05-2 mm particles), silt (0.002-0.05 mm) and clay (<0.002 mm), drying and weighting. Soil pH was determined using 1:2.5 soil to H_2O solution, shaken for an hour, and also determined in 1 M KCl solution (same procedure but with KCl solution instead of water). Both pH measures were used in the data analyses, but pH H_2O was used as the main metric to measure soil acidity since that metric is most often reported in studies in the miombo region. Carbon and nitrogen were measured using a combustion tube and an automated elemental analyser (*Vario MICRO* cube analyser). Mg, Al, Na and K were obtained using the silver thiourea method (using a mixture of 0.01 M silver nitrate and 0.2 M thiourea for the thiourea solution) which includes shaking and then using a centrifuge with 5 g of soil in the thiourea solution, and then analysing the supernatant with spectroscopy. CEC was calculated by converting the concentration measured through spectroscopy (mg/l) to mass concentration (mg/kg), and then converting to mmols equivalents (mg/kg to mmol/kg). The sampling and analyses followed methods from Quesada et al. (2010) and Gilpin (2022). For more details on the methods for soil analyses see Gilpin (2022).

3.2.3 Data analyses

Structure and floristics within the Angolan highlands

I quantified the differences in structure among the vegetation types within my plots (Godlee et al., 2020). Diameters and stem counts were used to derive forest structural metrics,

namely stem density (stems/ha), basal area (m^2/ha) and aboveground biomass (AGB, Mg/ha). Basal area for each tree was estimated as follows: $BA = (\pi D^2)/4$, were *D* stands for diameter at breast height. Basal area for all tree species in each plot was summed and divided by the area of the plot, and then extrapolated to give basal area per hectare for each plot. Above ground biomass was estimated using the following equation:
$AGB_{est} = \exp[-1.803-0.976E+0.976 \ln(\rho)+2.673 \ln (D)-0.0299[\ln(D)]^2]$ (Chave et al., 2014, Equation 7), where *D* stands for diameter and ρ for wood density. I used Chave et al. (2014), to estimate wood density and the coordinates of my plots to estimate *E*, which is a measure of environmental stress that considers mean annual temperature and precipitation seasonality, and it is extracted from a raster file of *E* values using the site coordinates (also from Chave et al., 2014). This approach uses this measure of environmental stress to estimate tree height when tree height measurements are lacking.

I analysed the difference in woodland structural variables among vegetation types using Analysis of Variance (ANOVA) statistical models, with a null hypothesis that there was no difference among the mean values of the structural metrics of vegetation types. Post-hoc Tukey's HSD tests were used to investigate which pairwise combinations of vegetation types differed. In cases where the residuals were not normally distributed or showed heteroscedasticity, I used Kruskal-Wallis tests to assess differences among vegetation types. In these cases, I used post-hoc Dunn's tests to investigate which pairwise combinations of vegetation types differed. I also extracted values for the elevation and topographic position index (TPI; CSP, 2024) of plots, to investigate the effect of topography on the vegetation types, and I used an ANOVA to assess differences.

In order to understand variation in soil properties across vegetation types whilst reducing the dimensionality of the soil data, I used a Principal Component Analysis (PCA) based on a correlation matrix (Fox & Metla, 2005). The PCA was done on a site (plots) by soil variables matrix. I log-transformed right-skewed variables prior to the PCA. Additionally, I analysed the difference in soil metrics among vegetation types using Analysis of Variance (ANOVA) statistical models. Depending on the distribution of the residuals, I used Post-hoc Tukey's HSD and Dunn's tests to investigate which pairwise combinations of vegetation types differed in soil metrics. I also used linear models and Pearson correlations to examine the relationships between elevation, TPI, and soil metrics.

To assess variation in species composition across vegetation types within the study area, I used a Detrended Correspondence Analyses (DCA) (Gonçalves et al., 2018). This analysis is often used to analyse species abundance data and to visualize the relationships between species and sample sites whilst reducing the dimensionality of the data. The DCA was done on a species by plot matrix, with abundance information (each cell in the matrix is the abundance of a species in a given plot). For this analysis I excluded plots with less than three species and less than 14 stems (as such plots lacked sufficient information to be placed reliably in an ordination space).

Research question 2. Structure and floristics across the broader southwest Africa miombo region (Democratic Republic of Congo, Angola, Zambia and Namibia)

To place plots within the context of floristic variation across the surrounding region, I compiled data from a total of 596 plots in the Democratic Republic of Congo, Zambia, Southwest Angola and Namibia from the SEOSAW network (SEOSAW, 2023). I excluded plots with less than three species and less than 14 stems from the analyses. I ran an analysis based on a species by plot matrix, with abundance information. I calculated the dissimilarity among sites based on species composition using the Bray-Curtis metric of each pair of plots and created a dissimilarity matrix. I then used a hierarchical clustering approach (unweighted paired group method using averages; UPGMA; Kreft & Jetz, 2010) based on the dissimilarity matrix (sites with lower distances between them would appear closer in the clustering analysis) (Silva de Miranda et al., 2018). I calculated the co-phenetic value for different clustering approaches and used the approach (UPGMA) with the highest value (0.71). Lastly, I converted the clusters into a phylogenetic tree for data visualisation (FigTree v.1.4.3; Rambaut, 2016). I assessed which plots outside my study area were floristically most similar to plots within my study area to identify to which floristic vegetation types those plots would correspond to. I set a height of 1.0 in the clustering diagram as the threshold for considering plots to be 'closely related floristically', and then I focused on clusters that contained plots from my study region. To characterise these clusters, I determined the five most dominant species within each cluster and calculated the proportion of individuals of each of these species across the plots sampled. I named each cluster based on the dominance of the 1st and 2nd genus. If the most dominant species had a dominance higher than 50%, then the name of the cluster had only the name of the most dominant genus, but if the value was lower, then the name of the cluster had the first two most dominant genera. The type of vegetation appearing besides the dominant species (i.e., *savanna* or *forest*), was determined from structural characteristics of the vegetation types within my study area occurring in that cluster. For example, a cluster named '*Brachystegia-Erythrophleum* miombo woodland' would have a dominance of the previous two genera lower than 50% each and within that cluster, plots within my study area that I termed as miombo woodlands dominating.

Furthermore, I conducted this study with a commitment to ethical research principles guided by decolonising methods. This included recognising local ecological knowledge, and conducting research grounded in care, reciprocity and respect (Staddon, 2014; Shanley & Laird, 2002; Datta, 2018).

Analyses were conducted in the R Statistical Environment (R Core Team, 2019) using the following packages: *Biomass v.2.1.11* (Rejou-Mechain et al., 2017), *vegan v.2.6-4* (Oksanen et al., 2022), and *seosawr 3.1* (Godlee et al., 2024).

3.3 Results

3.3.1 Structure and floristics within the Moxico highlands

The vegetation types showed important structural differences among each other. Dense woodlands had the highest stem density, with an average of 2034 ± 247 (mean ± SEM) of stems ≥ 5 cm DBH per hectare, whilst open savannas had the lowest stem density with an average of 222 ± 63 stems per hectare (Figure 3.2b). All plots, except those in dense woodlands, ranged from 81-742 stems per hectare. Dense woodlands had the highest basal area (22.4 ± 1.7 m^2/ha), whilst savannas had the lowest (1.8 ± 1.4 m^2/ha, Figure 3.2c). Dense woodlands presented the highest above ground biomass on average (125 ± 9.9 Mg/ha), although miombo were close with 118.8 ± 25.1 Mg/ha. Although open woodlands had similar stem density to miombo, the AGB was around half (61 ± 10 Mg/ha). Open savannas had the lowest AGB (8.3 ± 3.1 ton/ha). All vegetation types but miombo woodlands were dominated by stems with diameters no larger than 10 cm (for size distribution histograms see Appendix A2.1). Miombo presented the highest proportion of stems with diameters of 10-20 cm.

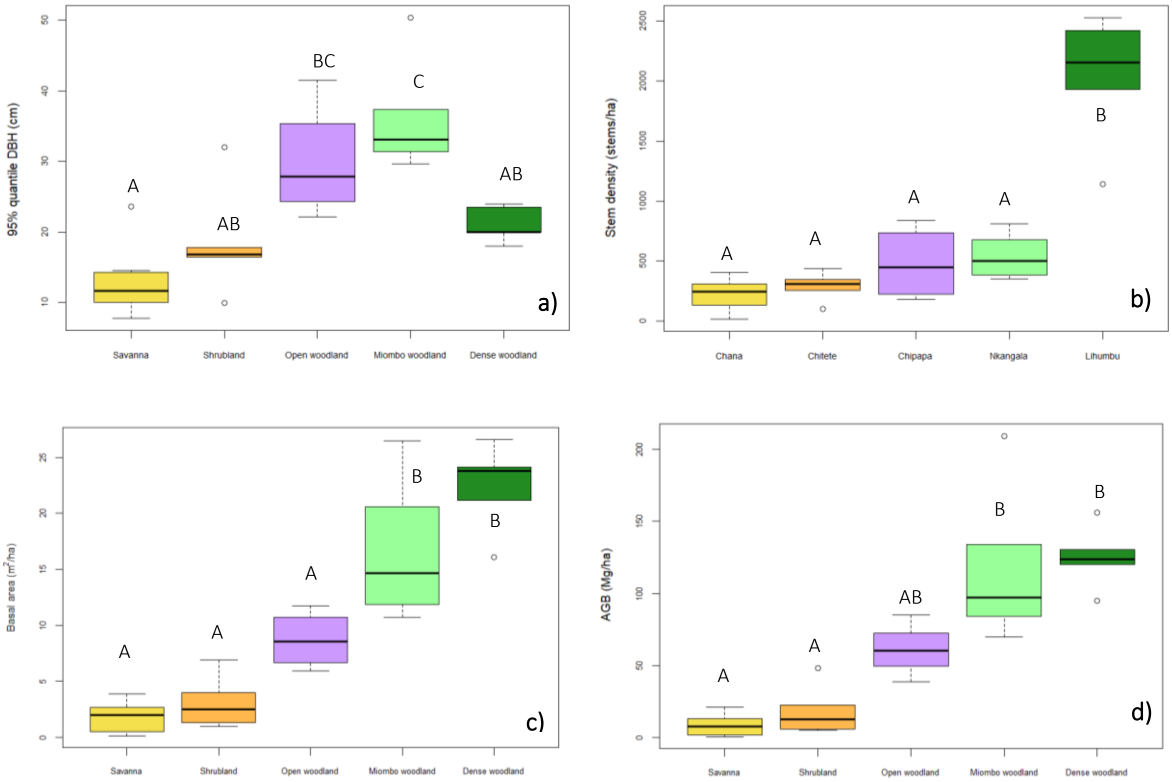

Figure 3.2. a) 95% quantile of DBH reflecting how large trees can become in a given vegetation type (for mean DBH see Appendix A2.2), (b) stem density, (c) basal area, and (d) above ground biomass per hectare by vegetation type based on local classifications. Different letters above boxes mean significant differences according to post-hoc Tukey's HSD tests or Dunn tests. Boxplots show the range of the data, with the median as the thick horizontal line.

Grass, shrub and canopy cover

The structure of the understorey among the vegetation types was highly variable (Figure 3.3). Open woodlands had the highest shrub cover (around 75%) whilst open savannas had the lowest. Conversely, open savannas had the highest grass cover (95%) and the lowest canopy cover, whilst dense woodlands had the lowest grass cover and the highest canopy cover. There was a negative correlation between tree density and grass cover (-0.87, Figure 3.3d).

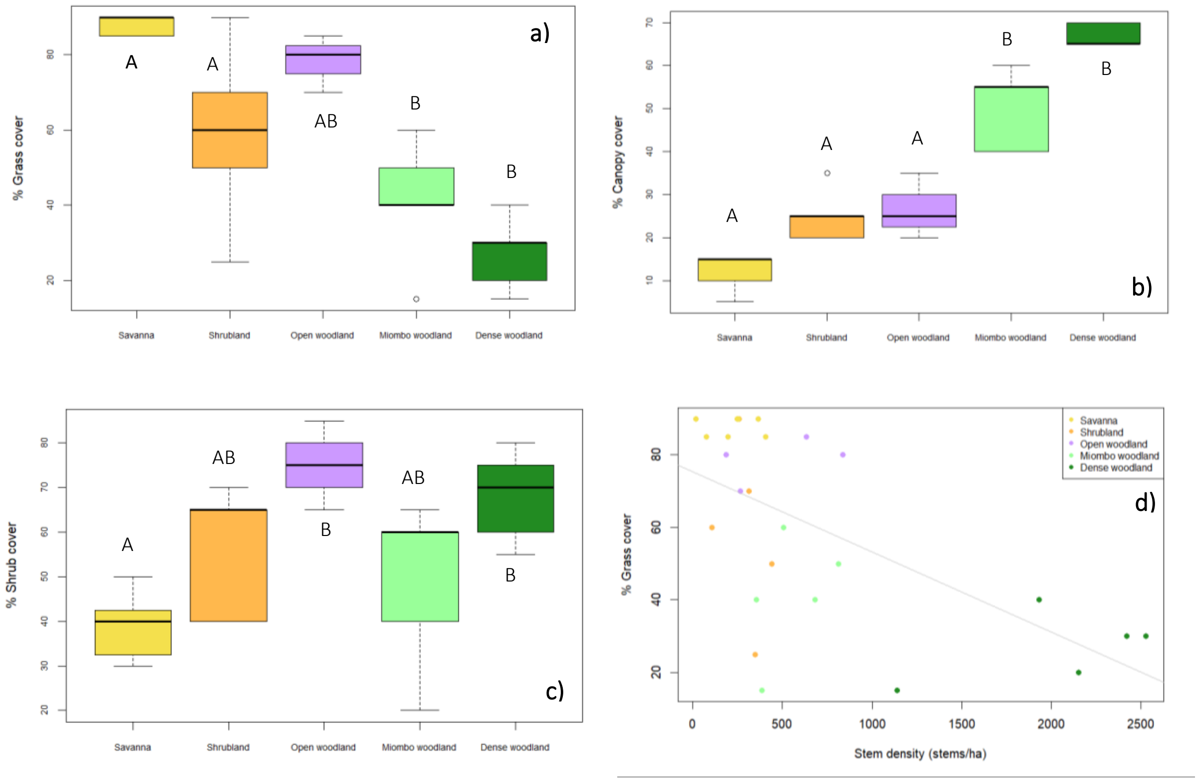

Figure 3.3. Differences in a) grass cover, b) canopy cover, and c) shrub cover among vegetation types, and d) relationship between grass cover and stem density. Different letters above boxes mean significant differences according to post-hoc Tukey's HSD or Dunn tests.

Stumps and termites

I found the highest number of stumps per hectare in both open and miombo woodlands and the lowest in savannas, although none of these differences were significant. All vegetation types had a similar average number of termite mounds, with open woodlands having the highest number (up to around 140 per ha in one of the sites) and miombo having the lowest number (around 20 per ha) (see Appendix A2.3).

The vegetation types showed differences in elevation and TPI although not significant (Figure 3.4). Dense woodlands generally occur at higher elevation and savannas at lower. Open woodlands had high positive TPI, but also highly variable. Dense woodlands had a positive, and the least variable TPI. Shrublands had the largest negative TPIs.

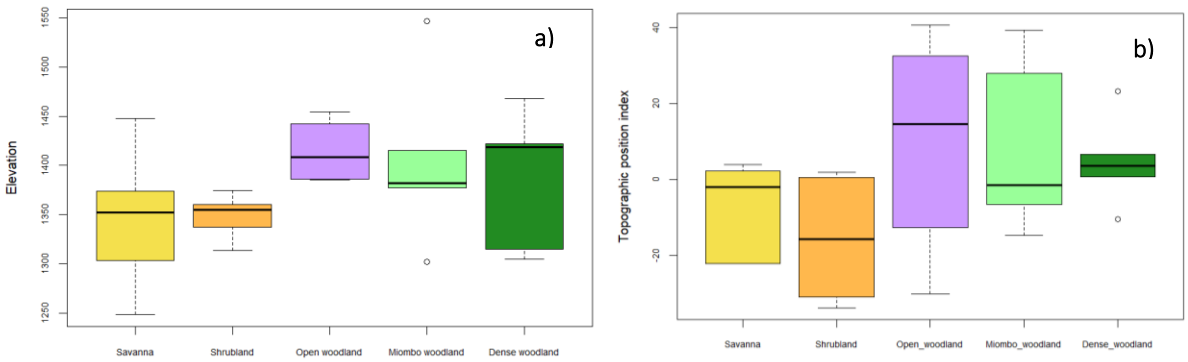

Figure 3.4. Differences in a) elevation and b) Topographic Position Index among vegetation types based on local classifications. No significant differences were observed.

3.3.2 Soils

As for soil properties, texture was similar for all vegetation types, with sand predominating (94.2-95.8%) and clay being scarce (2.6-3.8%). Soil pH did not vary significantly, with open woodlands presenting the highest pH (4.5 ± 0.4, mean ± SD), and open savannas and dense woodlands the lowest (4.1± 0.09 and 4.2 ± 0.2 respectively). Open woodlands and dense woodlands had the highest percentage of nitrogen (0.05 ± 0.1 % and 0.04 ± 0.02 % respectively) and carbon (1.02 ± 0.3 % and 0.7 ± 3 % respectively), although only the levels of C were significantly different ($F_{4,19}$=3.56, p=0.025) between open woodlands, open savannas and shrublands. As for base cations, both miombo and open woodlands had the highest concentrations of calcium (15.6 ± 10 mg/kg and 12.4 ± 10 mg/kg), and open woodlands had the highest levels of potassium (15.2 ± 4 mg/kg); about twice as much as open savannas. Aluminium was also highest in open woodlands (25.1 ± 10 mg/kg). Open woodlands also showed the highest cation exchange capacity (4.2 ± 0.5 mmol$^+$/kg), followed by dense woodlands (3 ± 0.5 mmol$^+$/kg). Overall, savannas and shrublands consistently had the lowest levels of nutrients. Values of each property for all five vegetation types can be found in Appendix A2.4. Additionally, I found a negative correlation between sand and elevation (-0.4) and a positive correlation between elevation with nitrogen (0.7), carbon (0.7) and eCEC (0.65).

Based on the PCA analysis (Figure 3.5), open woodlands, miombo woodlands and open savannas showed somewhat distinct soils, and the other two vegetation types were less distinct in soil properties. The 1st PC explained 41.1% of the variance and the 2nd PCA explained 20.5% of the variance.

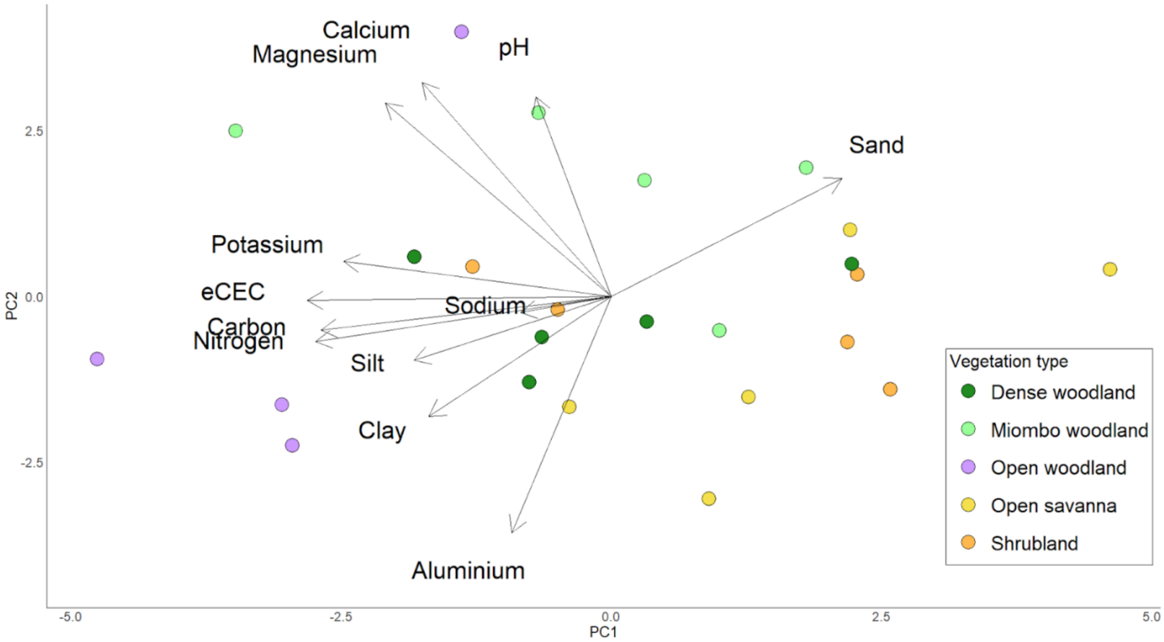

Figure 3.5. Principal component analysis. Coloured circles represent plots of the different types of vegetation. Soil variables are displayed as arrows with their length and direction corresponding to their relationship with components one and two.

3.3.3 Floristics

Within the 26 plots, I found 51 tree species that belong to 22 different families (Appendix A.2.5). Fabaceae was the most common family in all vegetation types, with open savannas and dense woodlands presenting the highest proportion of Fabaceae individuals. The ten most common species across all plots, in decreasing order were: *Cryptosepalum exfoliatum* (33.5% of all stems), *Erythrophleum africanum* (8.5%), *Burkea africana* (7.3%), *Diplorhynchus condylocarpon* (5.44%), *Julbernardia paniculata* (4.5%), *Brachystegia spiciformis* (3.6%), *Brachystegia longifolia* (3.5%), *Diospyros batocana* (3.3%), *Dialium englerianum* (2.8%), and *Monotes africanus* (2.1%). *Chrysophyllum bangweolense,* (28.1 cm), *Julbernardia paniculata (19.5*±10.3 cm*)*, *Brachystegia spiciformis* (18.8 ± 12.4 cm), *Parinari curatellifolia* (16.6 ± 8.8 cm), *Monotes dasyanthus* (15.8 ± 11.1 cm), and *Guibourtia coleosperma* (15.2 ± 10.3 cm) were the trees with the largest average DBH values.

Species richness

The highest species richness was observed in dense woodlands with an average of 26.8 ± 1.4 tree species per plot, and the lowest in open savannas with an average of 6.2 ± 4.2 tree species per plot (Appendix A.2.6).

Variation in floristic composition

The Detrended Correspondence Analyses (DCA) showed a gradient along DCA1 which segregates the vegetation types. Dense woodlands (dark green in Figure 3.6) and savannas (yellow polygon) occupy the ends of this gradient. The shrublands (orange), and both open (purple) and miombo woodlands (light green) lie in the middle. Along the second axis, I found miombo separating from open woodlands and open savannas from shrublands. Overall, the DCA showed dense woodlands to be the most floristically distinct. One third (33%) of the variation in species composition among sites is explained by the first two axis (DCA1 and DCA2).

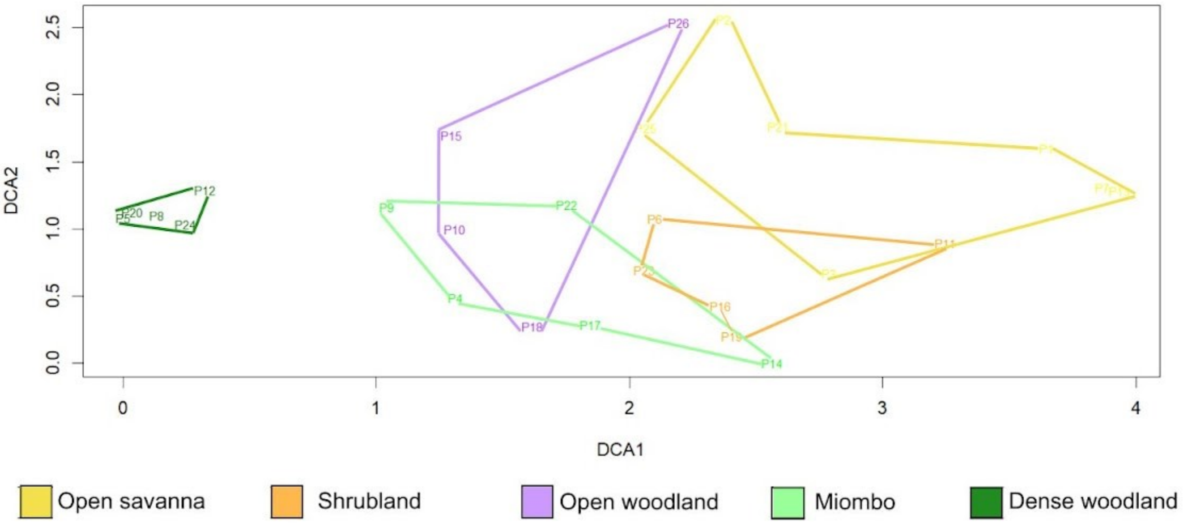

Figure 3.6. DCA based on floristics within vegetation types sampled in southeast Angola. Dense woodlands are more distinct from the other vegetation types in terms of floristic composition.

3.3.4 Floristics within the broader region

Plots from southeast Angola appeared in different places across the large-scale floristic analysis, namely within nine distinct clusters (Figure 3.7). Plots in my study area were mostly clustered with plots in west Zambia and south Angola, and a few in northeast Namibia (Figure 3.8a). Plots from all the vegetation types in my study area (Figure 3.8b), except the dense woodlands, fell in more than one cluster in the broader context.

The nine clusters I found were: 1) *Burkea- Erythrophleum* open savanna, 2) *Monotes-Burkea* shrubland, 3) *Brachystegia- Burkea* miombo woodland, 4) *Brachystegia-Diplorhynchus* miombo woodland, 5) *Julbernardia- Cryptosepalum* miombo woodland, 6) *Julbernardia-Erythrophleum* miombo woodland, 7) *Brachystegia-Diospyros* miombo woodland, 8) *Erythrophleum-Isoberlinia* miombo woodland, and 9) *Cryptosepalum* dry forest. Six out of the nine clusters are representative of miombo woodlands because of the dominance of *Brachystegia* and/or *Julbernardia* spp. Maps reflecting the nine clusters showed the *Burkea* clusters mostly towards the south and the *Cryptosepalum* forests towards the north (Figure 3.8a).

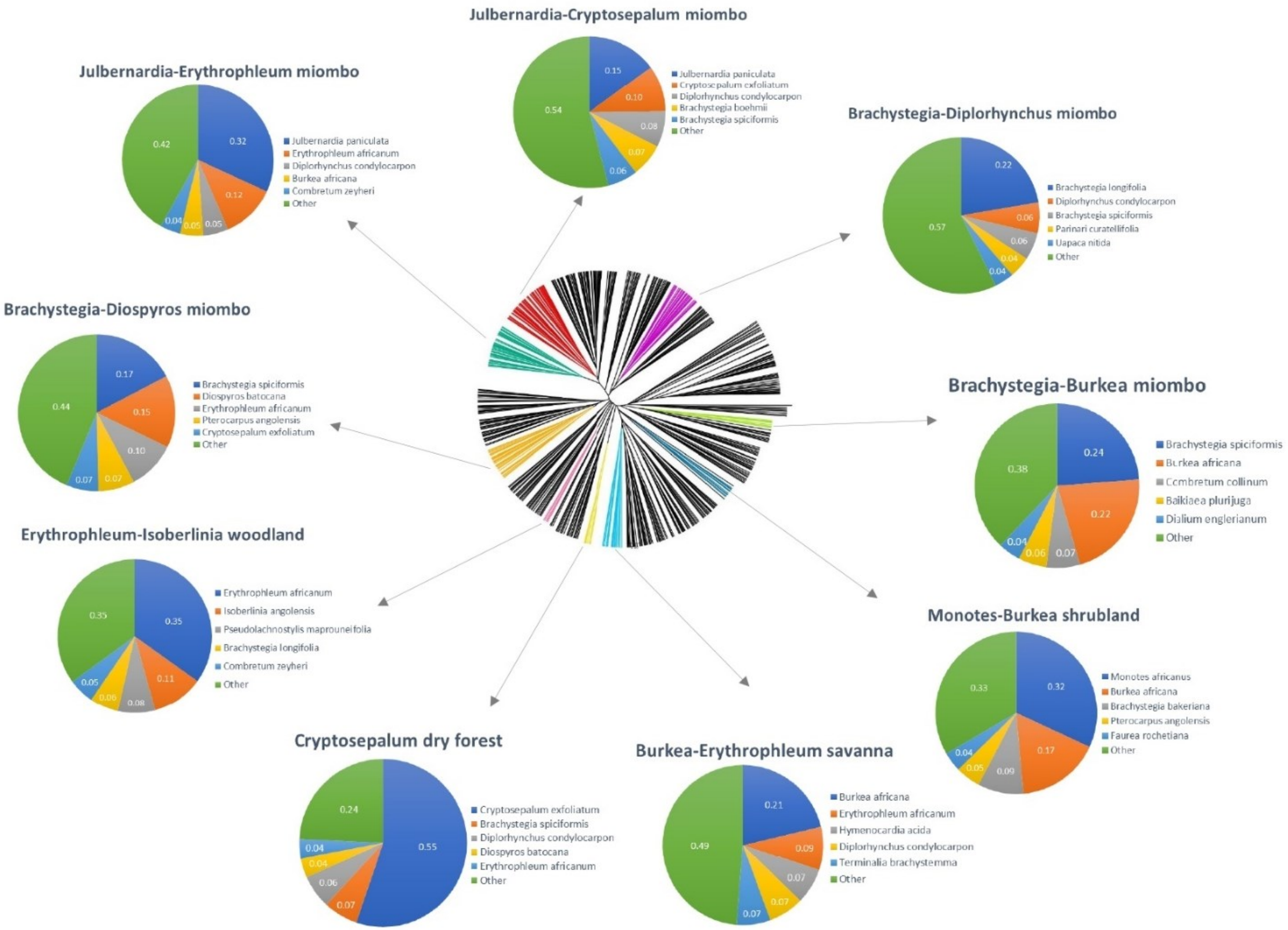

Figure 3.7. Clusters in the broad context and proportion of the five most dominant species on the clusters. The blue wedge in pie charts corresponds to the proportion of the most dominant tree species in the cluster and the green wedge corresponds to individuals that belong to other species than the top five.

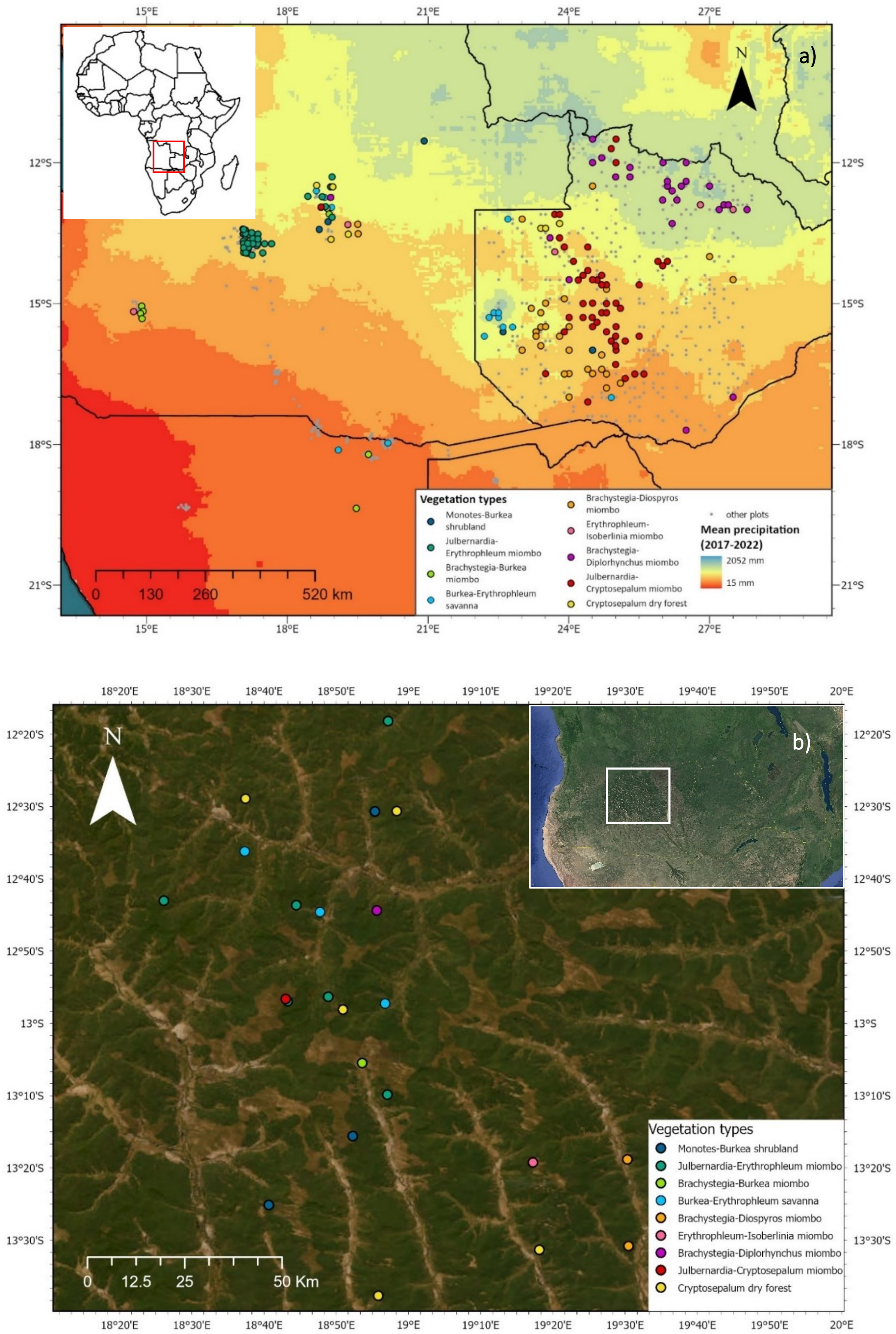

Figure 3.8. Plot clusters based on a a) hierarchical cluster analysis in the broader region and b) inset of those clusters in my study area. *ArcGIS* Pro v.2.6 was employed to create these maps.

3.4 Discussion

In this study, I have shown that vegetation in southeast Angola is diverse, encompassing a variety of vegetation types beyond the widely recognised miombo woodlands, including tropical dry forests and other distinct vegetation types. In Africa, terms such as savanna, woodland, bushland, thicket, and dry forest have been applied to tropical woody vegetation, with terms sometimes being used interchangeably. However, using accurate terminology is crucial, as it can significantly influence management strategies and outcomes. Fire, for example, plays contrasting roles in different ecosystems, being essential for the health and function of savannas but detrimental to tropical dry forests. Common tropical vegetation classifications (Ratnam et al., 2011; Torello-Raventos et al., 2013) categorize miombo woodlands as savannas, which require fire as part of their management. Notably, the main contribution of this chapter, is that floristic and physiognomic analyses reveal the presence of dry evergreen forests in southeast Angola, which were not previously identified in the international scientific English literature and which are likely an extension of the *Cryptosepalum* dry evergreen forest ecoregion of West Zambia (Burgess et al., 2004; Syampungani et al., 2014; White, 1983). Whilst fire may be appropriate for managing miombo woodlands, it should be excluded from dry forests to preserve their ecological integrity. The overlooked diversity of vegetation in southeast Angola highlights the value of conducting ground-based research. This approach offers valuable insights to understand the heterogeneity of African woodland formations and to acknowledge the crucial role that vegetation diversity plays in both local livelihoods and broader ecosystem functioning.

Characterisation of the vegetation types in my study area

Woodlands in southeast Angola exhibit significant differences driven not only by floristics, but also by structure. Rather than being uniform miombo woodlands, there are distinct vegetation formations that overlap with local classifications. Local peoples showed extensive knowledge about each of the five distinct vegetation types (social science methods to collect data regarding the vegetation types can be found in Chapter 2), and their inclusion in this work was essential to understand each vegetation type. The following is a summary of the characteristics of each vegetation type, aimed at providing a concise overview of their floristic composition, structural attributes, and soil properties, ultimately to help clarify what distinguishes them.

Open savannas

Open savannas displayed the highest grass cover (88%) and the lowest canopy cover (12%). They presented the lowest stem density of the five vegetation types as well as the lowest above ground biomass. Open savannas occurred mostly at the lower elevations but were also found at higher elevations. Relative to the other vegetation types, open savanna soils were some of the most acidic, and in general, they had some of the lowest concentration of nutrients and base cations. Open savannas had the lowest relative species richness and the dominant tree species were *Burkea africana* and *Terminalia brachystemma.* Fire is frequent in these savannas, which seems to be crucial to maintain their structure and biodiversity (Dexter et al., 2015). The presence of the previously mentioned species, along with *Combretum zeyheri* and *Diplorhynchus condylocarpon*, might be indicative of a history of fire, as previous studies in southcentral Angola have shown these species to be fire-resistant (Gonçalves et al., 2017).

Shrublands

Shrublands had a relatively low stem density and above-ground biomass. Grasses covered around 60% of the ground, whilst canopy cover, although variable, averaged 25% cover. Shrub cover was on average 56%, even though it could reach up to 70%. Soils in shrublands had similar levels of nitrogen to miombo woodlands and open savannas, but low carbon and some of the lowest levels of base cations and cation exchange capacity (CEC). Their species richness was the second lowest. Shrublands were dominated by *Monotes africanus* and *Erythrophleum africanum*.

Open woodlands

Open woodlands had an elevated grass cover (79%), the highest relative shrub cover (75%), and a low canopy cover (26%). They showed a similar stem density to miombo woodlands, although the AGB was less than half that of miombo. These woodlands occurred at the highest elevations (together with dense woodlands), but presented the most variable topographic position index (TPI). Open woodlands had the highest pH as well as some of the highest levels of nitrogen, carbon, calcium, potassium, aluminium, and cation exchange capacity. They also had one of the highest number of stumps and the highest number of termites. Species richness was intermediate, with a dominance of *Erythrophleum africanum* and *Hymenocardia acida.* The high grass cover and significant levels of AGB in this vegetation likely increases the susceptibility of these woodlands to fires. Fire in turn helps mineralize soil nutrients, increasing pH and available cations (Oliveras & Malhi, 2016; Strømgaard, 1992), which might explain the higher nutrient levels. Open woodlands might resemble what has been termed in the literature ‘chipya’, a vegetation that grows in abandoned crop fields or that has been consumed by fire (Frost, 1996; Trapnell, 1943). Frequent fires in this case might cause the replacement of miombo fire-sensitive species by those tolerant to fire (Chidumayo, 1997c; Morris, 1970). *E. africanum*, a dominant species in this vegetation, has been shown to resist fire (Trapnell, 1959), which might support this hypothesis. Whether miombo species (e.g., *Brachystegia spp.*) fail to establish because of frequent fires or because other environmental determinants is unknown. Lastly, although the floristics of open woodlands are not strictly representative of miombo woodlands, the common tree species of this vegetation are often found within the miombo region (Gonçalves et al., 2017).

Miombo woodlands

Miombo woodlands had the second highest canopy cover (50%) with an important shrub (49%) and grass cover (40%). Miombo woodlands had similar stem density to open woodlands; however, basal area was twice as much due to the presence of large trees. Miombo woodlands had the largest trees of all five vegetation types. AGB was also high, similar to that of dense woodlands, despite having much lower stem density. These woodlands had the lowest number of termite mounds and some of the highest number of stumps, probably because it contains an important abundance and diversity of tree species useful for local livelihoods. Miombo woodlands occurred at higher relative elevations, and their TPI, although positive, was variable. Soils in miombo woodlands had the highest levels of calcium and magnesium. Species richness in this vegetation was the second highest. Miombo woodlands presented dominance of *Julbernardia paniculata* and *Erythrophleum africanum,* but *Brachystegia spiciformis* and *B. longifolia* were also frequent. Miombo woodlands had a basal area and a stem density within the range reported previously for miombo woodlands (Frost et al., 1996; Chidumayo & Gumbo, 2010; Godlee et al., 2020; Mwakalukwa et al., 2014; Ribeiro et al., 2020b). Based on its structural characteristics, and since fires in miombo are frequent (Frost, 1996; Chidumayo, 1997), this vegetation is representative of savanna ecosystems, just as the previous three vegetation types, since they all have an open canopy and an open grassy ground layer that regularly burns (Ratnam et al., 2011; Torello-Raventos et al., 2013).

Dry *Cryptosepalum* forests

Dense woodlands, or better termed dry *Cryptosepalum* forests, showed the highest canopy cover (67%) of the five vegetation types and the lowest grass cover (27%). The ground in dry forests was covered with mosses which seem to create a protective layer from fire due to its moisture content (Schmitz, 1962). Shrubs were abundant (68%), either due to a canopy that still allows for some sunlight, or as a result of a humid microclimate derived from a dense canopy and understorey (Schmitz, 1962). Dry forests had the highest stem density, basal area, and above ground biomass of all vegetation types. Dry forests occurred at higher elevations and at the highest relative topographic positions, which likely means that these are restricted to stretches of the catenal sequence with particular edaphic characteristics. Soils in this vegetation showed some of the lowest pH values and the highest percentages of nitrogen and carbon. This vegetation also had a relatively high cation exchange capacity. Dry forests presented the highest tree species richness, even when they were strongly dominated by *Cryptosepalum exfoliatum* (56%). Other important tree taxa in this vegetation were *Diplorhynchus condylocarpon* and *Erythrophleum africanum*.

Comparison of structure and floristics among my study area and the broader literature

In general, stem density and basal area in my study area were consistent with values reported previously for the miombo region (Frost et al., 1996; Chidumayo & Gumbo, 2010; Godlee et al., 2020; Mwakalukwa et al., 2014; Ribeiro et al., 2020b), including central and southwest Angola (Godlee et al., 2020; Gonçalves et al., 2017). However, the dry forests exhibited nearly 60% higher stem density than that reported for miombo (Frost et al., 1996; Chidumayo & Gumbo, 2010; Ribeiro et al., 2020b), and up to three times the basal area compared to miombo woodlands in drier southwest Angola (Godlee et al., 2020), further confirming that dry forests in southeast Angola are structurally distinct from miombo woodlands. In addition, above ground biomass in dry forests and miombo woodlands was higher than reported for Zambezian woodlands and wet miombo (Chidumayo, 1997d; Chidumayo & Gumbo, 2010). Moreover, whilst soil CEC was lower at my site compared to other sites, Ca and K were substantially higher (Frost et al., 1996, Chidumayo, 1997d).

In terms of floristics, my findings align with previous studies in southeast Angola, which identify the Fabaceae family as dominant in woody vegetation (Chisingui et al., 2018; Godlee et al. 2020). In the Angolan Central Plateau, *Brachystegia spp*., *Julbernardia paniculata*, *Cryptosepalum exfoliatum subsp. pseudotaxus*, and *Erythrophleum africanum* were also noted as locally dominant (Gonçalves et al., 2017). Towards the west of my study region, common trees include *Brachystegia bakeriana*, *B. longifolia*, *Julbernardia paniculata* and *Cryptosepalum exfoliatum* (Goyder et al., 2018; Pröpper, et al., 2015; Revermann et al., 2017). Moreover, I found three *Brachystegia* species (Appendix A.2.5), and whilst previous studies reported *B. spiciformis* to be rare in southeast Angola (Goyder et al., 2018), *B. spiciformis* was frequently found in some locations in my study area.

Notably, the woodlands in my study area support valuable and threatened tree species including *Pterocarpus angolensis*, *Brachystegia spiciformis* and *Guibourtia coleosperma,* which are declining due to habitat loss and overexploitation (Catarino et al., 2020; Jew et al., 2016). Although these tree species are used locally for livelihoods, I did not find signs of scarcity of these woodland resources.

Drivers of distribution of the different vegetation types

The drivers of vegetation patterns in southeast Angola are likely diverse in origin. In this study, soils did not appear to be a strong determinant of the distribution of the vegetation (Figure 3.5), and vegetation patterns are likely influenced by the determinants of vegetation in savanna-dominated regions: a combination of plant available moisture, plant available nutrients (measured in soil parameters), disturbance factors (such as fire) (Mistry, 2014), topographic variation, or an interaction among all.

In terms of disturbance, fires set by humans are likely important drivers of vegetation patterns in southeast Angola, with its presence or absence resulting in contrasting outcomes. In areas with frequent fires (e.g., open savannas), the vegetation remains open and grassy, whilst in areas with less or no fire, woody biomass may increase, leading to a denser canopy. This canopy closure suppresses the grass layer, which in turn reduces fire frequency, creating a feedback loop that further promotes the establishment of fire-sensitive trees and maintains a closed canopy (Frost, 1996; Chidumayo, 1997; Oliveras & Malhi, 2016).

However, whilst fire is an important controlling factor of African woodland ecosystems (Malaisse, 1985), it might not be the only factor, since different vegetation types that experience fire exhibit different structural responses. For instance, in my study area both miombo woodlands and dry forests are burned for cropland preparation but uncontrolled fires are widespread in all vegetation types except in dry forests. Dry forests only burn where the vegetation has been removed and with planned fires, because the mossy ground layer does not allow the fire to advance, whilst the other vegetation types often burn in an uncontrolled manner due to the presence of a grass layer. The greater flammability of miombo woodlands due to their open structure (also the result of other disturbances like wood harvesting), allows fire to spread more easily which might help maintain this vegetation (Morris, 1970), whereas the structure of dry forests limits fire spread, also possibly helping to maintain this vegetation.

The topography of the landscape is also likely to have an important influence on the spatial distribution of vegetation in this area. The differences in elevation and topographic positions among the vegetation types might indicate a preference for certain soil depths, water drainage, plant available moisture, or tolerance to frost (Finckh et al., 2021). Miombo ecosystems often display a catenal sequence along topographic gradients, ranging from well-developed plateau woodlands or evergreen forests in deep, well-drained soils to less developed hill woodlands, to shrublands in low elevations (Chidumayo, 1997a). The latter typically results from restricted drainage, surface-level lateritic pans, and frost, conditions to which many miombo tree species are intolerant (Chidumayo, 1997a; Malaisse, 1993). In my study area, the presence of dry forests in higher topographic positions may therefore be associated with deeper soils and better drainage (Campbell et al., 1996; Chidumayo, 1997a; Frost, 1996; White, 1983). Likewise, the patchy distribution that dry *Cryptosepalum* forests exhibit might be linked to the combined effects of topography and fire (Schmitz, 1962).

Several other variables have been linked to vegetation patterns and distribution in tropical woody landscapes, namely temperature, drought, past and present land use, land tenure, and land protection (Banda et al., 2008; Campbell et al., 1996; Lupala, 2009; Marshall et al., 2021; Oliveras & Malhi, 2016; Pennington et al., 2018). For most of these potential drivers of vegetation patterns, I did not collect direct evidence. Therefore, gathering broader data on these factors would be a valuable next step toward a deeper understanding of the drivers behind differences among vegetation types. Furthermore, changes in canopy cover can also be influenced by social dynamics, such as the case of Angola after the end of the civil war, where opening of the canopy seems to be linked to resettlement in rural areas and increased cultivation (Andrews et al., 2024). Lastly, although in savanna environments herbivory is an important determinant of vegetation patterns (Mistry, 2014), in this region, as informed by LEK, herbivory does not play an essential role (as large herbivore populations greatly decreased during the war and to date remain low).

Vegetation in the highlands of southeast Angola within a broader context

The vegetation types in southeast Angola clustered with nine different floristic groups in the broader region (including surrounding countries). Over half of the clusters belonged to what is traditionally termed miombo woodland, as the dominant species corresponded to *Brachystegia* and/or *Julbernardia.* Miombo woodlands within my study area showed dominance of only *Julbernardia paniculata*, but plots in Namibia and Zambia were also dominated by *Brachystegia spp* (despite the absence of *Brachystegia* in Namibia, thus the dominance of *Brachystegia* in the other plots of the cluster might be exerting an overriding influence). Besides miombo woodlands, other vegetation formations also exist in the region. For instance, *Burkea-Erythrophleum* savannas occur towards the south of the region fitting with previously reported presence of *Burkea* savannas in Namibia, Zambia, Zimbabwe, South Africa, and Malawi (Frost et al., 1996; White, 1983).

The most distinct vegetation type in the broader context were the *Cryptosepalum* forests which were only found in one cluster with plots from west Zambia. Dry evergreen forests have been documented in the north and wetter miombo region, occurring in areas with mean annual rainfall of more than 1200 mm and at 1100–1200 m of elevation above sea level (Burgess et al., 2004; White, 1983). Based on my results, I suggest the dense forests of the highlands of southeast Angola are a continuation of the Zambezian dry evergreen forest ecoregion (Burgess et al., 2004). Although the presence of trees of *Cryptosepalum spp.,* has been recorded in Angola previously (Gonçalves et al., 2017; Gonçalves et al. 2018; Goyder et al., 2018; Revermann, 2013), *Cryptosepalum* dry evergreen forests, as a type of vegetation or ecoregion, have not been described in this region before, rather they have been described in West Zambia with a small fraction across the Angola-Zambia border (Burgess et al., 2004; Campbell et al., 1996; Syampungani et al., 2014). This vegetation belongs to the Zambezian *Cryptosepalum* dry forest ecoregion, which has been termed 'the largest area of tropical evergreen forest in Africa outside the equatorial zone' (Hansen et al., 2016; Martin & Burgess, 2024).

The *Cryptosepalum* evergreen forests in Zambia, locally termed *mavunda* (Chishaleshale et al., 2024), cover approximately 31 770 km^2 and are recognised as having 'globally outstanding conservation status' (Burgess et al., 2004). They are described as being covered in mosses at ground level and are restricted to poor Kalahari soils which determine their extent (Burgess et al. 2004; Malaisse, 1993; Martin & Burgess 2024; Schmitz, 1962). These forests might be able to remain evergreen because of their ability to access moisture in the subsoil which could also be linked to deep soils (Frost, 1996). Notably, the *Cryptosepalum* forests in southeast Angola are distributed in an area of approximately 83 842 km^2, more than double the extent in Zambia.

The *Cryptosepalum* forests are a unique vegetation type in southern Africa, often occurring in mosaics with grasslands and wooded savannas. It is possible that dry evergreen forests were once more widespread but have become scarce due to cultivation, fire and herbivory (Fanshawe 1971; Lawton, 1978; Morris, 1970; Oliveras & Malhi, 2016; Trapnell, 1959; White, 1983). The scattered evergreen thickets and forests that remain in the miombo region have been interpreted as evidence of their past wide distribution (Malaisse, 1993), whilst the presence of miombo species such as *Brachystegia* spp., in these mosaics might be the result of fire adaptations linked to disturbance, which allowed these species to expand their distribution (Boom et al.,2024; Dexter et al., 2015; Morris, 1970). Open savannas, woodlands, shrublands and dry forest in southeast Angola might therefore represent dynamic stages of forest succession, with shifts driven by anthropogenic disturbances (Frost et al., 1996; Malaisse, 1985). In this context, *Cryptosepalum* dry forests may represent the climax community (Schmitz, 1962). An alternate hypothesis may be that dry forests can occur only where certain environmental conditions allow them to thrive, such as deep sandy and plateau soils. Further work, particularly from a paleoecological perspective, could help understand past scenarios that have led to the present distribution of dry forests in Angola. Regardless, the novel finding of large extents of *Cryptosepalum* in this region suggests that more unmapped dry forests may exist in southern Africa, whether dominated by *Cryptosepalum* or other tree species (Chidumayo, 1997a; Schmitz, 1962). However, although some literature exists on the *Cryptosepalum* forests (Fanshawe, 1960; Cole, 1963; Schmidtz, 1972; Malaisse, 1993; Fanshawe, 2010), research remains limited and ecological and habitat assessments are lacking (Burgess et al., 2004).

Lastly, but not least important, is the recognition of the role of local ecological knowledge (LEK) in understanding the vegetation. Bridging LEK with scientific ecological methods revealed important complementarities, and offered a more holistic understanding of the wooded ecosystems in southeast Angola. Although the approaches in this chapter were primarily ecology-oriented, my fieldwork was significantly enriched by the guidance and expertise of local communities. Such work was guided by ethical research principles of mutual respect and recognition of local peoples as knowledge co-producers (Datta, 2018).

Implications for management

Accurate classification of vegetation types in southeast Angola is essential for effective management and conservation, since these landscapes support both biodiversity and vulnerable human populations (Pennington et al., 2018; Ratnam et al., 2011). For example, fire is a key tool to maintain savanna structure and biodiversity (Dexter et al., 2015), but it can be detrimental in forests. Meanwhile, fire suppression in savanna ecosystems can be as detrimental to their structure and composition as allowing fires in closed forests (Durigan & Ratter, 2006). Therefore, I suggest that management in southeast Angola should be tailored to the particular conditions of each vegetation type whilst accounting for the interactions and influences among them. This includes maintaining fire in the fire-adapted vegetation and limiting it in the evergreen *Cryptosepalum* forests.

Finally, any management approach should challenge assumptions that view local communities as threats to ecosystems (Muller et al., 2019). Instead, an approach to decolonise conservation that stands against the marginalisation of local knowledge systems and decision-making authority must recognise local users as stewards of their landscapes (Chilisa, 2017; Muller et al., 2019; Chidumayo, 2002). Without shifting power to local communities to lead conservation efforts according to their worldviews, conservation risks perpetuating colonial dynamics under the label of protection (Muller et al., 2019). In this context, a socio-ecological approach is instrumental for understanding the intertwined dynamics of land, people, management, and power.

3.5 Conclusion

This study reveals that the vegetation of the highlands in southeast Angola is more complex and diverse than previously recognised. Through vegetation sampling based in ecological methods guided by local ecological knowledge, I found alignment and complementarity, identifying five distinct woodland formations based in differences in structure and floristics. Within these, a rare dry forest dominated by *Cryptosepalum exfoliatum pseudotaxus* was revealed, an occurrence not previously mapped in the scientific English literature in this part of Angola. Significantly different from miombo woodlands, dry forests in this region align with Zambezian dry *Cryptosepalum* evergreen forest descriptions.

Similarly, many unique vegetation formations may exist across Africa, but have been overlooked or misclassified within larger dominant vegetation classes, particularly because often, differences among vegetation are only evident at the ground-level. To address this, more ground-based biogeographic and socio-ecological analyses are needed to map the less dominant vegetation types within the miombo region. This calls for the need to integrate quantitative and qualitative approaches, emphasizing incorporating diverse sources of knowledge in scientific studies. In this case, I arrived to the dry *Cryptosepalum* forests due to the guidance of local peoples who shared their knowledge of the landscape, recalling differences among dry forests and other vegetation types that might only be perceived by those who experience the landscape. The inclusion of LEK involves recognising research participants as knowledge holders and co-creators, not simply as sources of data, and committing to practices that amplify their voices and reflect their lived realities (Udah, 2024; Diver & Higgins, 2014). This approach emphasises the value of listening in the process of bridging different knowledge systems (Staddon et al., 2023; Tengö et al., 2014), and highlights how LEK inclusion can provide place-based insights that inform how landscapes are understood locally (Smith, 2012; Dominguez & Luoma, 2020).

This study also suggests that vegetation formations seldom fit into a single category or have fixed boundaries, instead, they are inherently dynamic, varying across both space and time. The diversity of vegetation is shaped by a complex interplay of factors, namely soil, fire regimes, moisture, land use, and elevation, which can cause similar vegetation types to appear different across regions (or different vegetation types to appear similar). This variability might reflect the dynamism of ecological processes, with vegetation responding to changes and disturbances over time. Moreover, depending on the parameter used (i.e., structure vs floristics) different classifications might arise, each with distinct implications for conservation.

In my study, most vegetation formations showed variability in terms of structure and floristics, with dry forest showing the least variability. A greater variability is important in terms of resilience against disturbance and environmental changes, but unique forest formations also provide essential habitats and resources for local communities. Thus, a mosaic with different types of forests and woodlands is important in terms of supporting biodiversity and delivering ecosystem services. Maintaining such diversity in the highlands of southeast Angola is essential since this ecosystem provides a wide variety of habitats for wildlife whilst supporting livelihoods in multiple ways.

Lastly, a revision of current miombo woodland definitions could help understand and better manage woody formations in southern Africa, as well as uncover other important habitats embedded within the miombo region. Ecological definitions of vegetation could take into consideration not only species composition but also structure, fire regimes, and understorey composition, among other characteristics, whilst remaining aware of local social interactions.

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Chapter 4. War and the decline of fire: the impact of the civil war on fire regimes in the highlands of southeast Angola

Abstract

Research on the environmental impacts of warfare is limited and often not interdisciplinary. Of the many impacts that war can have, its effect on fire regimes is particularly understudied, despite the importance of fire to livelihoods and ecosystem functioning in fire-dependent ecosystems. This work investigates the impact of the Angolan civil war on fire dynamics in the highlands of southeast Angola, an area that served as a stronghold for the 'guerrilla' forces during the conflict and where local populations have used fire as a subsistence tool for generations. This study employs historical remote sensing data and interviews with elders of three communities to reconstruct wartime fire regimes. Local peoples reported a significant decline in fire events during the war (1975-2002), a trend corroborated by satellite-derived time series analyses. I identified possible reasons for such decline, linked to three main factors: displacement of people, risk of signalling one's location through fire and smoke, and strict fire governance. This study challenges the notion that ecological and climatic factors are the primary determinants of fire behaviour, emphasizing the intricate interplay between fire, war, and socio-ecological systems. It demonstrates that conflict can restrict fire use, altering the fire dynamics of entire ecosystems. Furthermore, it challenges existing narratives which suggest that war leads to increased fire activity as a result of fire being used as a tool or strategy during conflict. This research reveals that socio-political dynamics significantly shape fire regimes, and illustrates how human dynamics and decisions regarding land management during conflict can profoundly affect ecosystems and livelihoods. Moreover, it emphasizes the necessity of interdisciplinary approaches to fully understand how socio-ecological dynamics are influenced by war.

4.1 Introduction

The complex effects of war on socio-ecological systems are seldom well understood. War ecology has emerged as a sub-discipline of ecology to understand these complex interactions. War ecology examines the environmental consequences of conflict across all stages; before, during, and after war, and integrates ecological theory with insights from political ecology, peace and conflict studies, and environmental science (Machlis & Hanson, 2008). Studies from war ecology reveal that war can result in land degradation, fragmentation and disturbance to soils and vegetation, water pollution, a decrease in wildlife populations, and changes in forest cover (Daiyoub et al., 2023; Gbanie et al., 2018; Gorsevski et al., 2013; Hanson et al., 2009; Hanson, 2018; Machlis & Hanson, 2008; Mason, 2011). However, war can also lead to ecological benefits because of limited access to contested territories, altered settlement patterns, and reduced resource exploitation (Hanson et al., 2009). The implications of war for humans and nature are complex, multiscale, often cross disciplinary boundaries and produce effects that range from intuitive to unexpected, reinforcing the need for integrative approaches like war ecology to better capture the complexity of socio-environmental transformations caused by conflict (Hanson, 2018; Mason, 2011).

Of the many impacts that war can have, its effect on fire regimes remains understudied (Zubkova et al., 2021), despite the importance of fire regimes to livelihoods and ecosystem functioning. Research shows that during war, fire can be used by armies to clear space, improve visibility or damage enemy land (Daiyoub et al., 2023). Fire can also increase as a consequence of warfare through the use of explosives or as a result of hunting animals for consumption (Daiyoub et al., 2023). However, the effects of war on fire dynamics are not always predictable since armed conflict can reduce anthropogenic fires if the population is displaced, or increase the frequency and intensity of fire if management decreases (Gorsevski et al., 2012; Gorsevski et al., 2013).

Despite the importance of these dynamics, research in war ecology remains constrained by the unpredictability of armed conflict, inaccessibility of affected areas, and lack of pre-conflict baseline data (Lawrence et al., 2015). As a result, studies often focus narrowly on certain regions or impacts, leaving many effects, such as shifts in fire regimes, poorly understood.

Research regarding the links among fire and war has been dominated by the use of remote sensing, whilst field-based approaches are almost absent. Satellite data show that war often results in an increase in fire and fire risk associated with military activities (Daiyoub et al., 2023; Grimes et al., 2023; Zubkova et al., 2021). Remote sensing analyses show that during the South African Border war, there was a prevalence of fires due to the use of military artillery and the burning of vegetation during combat (Humphrey et al., 2021). In Syria, war promoted fire activity by increasing ignitions and decreasing fire suppression (Zubkova et al., 2021). During the wars in South Sudan and Mozambique, efforts to promote responsible fire management, ceased (Gorsevski et al., 2013; Shaffer, 2010). In Turkish Kurdistan, the Turkish army burned forests, fields and villages as a strategy in the conflict against guerrilla forces (de Vos et al., 2008). The impact of war on fire dynamics often persists long after the conflict has ended. Such is the case in the Colombian Amazonia where wildfires have increased in several protected areas and surrounding regions following the 2016 peace agreement (Tebbutt et al., 2021).

Although the links between war and fire have been underexplored (see Gorsevski et al., 2012; Gorsevski et al., 2013), research indicates that fire dynamics are closely linked to social and political contexts (Berkes & Folke, 1998; Shuman et al., 2022). Evidence suggests that fire management practices evolve over time in response to shifting socio-political circumstances, and that changes in population and cultural dynamics often coincide with changes in fire frequency (Guyette et al., 2016; Humphrey et al., 2021). For instance, changes in fire dynamics in Namibia were associated with socio-political circumstances prior to independence (Humphrey et al., 2021) whilst the Bateke peoples in Gabon saw changes in fire regimes when the state took control over land traditionally managed by Indigenous groups (Walters, 2010). Furthermore, socioeconomic changes can also affect fire activity by modifying the degree of anthropogenic pressure in the landscape (Zubkova et al., 2021). In African landscapes, studies incorporating local knowledge found that fire management and perceptions about fire are influenced by historic fire policies, colonial legacies and social power dynamics (Butz, 2009; Copes-Gerbitz et al., 2021; Eriksen, 2007; Humphrey et al., 2021; Moritz et al., 2014; Shaffer, 2010; Spies et al., 2014). However, some scholars have argued that fire behaviour is mainly determined by climatic, environmental and ecological factors (Countryman 1972; Kitzberger et al., 2007).

The links among ecology and fire have been studied more extensively. Across the African dry tropics, fire plays an integral role in the structure and distribution of ecosystems (Catarino et al., 2020; Wei et al., 2020), which makes crucial to understand how armed conflict influences fire regimes in those landscapes. Regular anthropogenic burning has historically been a tool for landscape management, contributing to vegetation diversity (Bond et al., 2005; Catarino et al., 2020; Kelly et al., 2020). In tropical forests, savannas, and agricultural regions, human activity is the primary source of ignitions (Andela et al., 2017; Roy et al., 2008), and many traditional fire users have developed, maintained, and transmitted knowledge around fire that has allowed them to co-exist with it. However, dynamics regarding anthropogenic burning in savannas remain understudied (Humphrey et al. 2021; Laris, 2002), whilst customary burning practices are changing because of shifts in the demography of fire users, conflict, land use change, policy, and climate change (Huffman, 2013; Mistry et al., 2005; Seijo & Gray 2012).

Although there is evidence that both climate and human activity affect global burned area (Bowman et al., 2009), there is little agreement over the degree of influence people have, relative to abiotic factors, in controlling fires (Archibald et al., 2009), let alone during armed conflict. Likely, human activities influence decadal-scale fire dynamics, whereas climate variability could drive short-term fluctuations (Teckentrup et al., 2019). Humans tend to suppress fires in regions with high population density, but areas of low population density see either fire increase or decrease due to human activities (Teckentrup et al., 2019). Humans can influence fire regimes by changing the types, structure or continuity of fuels (e.g., fragmentation), and by igniting fires during different weather conditions and at different times (including early burning) (Andela et al., 2019; Archibald et al., 2009; Archibald et al., 2010; Bowman et al., 2011; Eriksen, 2007; Syphard et al., 2007). However, humans are unable to completely control fires they set, nor control natural fires (Bowman et al., 2011).

The limited understanding of the complex relationship between social dynamics and fire ecology hampers our ability to address pressures on historical management practices, thereby endangering the crucial role of anthropogenic burning in fire-dependent ecosystems. This is particularly relevant in places like Africa where humans are the main source of ignition (Archibald et al., 2009; Catarino et al., 2020; Roy et al., 2008). Angola, one of the countries with the highest fire activity in the world (Archibald et al., 2010), underwent a prolonged war of independence followed by a civil war (1961-2002), and the effects of these conflicts on fire regimes remain understudied. In general, Angolan ecosystems are some of the least studied in Africa (Huntley & Ferrand, 2019). This is the case in the southeast (Lourenco et al., 2023), which contains some of the best-preserved woodlands and forests of the country.

The highlands of southeast Angola in the Moxico province have mosaics of vegetation comprising flammable savannas intertwined with non-flammable forests, a configuration that might be strongly linked to fire regimes influenced by humans, but the understanding of fire regimes in the area is limited (van Wilgen et al., 2022). This area is one of the most remote and marginalised of the country, with its isolation possibly due at least in part to political affiliations during the war (Brinkman & Alessi, 2009). Landscapes relatively free from external influences (and thus mostly governed by customary systems), such as those in southeast Angola, offer a valuable opportunity to isolate and examine how local dynamics shape broader phenomena, including fire regimes. Moreover, incorporating local knowledge and experiences to understand past socio-ecological dynamics is not only valuable but essential, particularly in historically marginalised contexts where conventional data sources are limited, and where local lived experiences offer critical insights that can reshape how these landscapes are understood and managed.

This study investigates fire dynamics during the civil war (1975-2002) in the highlands of southeast Angola, a landscape prone to burning that played a crucial role during the war. Three key questions are addressed in this chapter: 1) Was there a decrease in fire activity during the Angolan civil war? If so, 2) was the decrease in fire activity linked to the war? and, 3) What were the reasons behind the changes in fire activity during the war? To answer these questions, I combine historical remote sensing analyses of burned area with interviews from elders from three communities, focused on changes in fire use and reasons behind these changes within these highlands during wartime.

4.2 Methods

4.2.1 Study area

I conducted the ground-based component of this work in the Luchaze municipality in the highlands of Moxico, in southeast Angola. These highlands occur mostly in the province of Moxico (Figure 4.1) with a smaller portion in the provinces of Bié and Cuando Cubango. Most of the population of Moxico is concentrated in the capital Luena. In the highlands, population is sparse, particularly in the Luchaze municipality, which has the lowest population density of the country at 0.3 persons/km^2 (Instituto Nacional de Estatistica, 2014).

The highlands in southeast Angola have been recognised as containing some of the 'largest undisturbed miombo woodlands in Africa' (NGOWP, 2017). The area is dominated by woodlands at upper elevations and grasslands and rivers at lower elevations. Miombo woodlands and dry forests are the common vegetation types, which present a dominance of *Julbernardia paniculata, Erythrophleum africanum* and *Cryptosepalum exfoliatum.* Climate is seasonal with high temperatures and wet conditions during the summer and low temperatures and dry conditions during the winter. The dry season, when fires are common, starts in May and lasts until October. Temperature ranges from 10°C to 28°C and rainfall averages 1037mm ± 99 mm (mean ± SD) per year (USGS, 2020). Elevation ranges from 1228 to 1580 masl. The study site encompasses an area of 184 220 km^2.

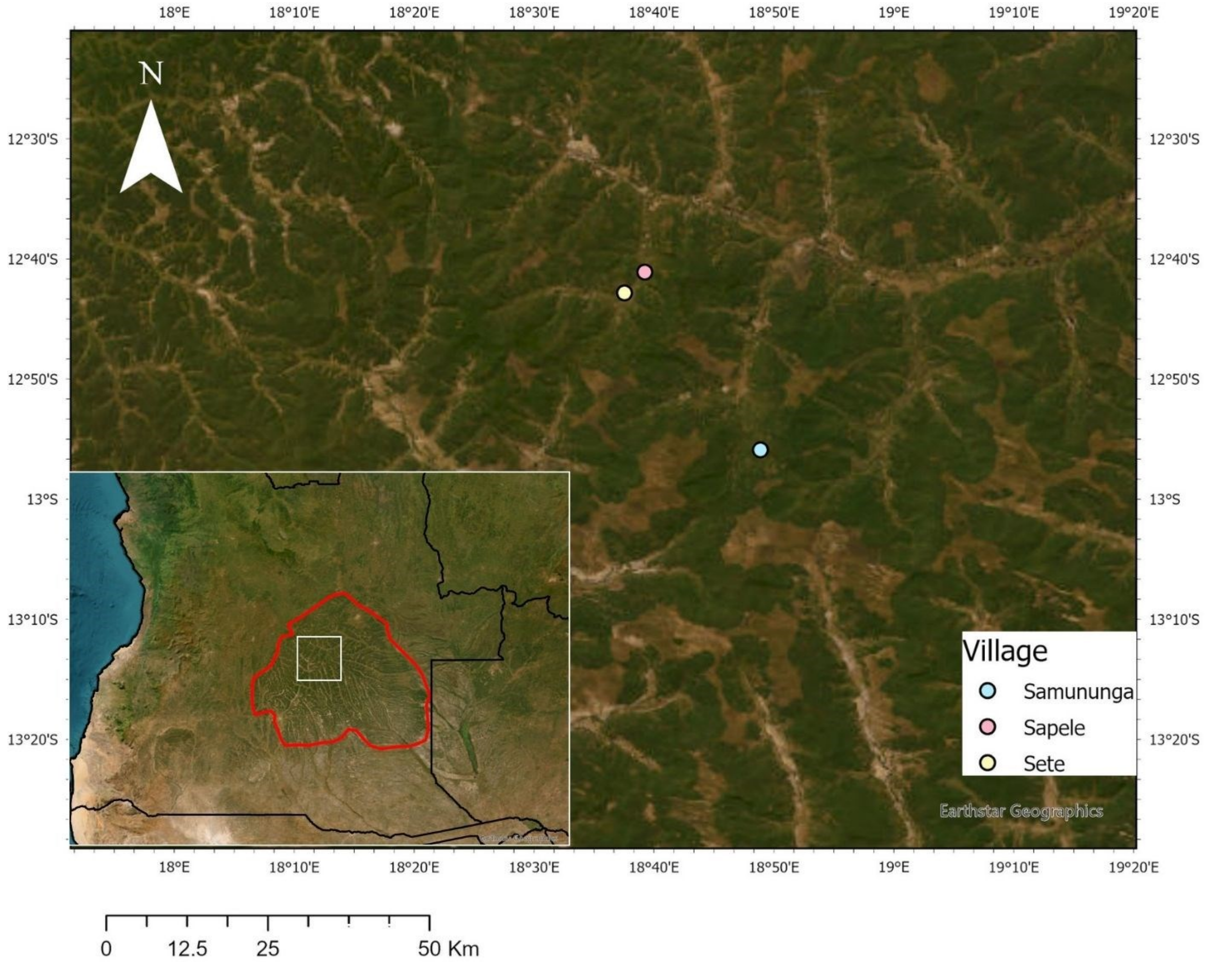

Figure 4.1. Study area in southeast Angola. The inset map shows in red the polygon used for remote sensing analysis, which encompasses the highlands physiographic region, and in the white square, the area where interviews took place. The zoomed in map shows the location of the villages where interviews were conducted.

Fire is common in this region and most fires are caused by human action (Catarino et al., 2020). Fires are less frequent in dry forests than in open grass-dominated ecosystems (Lourenco et al., 2023; Stellmes et al., 2013).

The main languages spoken are Luchaze and Tchokwé, but Nganguela and Umbundu are also widely spoken. Most villages have churches that are self-organised and many have schools, but they often lack teachers. Villages are usually situated near water bodies but at mid-elevations, often surrounded by savannas and shrublands but close to wooded areas. Socio-political organisation in communities is based on a tribal structure, with the *soba* (an inherited role) as the authority that leads the village alongside a council of elders. Population in the area is clustered in small villages with kinship ties that exert control over assigned territories. Governance over natural resources, and over fire specifically is not strict.

The southeast of the country was one of the most heavily affected by the relatively recent civil conflict (1975-2002). Many residents of communities in the area actively took part in the war (fulfilling different roles such as combatants, nurses, sentinels, carriers, etc.) and livelihoods were heavily impacted by the conflict. Moxico was the stronghold of the UNITA guerrilla movement (União Nacional para Independência Total de Angola which translates to National Union for the Total Independence of Angola,) led by Jonas Savimbi, which fought for over two decades against the MPLA (Movimento Popular de Libertação de Angola which translates to Popular Movement for the Liberation of Angola). The war ended in 2002 with the defeat of UNITA. Since then, MPLA has held power in the national government.

4.2.2 Data collection methods

Spatial data

Reconstructing past fire regimes using remote sensing presents significant challenges, including the limited resolution of early satellite sensors, inconsistencies arising from evolving technologies, and difficulties in accessing independent reference data (such as ground-based information) (Wooster et al., 2021). Fire detection through remote sensing relies on thermal imaging to capture elevated surface temperatures, multispectral data to identify reflectance of burned material, and active sensing technologies to detect smoke or particulate matter (Chen et al., 2024). Since the 1980s, burned area estimates have primarily relied on active fire (AF) pixel counts (derived from thermal imaging and multispectral data) from Advanced Very High Resolution Radiometer (AVHRR) data (Matson et al., 1987). This method had limitations to directly map burned areas due to cloud cover or fires burning when satellites were not overhead (Giglio & Roy, 2020; Wooster et al., 2021). However, they are the only data available to consistently understand past fire regimes over long time scales when ground observations are scarce. Because of these limitations, it is fundamental to use ground-based methods to corroborate insights from remote sensing and to gain a deeper understanding of socio-ecological dynamics (see Robins, 2003; Dennis et al., 2005).

For the remote sensing part, I used the NOAA/AVHRR-LTDR Fire_cco v1.1. product from the European Space Agency (ESA) Climate Change initiative (CCI) (Chuvieco et al., 2020) which extends back in time until 1982. Although the war began in 1975, I did not find satellite data before 1982 that informed on fire, so I studied the time frame from 1982 to 2018 (excluding 1994 as there were no data available).The AVHRR-LTDR product calculates burned area (BA) using temporal composites of global images at 5 km resolution, incorporating daily surface reflectance data in the RED, Near Infrared (NIR), and Mid-wave Infrared (MWIR) spectral bands, along with atmospheric, temperature, and land cover data from CCI and Copernicus (ESA) to help distinguish burnable from unburnable areas. The FireCCI51 (MODIS, 2001-2017) dataset is used to train the BA detection algorithm with a random forest approach to produce the AVHRR-LTDR data set. The burned proportion of each pixel is presented as monthly composites, potentially capturing multiple burn events within the same month (Otón, 2020).

To explore if observed changes in burned area through the time series were due to inconsistencies in satellite data, I compared burned area data from the AVHRR-LTDR product with MODIS/061/ MCD64A1 (Giglio et al., 2021) for the years 2002-2018 through a correlation analysis. The comparison showed a moderate correlation ($r = 0.4$) between the two data sets and no temporal bias in the values of the AVHRR-LTDR product with respect to the MODIS product (see Appendix A.3.1). The latter suggests that there are no temporal shifts in the AVHRR-LTDR product itself that could artificially create the appearance of a biased shift in burned area.

Furthermore, I obtained data from the same time period (1982-2018) for rainfall and temperature (LANDSAT 5 monthly climate dataset; USGS, 2020) for my study area to assess correlations among changes in burned area and climatic conditions.

Social science data

In order to understand historical patterns of fire use during and after wartimes, I interviewed elders in three villages within the region of study; Samununga (376 residents), Sete (256 residents), and Sapele (164 residents), all within the Luchaze municipality. All three villages re-established after the war ended. I used semi-structured interviews with rural residents to explore how fire use and fire regimes have changed over time (Shaffer, 2010; Christianson et al., 2013), how these dynamics were shaped by the experience of war and displacement, and how such changes impacted their livelihoods (Humphrey et al., 2021; Norgaard, 2014).

The villages I selected for this work were those that were logistically accessible and where the National Geographic Okavango Wilderness Project (NGOWP) had previously worked. These villages were also home to elders who, in past interviews, had described being actively involved in the civil war. Some even shared personal memories of fighting alongside the leader of UNITA.

I conducted a total of 34 interviews: 12 individual and 22 collective. The division among collective and individual interviews was not based on a predefined strategy. Whilst I initially sought to conduct individual interviews, people often asked to participate when they saw an interview taking place, or additional individuals would join the conversation as it unfolded. In the interest of respecting local cultural norms and allowing participants to choose how they wanted to engage, I accommodated both individual and collective interviews. Women, in particular, often felt more comfortable speaking in groups than alone. Collective interviews were not focus groups, rather, I would pose a question, and each participant was invited to share their thoughts. Sometimes this led to discussion among the group and other times they responded directly to me.

The main themes of the interviews included: (1) reconstructing the timeline of the war as remembered locally; (2) recollections of changes in fire activity during the war, including possible causes; (3) perceived consequences of those changes in fire regimes; and (4) the current use of fire. Even though the focus of this chapter is on past fire regimes, I include a brief section on how local communities use fire currently to provide context to understand past fire-people interactions. The guiding questions I used for the interviews can be found in Appendix A3.2. Since these were semi-structured interviews, I allowed conversations to follow a natural flow, adapting to the directions set by participants' responses. In the interview process, trust, reflexivity, and ethical sensitivity where essential when engaging with communities on these topics (Aydoğan, 2023).

Fieldwork took place intermittently from May 2022 to October 2023, but the actual time on the ground totalled 2 months. Since the size of the villages is often small and the majority of the population are young, I was able to interview most of the elders in each community. I used an iterative approach, and interviews were built upon what I learned in preceding interviews. Lastly, as a foreign researcher, I was mindful of the asymmetries in knowledge and power that often accompany these encounters, particularly when dealing with sensitive topics like the war. I thus positioned myself humbly as a mere listener, acknowledging the elders' roles as knowledge holders (Molnár & Babai, 2021).

Ethical considerations of talking to people about sensitive/traumatic issues

Conducting research on sensitive topics like war and fire in post-conflict Angola requires ethical awareness, sensitivity, and reflexivity. During my fieldwork, I was aware that the environment where the interview took place had to be a comfortable place, so I usually went to interviewees' houses in the hopes of creating a comfortable setting (Westland et al., 2025). Building trust and showing empathy to try to minimise distress and foster mutual respect were also essential (Dempsey, 2016). Interestingly, interviewees often expressed a willingness to share their stories, possibly as a way to give voice to a historical record long ignored, a pattern observed in other post-war studies (Wood, 2006; Green, 1995; Nordstrom, 1997). Furthermore, I practiced oral consent, assured confidentiality, and made clear that participants could skip questions or withdraw anytime. Throughout, I remained attentive to signs of discomfort (Walker, 2007), recognising that emotional responses, both theirs and mine, are part of the ethical complexities whilst studying post-conflict settings (Brounéus, 2011). Finally, given the linguistic complexity of the region, I worked closely with interpreters who helped me understand not only words but also emotions, which also meant interviews were conducted at a slower pace, offering space for reflection.

4.2.3 Data analyses

Quantitative

From the AVHRR-LTDR data set, I extracted burned area within the study area (red polygon shown in Figure 4.1), masking negative values (which can arise in places that do not burn, such as water bodies). I obtained the monthly value of burned area from each year from 1982 to 2018, and then I added each value to calculate total burned area by year. I then conducted a breakpoint regression analysis to explore changes in burned area per year over the time series. This analysis uses a linear model with 'burned area' as a function of 'year' but then performs a segmented regression, to help identify points during the studied time frame where the relationship between burned area and year significantly changes. After testing models with different number of breakpoints (0, 1, 2, 3), I chose the model with the highest adjusted r^2. I also compared the AICc of each model with a different number of breakpoints and chose the one with the lowest value (which matched the regression with the highest adjusted r^2). In addition, I explored relationships among climatic variables and burned area through linear regressions. The breakpoint analyses were repeated, including precipitation (the year before and the same year) and temperature as covariates. I assessed if including these covariates improved the model (as judged by lowering the AIC value more than 2 units), and if so, whether it changed the value of the estimated breakpoints. Given that these analyses can present temporal autocorrelation (Di Cecco & Gouhier, 2018), I obtained the residuals of the breakpoint analyses and then tested their correlation with the variable 'year' with a Moran's I test. The results showed no significant temporal autocorrelation with a p-value=0.32.

In addition, I divided the dataset before and after each year of the time series (e.g., before 1983 and after 1983, before 1984 and after 1984, etc.) and conducted an ANOVA comparing the mean burned area before versus after each year. I then recorded the 'dividing year' that produced the highest F statistic, indicating the year across the time series when the greatest mean change in burned area occurred. I also compared the mean burned area during the war (1982-2002) and after war (2003-2017) using a two-sample t-test.

Finally, I classified fires by early (April to June) and late dry season (July to October) based on local ecological knowledge in the region. According to community members, a greater proportion of early fires are controlled and accidental fires occur more often in the late dry season. The reason behind analysing the time series by dividing early *vs* late season fires was to explore if war affected not only burned area but also fire seasonality.

Rstudio v.4.3.2 packages *Segmented v.2.0-3* (Muggeo, 2023), with functions ‘segmented’ and ‘segmented.lm’; *MuMIn v.1.47.5* package (Bartón, 2023), with ‘AICc’ function; and a *Moran.I* function from package *ape v.5.7.1* (Paradis & Schliep, 2019), were employed for these analyses.

Qualitative

I used an inductive thematic coding approach based on Grounded theory to analyse the interviews. Grounded theory is a method based on exploring key concepts and relationships among the data during the collection process (Glaser, 2002), and was used to establish themes regarding the perspectives around fire use and changes in fire regimes during wartimes. The themes identified for fire use during wartimes were: a) use (or absence of use) of fire as a tool for warfare, b) changes in subsistence fire use (including fire knowledge), c) reasons for changes in fire use, d) governance of fire, and e) changes in vegetation due to changes in fire dynamics. I used the software *Nvivo* v.20 (QSR International, 2018) to code the data.

Lastly, I reviewed historical literature related to warfare dynamics in Angola with an emphasis in southeast Angola.

Bridging the different types of data

To answer my three research questions, I compared analyses from interviews with remote sensing analyses. Through satellite images I was able to identify temporal and spatial fire patterns for the region of study. The field-based methods were fundamental to understand how and why fire is used in the landscape. Moreover, bridging diverse sources of knowledge helped me to better interpret local experiences of fire and land cover change (Dennis et al., 2005), and to situate personal narratives within broader spatial patterns. This approach also allowed me to consider the social, historical, and ecological dimensions of fire during the civil war (Wood, 2006).

4.3 Results

4.3.1 Current uses of fire

Fire in this region is regular. The adaptations in the vegetation (evidenced by the presence of fire-adapted species, presented in Chapter 3) and the local fire knowledge are evidence for historical regularity of fire. At present, the majority of the fires are started by people. They burn the vegetation intentionally for different reasons:

a) To obtain products and benefits from the landscape. Local peoples use fire to stimulate plant and fruit production in the open savannas. Mushroom production can also benefit from burnt grounds. Fire is also used as a tool to aid them in hunting. Traditionally, a collective hunt occurs where hunters create a circle of fire, with a narrow exit where hunters await the escaping animals (called *chikuna* in the local language Luchaze).

b) To modify the density and structure of the vegetation. They use fire to 'open and clean' the ground so they can move around as well as drive away animals (mainly snakes, but it also improves their visibility to spot bigger predators such as lions). Fire is also fundamental as a mean to prepare the land for the first round of cultivation, where trees are cut and burned in the late dry season (using firebreaks to prevent uncontrolled fires), to create a fertilizer from the ashes. Where grasses predominate, fires control grass growth which supports plant diversity by allowing resources useful for medicines or food to thrive.

c) To protect the landscape from bigger uncontrolled fires in the late season. Early dry season fires help eliminate dry fuel so that later in the dry season there is not enough fuel for large, destructive fires.

d) To maintain the structure and avoid change. Some respondents reported using fire to keep vegetation from changing due to grass, shrub or tree dominance. By maintaining the diversity of vegetation types, they can continue to obtain services and products from them.

Expanding upon intentional burns, fires also occur as a consequence of other activities. Honey harvesting is done by setting on fire a bundle of sticks and grasses, so that the smoke will drive away the bees. But the honey harvesting season coincides with the late dry season when fuel has accumulated. It often occurs that these bundles fall to the ground, causing grasses to burn. Fires might also travel, turning from a controlled fire to a wildfire if environmental conditions allow. Agriculture activities or hunting are common instances where fires become 'wild' or uncontrollable. The time of the year, the time of the day, and the amount of wind affect the risk of wildfires. Many people also reported wildfires occurring because of children playing with fire and hunting birds with the use of fire at times of year when the landscape is highly flammable.

Fire knowledge

In this region there is well developed generational knowledge around fire. This means that people understand the behaviour of fire and how to use it, and they pass this knowledge onto younger generations. Fire knowledge is reflected in vocabulary in the local languages around different types of fires. In Luchaze, there is a word for the action of setting early preventive fires, *kuvahuila* and one for intense, uncontrolled fires, *kutzimika*, additionally to a word for fire that might be used for cooking and heating, *tuhia*.

Fire knowledge is also reflected in how fire is used. The purpose and time of the burn depends on the vegetation type. Open savannas are burned early in the dry season as the grasses are dry enough to burn, but not too dry that fires become uncontrollable. Also, if they want to enjoy the fruits and medicines of the savanna in that same year, the burns need to happen early in the dry season. The more open the vegetation, the more it burns. Shrublands are usually not burned intentionally, but fires spread to them from burning other areas and from harvesting honey or hunting. Miombo and open woodlands burn late in the dry season since earlier, there is not enough dry fuel. Dry forests are not burned except for cultivation, and even though wildfires often get to the edges of dry forests, they seldom travel far into them since dry forests are covered by mosses on the ground. Some people mentioned that the only active fire management occurs in the open savannas. However, other local peoples said that miombo and open woodlands are also burned intentionally, but since they are only flammable in the late dry season when fuel has accumulated, accidents often occur. Not only does the vegetation around the villages burn, but also vegetation far from villages. People travel long distances to set up crop fields, and they might also burn in more isolated areas for the same purposes mentioned before. Although to some degree, all types of vegetation burn, not all burn at the same time nor during the same year. The burning is patchy, and people are used to a mix of controlled and uncontrolled fires happening through the dry season.

4.3.2 Remote sensing

Results from remote sensing analyses show that total burned area was, on average, significantly lower (36%) during the war (1982-2002) compared to subsequent peace times (2003-2018) (t_{34}= -6.14, p<0.001) (Figure 4.2). The lowest percentage of burned area occurred in 1998 (51% less than the average during peace) followed by 1991-1992 (46% less than the average in peace times) and 1986-1987 (37% less than during peace). The highest burned area was observed in 2003 (60% increase from the average during the war).

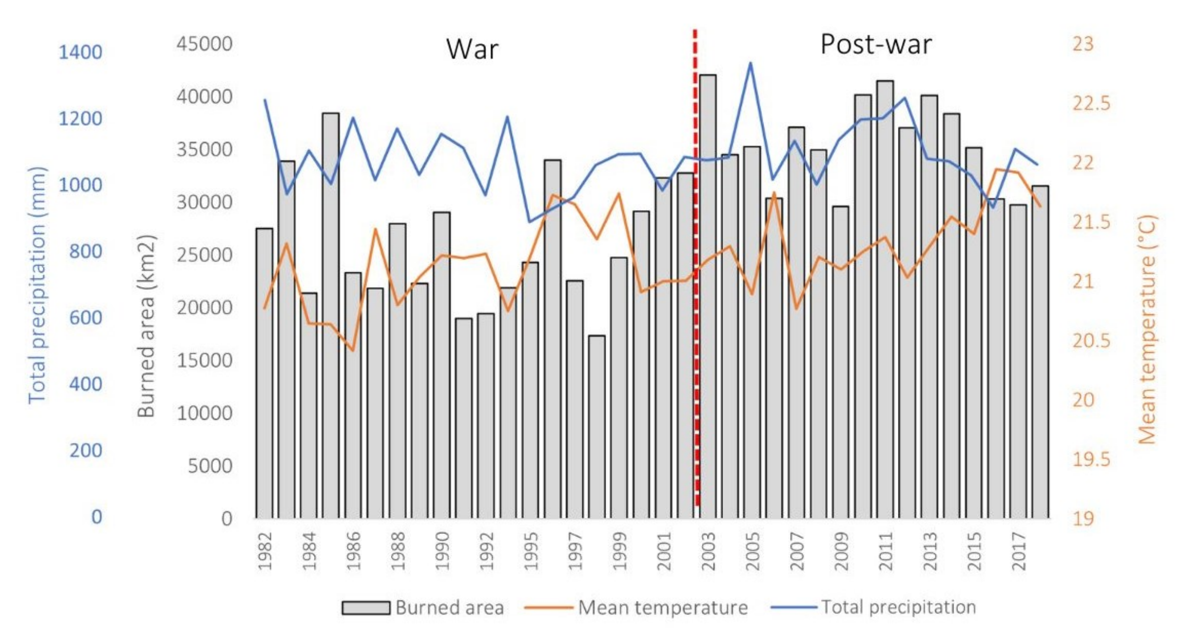

Figure 4.2. Total burned area (km^2) from 1982 to 2018 within the area of study, alongside with mean temperature (orange line) and total precipitation (blue line). Red dotted line divides the time series during and after the war.

The breakpoint analyses depicted 1998 and 2002 as years where the fire regime shifted significantly (Figure 4.3). There is a gradual decrease in burned area from 1982 to 1998 and then a sharp increase from 1998 until 2002. The year 2000 best divided the data between 'low fire' (during war) and 'high fire' (after 2000) (F_{34}=42.9, p<0.05). Neither rainfall (t_{34}= 1.1, p=0.27) nor temperature (t_{34}= 0.34, p=0.73) were significant predictors of burned area. Also, when temperature and precipitation were added to the breakpoint analyses the models did not improve (the AICc did not decrease greater than two units).

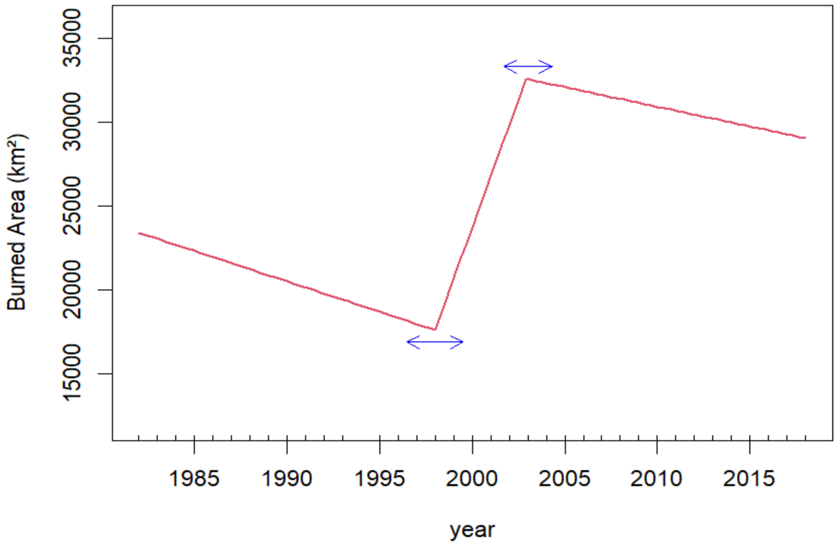

Figure 4.3. Breakpoint analyses for burned area in my time series. The years 1998 and 2002 fit the best model. Blue arrows indicate the bounds of the standard error of breakpoint estimates.

I then classified fires by early (April to June) and late dry season (July to October) (Figure 4.4). On average, 11% of burned area occurs in the early dry season as opposed to 75% in the late season. This average remained relatively constant through my time series. However, in the period of 1998-2000 and 2001-2002, as well as in 1993, the early season fires decreased by 40 to 43% in relation to early dry season mean burned area. Although 2003 is the year with the highest burned area of the time series, it has lower early dry season fires than other years after the war ended. This points towards the fact that not only burned area decreased, but also early fires, and respondents often link early fires to controlled burning. However, during the war the decrease in early dry season fires did not seem to cause an increase in late season fires.

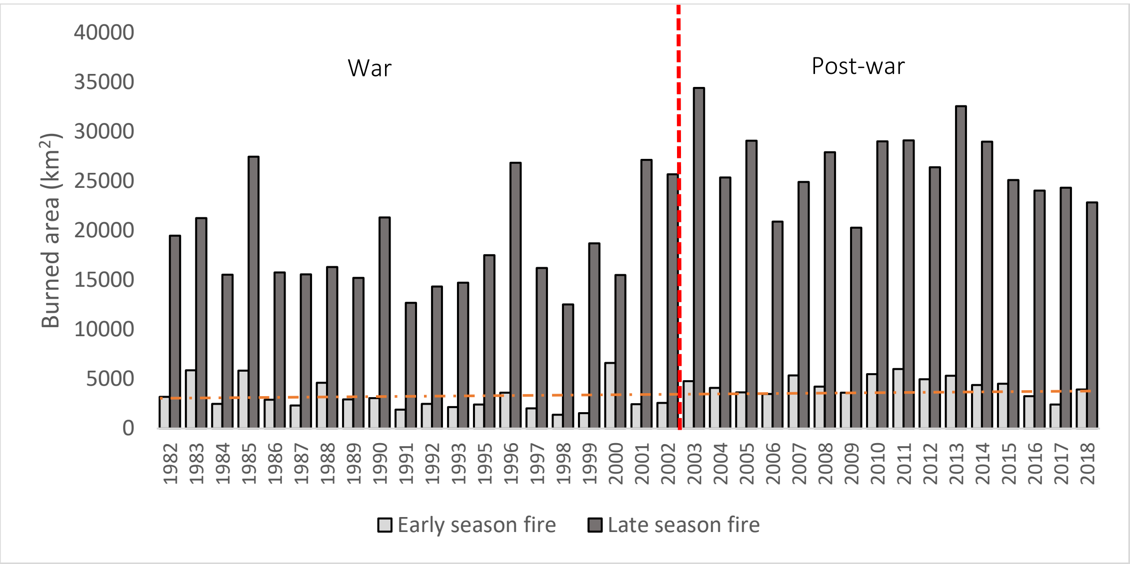

Figure 4.4. Early dry season fires *vs* late dry season fires. In average, around 11% of the landscape burns during early fire season (orange horizontal dotted line).

4.3.3 Qualitative analyses

Respondents reported an overall decrease in fire events during the civil war, attributing it mainly to three factors. The first reason was a decrease in population density and widespread displacement within the region, with some people relocating to urban centres where it was often safer. Others remained in the area but were forced to move frequently. People who remained in the area had to live precarious and mobile lives to escape from the war. Many became part of UNITA, relocating to their bases and moving around the country. The second reason given was that fire (and smoke) would inform potential enemies of people's location and would put them at risk:

> "During wartimes you couldn't burn, you couldn't. People were scared of the war… there couldn't be much fire in the bush. The burns were few because people didn't burn, and also because the villages didn't have many people around"
>
> male respondent, 73 years old

> "Woodlands didn't burn back then. They would only burn where the war passed… burning was not acceptable. If you burned, then where were you going to hide?... As

> soon as there was fire, it was a way to call the enemies to come find you… smoke can travel far so you would be giving a signal of your location to the enemies”
>
> male respondent, 53 years old

MPLA helicopters and planes could spot UNITA troops and civilians through fire flames and smoke.

> “If you burned during wartimes, when planes passed through, MiGs[1] or helicopters, they would spot you, so you had to be in closed woodlands, when MiGs passed, you had to get by the bushes to hide…”
>
> female respondent, 51 years old

Local peoples highly valued dry forests, which were often the preferred hiding spot since their closed canopy provided cover from aircraft used for war. For this reason, UNITA strategically placed their bases in dry forests. Notably, dry forests seldom burned since their ground is covered by moist mosses, which make fires unlikely. Even when a fire is set, it does not spread far.

> “I could not stay in open areas. You can’t. Helicopters will take advantage of it. So it was better to stay in closed woodlands… but you can’t burn the bush, you can’t burn there, that bush doesn’t burn. Those places with lots of trees. That forest is protected”
>
> female respondent, 58 years old

Furthermore, fire was not used as a warfare tactic to deliberately burn the forest but respondents reported that when enemies invaded their villages, they often used fire to destroy homes. They would set houses on fire as a tactic to debilitate opposing groups.

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[1] Soviet aircraft used for the war, named after Mikoyan-Gurevich Design Bureau. The Soviet Union supported MPLA in the Angolan civil war and these aircraft were a significant part of the military strategy in the conflict (Scholtz, 2009).

> "If people were mixed with the troops, the enemy would destroy everything, they would burn houses, people and everything… the enemies would kill people and then destroy the villages. Even if the village had no people, they would burn everything"
>
> female respondent, 70 years old

Fires sometimes resulted from warfare activities, but they did not seem to cause significant impacts on the vegetation. Both armies employed weapons, including war tanks and bombs. And although the objective was not to burn the vegetation, using these during dry conditions often led to fires as an unintended consequence of broader war strategies. The intensity of these fires depended on the time of the year and the place where bombs were used (for example, open dry grasslands burned more than forests):

> "If those bombs exploded in the bush during dry times, then there would be fires, but if it was during rainy times then there wouldn't be fire. Even when the bombs exploded during dry times, there weren't so many so that didn't cause much fire… where the bombs landed, it would burn where there were grasses but that fire wouldn't burn much, it would burn a bit but then it would go off"
>
> male respondent, 65 years old

Combatants used different type of bombs to attack. Certain bombs produced mostly smoke and others fire:

> "There were different types of bombs, some bombs only released smoke but others, when they exploded at night, it looked like it was day time, because they came with a flame, they made so much fire! …There were those phosphorous bombs that produced lots of fire, they would light up the floor. With those you could even see the others"
>
> male respondent, 67 years old

The third reason was strict fire governance. Because of the tense circumstances, people had to be extremely conscious with their use of fire. Interviewees said that during the war, strict restrictions for burning were put in place.

> "…even UNITA, it wouldn't let people burn because of the war, it would not let anyone burn the bush…because if you burned, you are giving a signal to the enemies that there are people there, so it was forbidden to burn. If you burned, you could not escape, that was a crime! … If you burned anarchically you are going to get the others killed, so that was a crime"
>
> male respondent, 79 years old

> "There were rules for the burns. The chief had orders. The rule then was to light up the fire after 18 hrs until 4 hrs, then fire had to be put off. Cooking was at 4 or 5 hrs, and just as you finished cooking, you put the fire off"
>
> female respondent, 59 years old

Furthermore, there were consequences for burning outside the rules and regulations:

> "Some soldiers would pass by the bonfire to check if there was smoke, if so, then you had to remove the firewood…if people set fires anarchically, the soldiers would ask, who burned? That *x* person burned, and they would kill them, so if someone was assassinated for that, the others would see and then they wouldn't burn anymore, because that was the order"
>
> male respondent, 67 years old

> "Those who made the mistake of burning, they would get a punishment, they'd beat you or give you a punishment or a job as a punishment. When soldiers gave orders, you cannot pass above their order, that is the law…they would beat you, two people would beat your body, they whipped you, they could do 100 or 200 or 250. It was whipping…"
>
> male respondent, 64 years old

Burning was carried out in a coordinated manner. Even during wartime, early burns were practiced (to prevent uncontrolled fires later on), mainly around crop fields, although significantly less than in peace times. In addition, instead of using fire to create firebreaks around the fields, they had to switch to manually cut vegetation to stop fire from spreading.

The burning had to start late at night when helicopters were not around, and had to be finished before dawn. They also had to stay away from the crop fields because helicopters could easily spot fields, increasing the risk of detection. When they burned the fields, it was safer to go far away and come back days later.

> "Yes! [during the war] I did burn the fields. But only during the night because of the planes… through the fire the enemies would bombard us, so you'd set the fire and then you go, you can't stay there... but to burn first thing you had to patrol, if the enemies were far, then you can do that job of burning"
>
> male respondent, 57 years old

Since agriculture was limited by the presence of MPLA troops, local peoples had to rely on honey, wild fruits, mushrooms and caterpillars as sources of food:

> "Life was very hard. Children were hungry and cold, but you couldn't set up a fire. You had to get your kid under your arm, and give them fruits so that they won't make noise"
>
> female respondent, 70 years old

In general, respondents noted that whilst there used to be an organised approach to burning during wartime, nowadays people burn without such coordination. Moreover, other subsistence activities were affected too. Hunting was possible but very limited, and the use of fire as a hunting technique was not practiced during the war (traditionally, it is widely used during peace time). Harvesting of honey with the use of burnt wood sticks also had to be done at night to decrease the risk of fire, but they would harvest with two to three people to prevent uncontrolled fires (one person climbs the tree to harvest and the others wait down the tree to set off flames from the burnt sticks used to collect honey). As for cooking, they shifted the preferred tree species for firewood to those that did not produce much fire and smoke (i.e., shifting from *Julbernardia paniculata*, a preferred firewood species at present to *Bobgunnia madagascariensis*). They also used a technique where they placed wood underneath cut termite mounds and set cooking pans on top. This prevented both fire and smoke from spreading far:

> "It was hard to cook, I had to use those trees, *munhenhe* (referring to *Bobgunnia madagascariensis)*, because that one doesn't make smoke. Because if you made smoke, the enemy will see you… Food was made at 4 hrs when the sun was not out yet, because of the smoke. That big firewood you could only light at night. But you had to remove the bark, and just leave the wood, that burns little by little…that coal that remains you'd use to cook in the morning because that one doesn't make smoke anymore"
>
> female respondent, 65 years old

War had other unexpected and indirect effects on communities and landscapes. The elder reported a disruption of traditional practices related to fire (like collective hunting with fire or celebrations with bonfires), with a particular emphasis on a decrease of knowledge transmission. They said the war caused a loss in fire knowledge and nowadays younger generations are less conscious of how to use fire. Another reported consequence of less anthropogenic fire is that people perceived an increased in density and area covered by dry forests.

Lastly, I found the decreased fire activity during the war consistent with accounts from interviewees and literature on the history of the Angolan civil war (Figure 4.5). Over the 27 years of the war, the intensity and geography of the conflict fluctuated. For analytical purposes, the war has conventionally been divided into three periods: 1975 to 1991, 1992 to 1994, and 1998 to 2002 (World Peace Foundation, 2015). Notably, these three periods intersect with changes in fire dynamics that I observed through remote sensing analyses. For instance, in 1985, respondents said that the war got more intense, which coincides when FAPLA (Forças Armadas Populares de Libertação de Angola which translates to Popular Armed Forces for the Liberation of Angola) attacked UNITA in southeast Angola, and the South African Defence Force intervened (Miskimon, 2022). Correspondingly, after 1985 fire activity decreased significantly and remained low for the next ten years. During that time, the

Battle of Cuito Cuanavale took place (August 1987 to March 1988), which was reported as ‘the second largest fight in Africa and the largest tank battle’ since World War II (World Peace Foundation, 2015). In 1991-1992, after an ineffective Bicesse peace accord, UNITA lost the elections, and war resumed, representing the beginning of ‘the most sustained period of military and state violence in Angola’ (World Peace Foundation, 2015). During those two years, I observed the second lowest burned area of the time series. However, after 1992, burned area increased in this region, likely because the war at that time was fought mostly in urban areas, so people were able to use fire for subsistence for a limited time period.

The year of 1998 was reported by local peoples as one of the most intense and difficult during the war, where the country went back into full-scale war after some years of ceasefire signed in the Lusaka accords in 1994 (Knudsen et al., 2000). During this time the MPLA initiated an armed offensive against UNITA territory, situated in the southeast of the country (Cilliers & Dietrich, 2000; World Peace Foundation, 2015). Notably, 1998 presented the lowest burned area during my time series analyses of burned area.

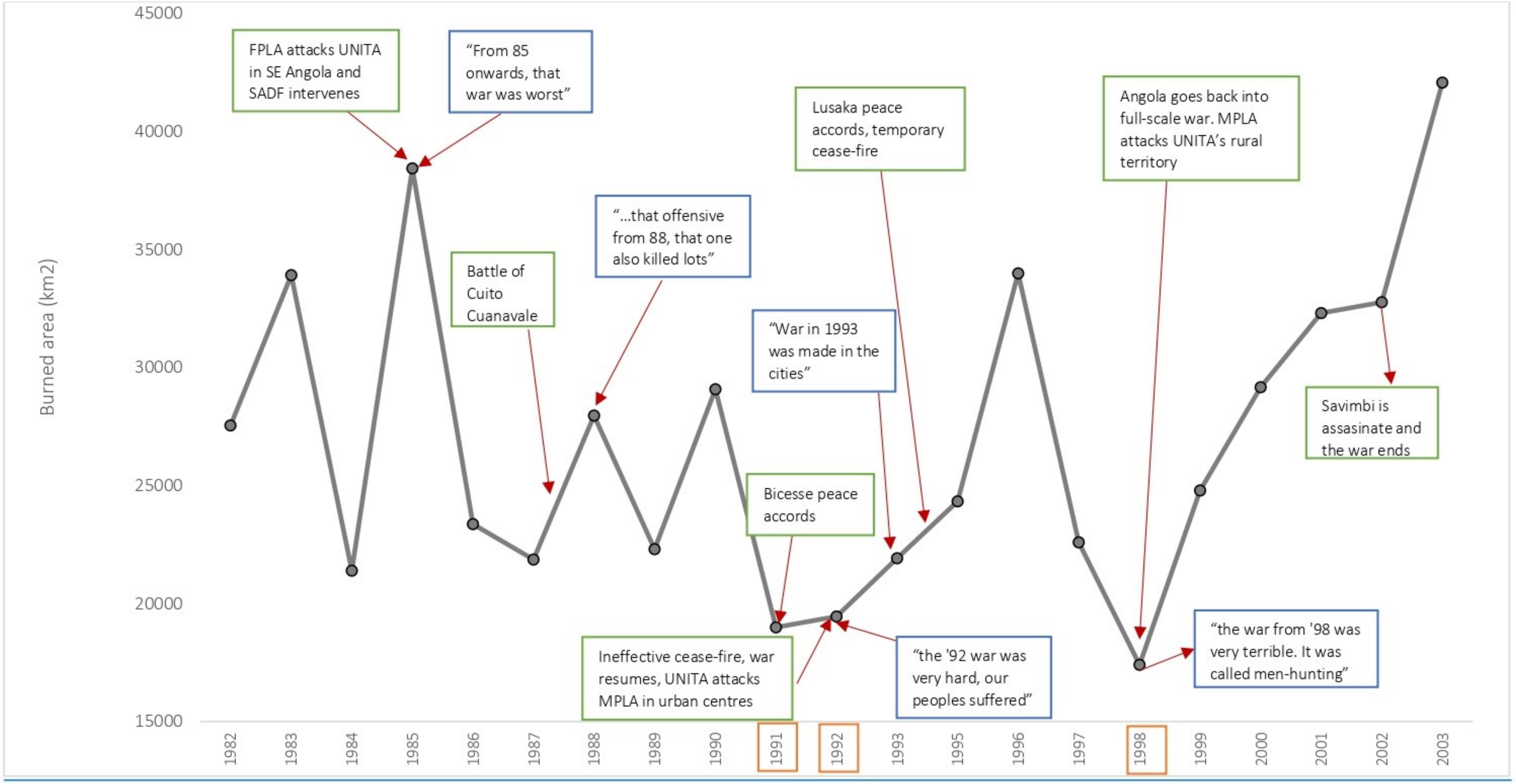

Figure 4.5. Historical (green rectangles) and testimonies (blue rectangles) linked to changes in burned area in southeast Angola. Orange rectangles represent the years with the lowest burned area.

4.4 Discussion

My analyses indicate a decrease in burned area during the Angolan civil war, followed by an increase as the conflict neared its end, and particularly after peace was restored in 2002. Altered fire regimes over the assessed time period were not correlated to climatic factors. Within my time series, I observed the most notable decrease in burned area from 1985 until 1998, with 1991, 1992 and 1998 as the years with the lowest burned area. Notably, changes in burned area can be linked to events reported by respondents as well as in literature of the history of the war. The main reasons for the decrease in fire identified by people with direct experience of war in Moxico were the displacement of population due to the conflict, a high risk of signalling their location to opponents as a result of using fire, detectable mainly from aircraft, and strict fire governance. Subsistence activities that usually require fire were either supressed or limited. Whilst remote sensing helped identify changes in burned area during wartime, bridging satellite data with social science approaches provided crucial insights into the underlying causes of fire decline during the conflict in southeast Angola. These results demonstrate that during the Angolan civil war, humans significantly influenced fire regimes, whilst war itself impacted human interactions with fire.

My results represent an important contribution to the understanding of fire dynamics in conflict zones by documenting a rarely observed decreased fire activity during wartime. This is relevant in the field of war ecology, since war's impacts on fire regimes have seldom been documented, and much less a decrease in fire activity during war. Contrary to the prevailing evidence that war tends to increase fire activity (Daiyoub et al., 2023; Grimes et al., 2023; Zubkova et al., 2021), this study revealed a notable decrease in burned area in the Moxico highlands due to the conditions brought about by the conflict, challenging the conventional view that war generally leads to more burning (Daiyoub et al., 2023; Humphrey et al., 2021). Although the relationship between warfare and fire dynamics can vary significantly depending on local contexts, ecological conditions, and the nature of the conflict itself, comparable patterns might emerge in other landscapes affected by conflict, emphasizing the need for further research to explore how these dynamics manifest in different landscapes.

Notably, my findings align with previous fire studies in Angola since the war (Catarino et al., 2020; Lourenco et al., 2023), which report the highest values of burned area between 2003 and 2005. This increase has been linked to the end of the civil war (Catarino et al., 2020; Lourenco et al., 2023) alongside a rapid expansion of agricultural areas (Schneibel et al., 2013). The drastic increase of around 42% burned area in 2003 compared to the average from 1986-1999 in my study, indicates a clear transition from limited fire activity during the war to regained autonomy of local fire use during peace times. The increase in burned area after the war was possibly driven by an increase in population along an increase in agricultural activities due to people's reestablishment in the area. Nonetheless, although fire decreased markedly during the war, it was never suppressed entirely. Also, settling permanently after 2002 rather than shifting locations, could have resulted in less patchy and opportunistic burning (particularly in more remote areas) and more focalized burning around villages, causing the accumulation of fuel in more remote areas and increasing the risk of intense fires resulting from anthropogenic burning (Rodriguez, 2007). In the region, fire is also an important tool for hunting and honey production, and it is likely that the increased use of fire for these activities, made possible by the absence of war, contributed to the rise in burned area after the war ended. Furthermore, following the end of the war, the expansion to market connections might have promoted agricultural production for the trade of goods.

The increase in fire activity in Angola after 2002 has been seen as an exception (Catarino et al., 2020), whereas the exception might actually be the marked decrease during the war. Perceptions on what constitutes a 'typical' fire regime have likely been affected by the sharp contrast in fire activity between wartime and peace time, and these shifting perceptions could influence current decisions regarding the management of fire in these landscapes. This underscores the importance of understanding the historical and political context of fire use through local voices, promoting listening as a means to more inclusive and context-sensitive approaches to research and conservation (Staddon et al., 2023). Particularly in this case, where the impacts of war have rarely been narrated by those most marginalised and affected by the conflict. Without such attention to local histories and perspectives, management approaches rooted in external or colonial values risk overlooking or undermining locally grounded practices and knowledge systems.

The reduction of burned area during the Angolan civil war not only reshaped local social dynamics at the time but may continue to affect livelihoods today, highlighting the lasting influence of war-induced changes in fire regimes. For example, considerable shifts in governance and fire management during conflict have impacted community fire practices in the region. Before the war, collective management of fire was more common (as reported by the elders), possibly driven by ancestral traditions aimed at managing land and resources, however, during the war this practice shifted its purpose to serve as a survival strategy. When the war ended, the benefits of managing fire lost their link to immediate survival strategies, and by this time, the pre-war traditions might have been lost. Currently, fire practices are largely driven by individual decisions, and governance over fire is significantly less strict than during wartime, possibly due to peace, abundant resources and a landscape adapted to fire.

The reduction in fire activity during the war was also evident in the decreased use of early season fires, particularly during the years with the lowest burned areas. This suggests that not only did anthropogenic fire decrease, but efforts to prevent wildfires also decreased, a shift that has been documented in other conflict zones (Gorsevski et al., 2013; Shaffer, 2010). Since preventive fires are important for the local culture, a decrease in the ability to conduct early dry season fires could undermine traditions around fire. Fire is not only essential for subsistence, but is an integral part of the culture of local peoples of southeast Angola.

The war not only suppressed the use of fire but also disrupted the intergenerational transmission of fire knowledge, with possible long-lasting cultural and ecological consequences. The restricted use of fire during conflict has most likely contributed to a disruption in fire knowledge and practices, creating tensions between elders, who retain expertise, and younger generations, who are increasingly disconnected from this knowledge. Similar patterns have been observed in other places, where fire knowledge remains largely with the older generation, threatening the continuity of culturally embedded fire practices (Christianson, 2015; Huffman, 2013; Bilbao et al., 2019; Shaffer, 2010). In the Moxico highlands, the erosion of LEK in general (including fire knowledge) is likely also influenced by broader shifts toward Western ideas and governance structures, which often replace collective fire management with individual or state-influenced approaches (Mistry et al., 2005; Walters, 2010). This erosion undermines culturally rooted fire management strategies and reflects the broader consequences of wartime, post-war and post-colonial disruptions.

The subtle impacts of war on the practice of fire-related cultural traditions have seldom been documented but the decrease and replacement of traditional fire practices have been previously reported in different regions (Christianson, 2015; Copes-Gerbitz et al., 2021; Humphrey et al., 2021; Mistry et al., 2005; Mistry et al., 2016; Walters, 2010). Loss of cultural identity and a diminished ability to cope with environmental changes are potential outcomes of restricting fire use (Smith et al., 2022; Aswani et al., 2018). Reduced fire knowledge can also lead to an increase in fuel accumulation, reduce the biodiversity of fire-dependent ecosystems, increase the risk and intensity of wildfires, and raise the costs for firefighting (Bilbao et al., 2019; Fischer et al., 2016). Nevertheless, some fire-related practices and knowledge endure, as livelihoods continue to depend on fire for accessing key resources, demonstrating the resilience of LEK despite the legacy of war (Shaffer, 2010).

The altered fire regimes during wartime might have also had ecological outcomes. The absence of fire in the Moxico highlands, a fire-prone ecosystem, might have favoured the expansion and/or densification of fire-sensitive vegetation (namely dry forests), which in turn might have led to a positive feedback where the flammability of the landscape decreased as the vegetation became denser, which in turn supressed grass development (Stellmes et al., 2013). This aligns with local perceptions about forest densification linked to decreased fire activity, supporting previous studies that highlight the ability of woodlands in the area to form a closed canopy in remote areas (Andrews et al., 2024). In forested areas, humans are more likely to influence fire regimes due to the lower flammability of tree-dominated landscapes, which limits the growth of grassy understories; conversely, in grass dominated ecosystems, climatic and environmental conditions are likely to override human efforts to control fire (Archibald et al., 2009). In the Moxico highlands, where even in the year with the highest burned area (during the entire time series, 1985-2018), only 23% of the total study area burned, the region's vegetation mosaic, comprising both open grassy areas, miombo and dry forests, likely plays an important role in shaping fire regimes. This mosaic may act as a natural firebreak, limiting the extent of fires. This suggests that ecological variables can both exacerbate and limit social issues and *vice versa*, depending on the context. This also highlights the complex and reciprocal interactions between social, political and ecological factors in shaping fire regimes. In this context, a socio-ecological framing is essential to capture the complex dynamics between people, fire, and landscapes.

Overall, the altered fire dynamics in the highlands during the civil war illustrate the ability of socio-political circumstances to influence fire regimes. My findings emphasise the power that local communities have over fire regimes and their ability to modify fire activity despite a landscape prone to burning. This calls for a need to reconsider when and where ecological variables are the main determinants of fire (Archibald et al., 2009; Catarino et al., 2020, Lourenco et al., 2023) and to rethink fire not solely as a natural process but also as a socio-political one (Moritz et al., 2014). As much as fire is influenced by physical and ecological variables, burning is also shaped by historical and environmental legacies and it is linked to social and political contexts (Berkes & Folke 1998; Copes-Gerbitz et al., 2021; Coughlan & Petty, 2012; Petty et al., 2015).

Lastly, this case serves as an example of adaptive strategies employed in the management of fire in the face of changing political circumstances, illustrating the resilience of local communities in re-establishing fire practices after conflict. It also exposes the intricate impacts of war on livelihoods. Hindering the ability of people to conduct fire-based subsistence activities is a consequence of war that has seldom been studied. Particularly when fire in these highlands represents an essential livelihood tool, a practice that is not only linked with practical and ecological objectives but also with culture. Besides its effects on subsistence activities, the Angolan civil war had multiple, long lasting and devastating impacts on those who lived through the war.

4.5 Conclusions

This study revealed the key role of war in influencing fire regimes. In the case of southeast Angola, the civil war caused a decrease in burned area during the conflict, the result of displacement of people, limited subsistence fire use, and strict fire governance. These findings highlight the crucial role that local communities have over fire regimes and their ability to alter fire dynamics despite a landscape prone to burning. Notably, the notion of increased fire activity following the war has often been viewed as exceptional, whilst it might be the decreased fire activity during the war that is exceptional. This distinction has important implications for current fire management strategies which might focus on addressing the post-war increase as a primary concern.

This study contributes to the field of war ecology by documenting and analysing the impact of prolonged conflict on fire regimes in a fire-dependent ecosystem. Whilst much of the existing literature in war ecology focuses on deforestation, pollution, and habitat degradation, this research uniquely centres on fire dynamics. This study also sheds light on how armed conflict can suppress, rather than intensify, fire activity in fire-dependent ecosystems, highlighting the need to consider human agency and governance in understanding the environmental impacts of war.

The significant contributions gained from this study on how shifts in fire governance and practices impact fire regimes and landscape dynamics highlight the importance of using field-based data collection methods. These methods offer valuable insights into how local fire management practices and human dynamics shape landscape patterns, especially in fire-prone ecosystems and post-conflict settings like the Moxico highlands. Including local perspectives is essential for understanding how communities adapt in the face of conflict, and engaging elders helps ensures that local knowledge is respected and recognised. Listening to these voices fosters more inclusive and context-sensitive approaches to research (Staddon et al., 2023), particularly when addressing sensitive topics.

Understanding the decreased fire activity during 27 years of war requires an interdisciplinary approach that bridges social science with historical ecological research, acknowledging that complex socio-ecological systems influence fire regimes. Such approach can be instrumental to adapt to future conflicts and to build more resilient socio-ecological systems.

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Chapter 5. Conclusions

The objective of this thesis was to contribute to an understanding of the socio-ecological dynamics of woodlands and fire in the highlands of southeast Angola, by bridging local ecological knowledge with western scientific approaches, in a setting where human-environment relationships are primarily governed by customary practices rather than by state governance. I approached this through multiple case studies and mixed methods research. I addressed three key themes: 1) the added value to vegetation maps when using ground-based participatory processes in addition to satellite data analyses, and the possible implications for conservation interventions; 2) the convergences between locally perceived vegetation types and floristic categorisation to define types of woodlands, and the possible implications for their management; and 3) the impacts of the Angolan civil war on fire use in the landscape, and the role of social dynamics in shaping fire regimes in my study area. In this section, I summarise the main findings from each chapter. I then present reflections from this work and recommendations for future work.

5.1 Key findings

In chapter 2 my objective was to explore the local descriptions of the landscape (focusing on wooded areas) in the highlands of southeast Angola, obtained through the use of ground-based social science approaches, and to explore the potential divergences from conventional mapping methods based on remote sensing. Maps are often used to make decisions around conservation, but maps that fail to capture the complexity of socio-ecological landscapes can undermine local livelihoods. In this study, local peoples revealed complex spatio-ecological knowledge with a classification of the vegetation that included five different woodland types and two grassland types. The vegetation types are differentiated by the density of trees, the tree species, and their fire regimes, along with the uses and products found in each, and local peoples do not make a clear distinction between vegetation cover and vegetation use. I found that combining remote sensing and ground-based methods provides a more complete understanding of the landscape, and such approach can be useful to address tensions between conservation and livelihoods.

The conventional mapping of landscapes can benefit from a socio-ecological system approach where vegetation types are understood in the context of their physical and ecological features with relation to their use by local communities. The value local peoples place on the land is shaped by their interactions with it, whether for livelihood, ecological, or recreational purposes, and these values play a crucial role in determining the effectiveness of conservation interventions. Moreover, it is the value not only of specific vegetation types, but the diversity of vegetation that makes this landscape important from a conservation as well as from a livelihoods perspective. If conservation initiatives are to be implemented in the highlands of Moxico, it is critical to consider local and regional contexts and to include the viewpoints of the land users.

In chapter 3, my objective was to improve the understanding of the vegetation in my study area, by classifying woodlands based on floristic analyses and comparing them to local classifications and to the broader context. Angola has been classified predominantly as a miombo ecosystem but miombo definitions are broad and often overlap with forest and savanna definitions. The semantic framing of vegetation classifications plays a critical role in informing conservation and management strategies. For instance, fire is a common element of savannas but not of forests.

Angola has been understudied in terms of vegetation ecology and its landscapes are more complex than previously reported. Southeast Angola has had less external influence than other regions, offering an opportunity to understand vegetation isolated from state governance and heavy anthropogenic pressure, which is otherwise common across the miombo ecoregion. I found that local classifications of vegetation align to a certain degree with scientific classifications in my study area. The locally perceived vegetation types differ in structure and floristics, and not all vegetation types in the study area were dominated by the typical miombo species, but rather by other species such as *Erythrophleum africanum*, *Burkea africana* or *Cryptosepalum exfoliatum*. Topography, fire and frost are possible drivers of these differences.

In the broader area of study (including DRC, Namibia and Zambia), my vegetation types matched diverse floristic vegetation types. Of particular interest was a group dominated by *Cryptosepalum exfoliatum pseudotaxus* that matches the description of the Zambezian dry evergreen forest ecoregion, which has not been mapped before in this area of Angola. These dry forests might be remnants of ancient forests previously extending across central Africa or, alternatively, they might only occur in certain areas due to environmental and anthropogenic factors. Based on these findings, I argue that the Angolan highlands of the southeast contain dry evergreen forests, most likely part of the dry evergreen forest ecoregion covering west Zambia. Accurate classification of vegetation types in southeast Angola is essential for effective management and conservation, as these landscapes support both biodiversity and vulnerable human populations. Furthermore, these findings suggest that the miombo region is more diverse than previously recognised, and unidentified and unique vegetation formations can occur throughout the region.

In chapter 4, my objective was to understand the role of socio-political dynamics in shaping fire regimes. Angola underwent a civil war that lasted 27 years, which had multiple and unexpected outcomes. Fire is common in the highlands of southeast Angola but changes in burned area during the war indicated a possible link between fire use and conflict. In this area, fire plays a crucial role in supporting livelihoods and influencing vegetation dynamics, and understanding how fire regimes are impacted by human activities is important in terms of fire management. I found that during the war, burned area decreased by up to 51% as a result of population displacement, a high risk of indicating one's location through fire and smoke, and strict fire governance. Livelihoods were affected by the decreased use of fire and communities had to adjust to the use of different species for firewood or to conducting farming during the night when helicopters were not flying.

Contrary to previous studies, my results identified a decrease in fire linked to war, as fire was not used as part of the war strategy. These results challenge both the idea that an obvious outcome of war is higher fire incidence, as well as the prevailing perception that ecology mainly determines fire regimes. Moreover, the perceived increase in fire events after the war have been seen as exceptional but the decrease in burning during the war might actually be the exceptional event. This is important for fire management strategies that might see the increase in fire after wartimes as an alarming event, and highlight the relevance of including local voices in the understanding of what constitutes a ‘typical’ fire regime in a specific context. Altered fire dynamics in the southeast during the Angolan civil war illustrate how socio-political circumstances influence fire regimes, and emphasize the significant role of local communities in influencing fire activity despite a landscape prone to burning. Lastly, this work exposed the intricate, multiple, unexpected and often overlooked impacts of war on livelihoods.

5.2 Implications, contributions, and learnings of this work

Taken together, the findings of this thesis demonstrate that managing landscapes like those of southeast Angola requires rethinking how we define knowledge, value land, and approach conservation. Whilst each chapter offers distinct insights, together they show that socio-ecological systems cannot be understood or governed without engaging with lived experiences and historical contexts. This work employs a socio-ecological systems framework that connects human practices and knowledge with ecological processes, hoping to contributing to more just conservation. Although many conservation initiatives now aim to be inclusive, they often overlook or marginalise local land users. Scientific research, when grounded in local knowledge systems, can play a key role in developing more effective and equitable policies.

This work argues that the landscapes of southeast Angola are more than ecological units, they are lived spaces, embedded with meaning and shaped by histories of conflict and marginalisation. The consistent presence of local ecological knowledge (LEK) across chapters challenges the notion that scientific approaches alone can offer a sufficient basis for research and conservation. Local peoples’ understanding of their landscape is not only ecologically robust but also reflects use, governance, and value systems that are often invisible to external entities. This research also reaffirms that LEK is not supplementary to science, it is a different but equally valid way of knowing that can improve the relevance, equity, and effectiveness of conservation (Reyes-Garcia, 2015; Aswani et al., 2018).

This thesis underscores the importance of a socio-ecological systems lens for understanding landscapes where ecological processes and social dynamics are deeply intertwined. Fire regimes, for example, are not merely ecological outcomes but are socially and politically constructed, shaped by war and customary governance. By showing how fire activity decreased during wartime, not due to ecological shifts but due to human choices, this work contributes to growing evidence that ecological patterns often mirror socio-political dynamics. Thus, this study highlights the agency of local communities in managing landscapes, despite colonisation, displacement, and conflict, challenging dominant narratives that see woodland and fire management as a top-down issue rather than a socially embedded practice.

In that context, this work challenges current narratives, often negative, about cultural fire use. An increase in fire events in previously non-flammable places has transformed fire into a critical issue worldwide. The common negative perception of fires, particularly in forested areas, has led to policies focused on fire suppression, often ignoring the implications for communities that have relied on fire for generations. Top-down approaches often attempt to regulate fire through uniform policies that overlook local contexts and the informal or customary mechanisms that communities use to manage fire. For example, the Congolian forests in Cabinda province in the north of Angola are likely to respond differently to the same fire policies compared to the mopane woodlands in Cunene province in the south (including the communities that depend on them). In southeast Angola, fire plays a crucial role in both livelihoods and vegetation dynamics, and contextualised (including vegetation-specific) participatory fire management is essential.

In this sense, we can learn from cultures that have long used fire as a tool. My experience in Angola challenged my own assumptions. In fire-adapted ecosystems, fire is an essential livelihood and ecosystem management tool, but it can also be destructive. Whilst local communities exercise some control over fire, they acknowledge its inherent unpredictability, accepting both the risks and benefits that come with its use. This is typical of many local knowledge systems, which assume that nature cannot be fully controlled (Berkes et al., 2000). The variable nature of fire might even promote ecological patchiness and create diverse conditions that support greater biodiversity. Local acceptance of fire's dual nature offers an alternative perspective, understanding fire as part of the landscape, especially in ecosystems where fire is an integral element.

Furthermore, this research contributes to the call for decolonising conservation and ecological sciences by documenting alternative knowledge systems and by questioning the structures that determine whose knowledge counts and whose interests conservation serves (Staddon, 2023; Yanou et al., 2023). By mapping previously undocumented dry evergreen forests, for instance, the study adds to ecological science; yet, it also challenges dominant legacies in vegetation mapping that have excluded or misrepresented these landscapes, highlighting the value of LEK.

In addition, this work contributes to growing evidence that community-led conservation can be effective. This is especially relevant in Angola, where protected area management has often relied on the displacement of local communities, whilst suffering from constant underfunding, weak technical capacity, and insufficiently trained staff (Oglethorpe et al., 2018; African Development Bank Group, 2009). The remoteness of southeast Angola, combined with the limited presence of state institutions and markets, has contributed to the preservation of local ecosystems. This preservation is also influenced by low human population densities and the relative abundance of natural resources, which have reduced pressure on the environment. Meanwhile, customary practices and local norms have played a role in regulating resource use. The communities there, though marginalised, have managed forests, savannas, and fire through adaptive systems rooted in LEK. Recognising and supporting these systems is not about romanticising the "local" (Posey, 2002), but about affirming the capacity and legitimacy of communities who have long sustained these landscapes under conditions of limited state presence.

Notably, for many local communities, conservation is not a distinct goal but a consequence of everyday practices that are inherently relational and respectful of ecosystems (Berkes et al., 2000). This embeddedness challenges conventional conservation paradigms (e.g., nature vs human dichotomies), and highlights the value of participatory and interdisciplinary approaches that engage LEK holders as equal partners in knowledge production and ecosystem management (Shackeroff & Campbell, 2007).

Ultimately, this thesis argues that conservation cannot be separated from politics. Conservation is not just about protecting trees or capturing carbon, it is about who benefits from the land and whose voices are heard. A conservation approach that ignores the relational, historical, and political dimensions of landscapes is likely to be ineffective and unjust. The contribution of this research, therefore, is an invitation to reframe the epistemologies that feed conservation interventions, and to advocate for participatory and context-based approaches that centre around those most closely connected to the land.

5.3 Limitations, challenges, and improvements

During this work, I encountered several limitations, some originating from my unfamiliarity with the study area and others arising from personal constraints. One significant limitation was my lack of familiarity with the social dynamics in the villages that served as case studies. Although I planned to employ randomised stratified sampling to interview people in the communities, cultural norms challenged such plans. With an ethical research lens, I respected these local rules, and adjusted as best as I could. But I acknowledge the possible implications of a biased sampling, for example, capturing only the views of people with power who stand closer to the *soba*. Nevertheless, to mitigate this issue, I strived to speak with as many individuals as possible until I reached saturation sampling. This sampling challenge is one of the many that researchers face when engaging with local knowledge systems. In ecology, many researchers lack training in social science methods, which complicates cross-cultural engagement and makes more difficult to navigate ethical challenges in the field (Huntington, 2000).

Language also posed a considerable challenge. Not speaking the local language meant that I often missed important nuances in communication, not only due to the complexities of real-time translation but also because language itself carries distinct cultural and epistemological worldviews. This highlights the complexities of translation, not only linguistic but also cultural and conceptual. Translation can indeed be an act that risks flattening nuanced meanings but for me, it was also an essential bridge between knowledge systems, particularly if approached reflexively (Marovah & Mutanga, 2023; Udah, 2024).

Furthermore, the difficult and isolated terrain limited my ability to work in villages that were more widely dispersed across the landscape. The prevalence of landmines in this part of Angola also restricted the locations where I could establish vegetation plots. These same spatial constraints affected the social science side of the research, limiting the diversity of community perspectives I was able to capture, revealing the limitations of conventional research models.

On a personal level, I encountered challenges with methods I was using for the first time, which concerned me regarding the quality of the initial data as I navigated the learning curve. Furthermore, whilst transdisciplinary research offers substantial benefits, it also imposes limitations on the depth of exploration within each discipline. Additionally, the range of skills I aimed to utilize proved challenging, making it difficult to excel in all areas. For instance, my skills in remote sensing are basic, and I wonder if further development in this area would have strengthened my spatial analyses. The same holds for my floristic analyses skills and my basic knowledge in the social sciences. Bridging social science methods with ecological research proved equally challenging. Future work in this place would thus benefit from interdisciplinary collaborations.

Reflecting upon my ethical standpoint, I left the study area with a sense of unease, feeling that I had not given back enough. As Gupta and Kelly (2014) observe, any attempt of giving back will inevitably be partial and incomplete. I am certain that I will never be able to fully reciprocate the kindness, time, and knowledge that these communities shared with me. Nor will I ever fully understand all the ways that my positionality shaped my experience in this place, including the products of this work. I hope that sharing meals, listening attentively, expressing gratitude and admiration to their teachings, are small forms of giving back. Whatever the case is, it is important to acknowledge the nuances of these 'exchanges' openly. Even when collaboration begins with extractive tendencies, it is still possible to shift towards more equitable forms of engagement.

In some cases, co-produced knowledge that emerges from long-term collaboration may be a way of giving back (Yanou et al., 2023). For me, that represented another challenge since at the end of my PhD, I did not have time or resources to return to my study area to share the final products of my research. Disseminating research findings must be treated as an ethical obligation (Van Blerk & Ansell, 2007) and finding ways that are accessible and useful to local communities is an essential, but often neglected, part of the research process. Instead, peer-reviewed articles are prioritised, and most likely these will be inaccessible or irrelevant to the communities from where the findings came. Moreover, the skills needed to translate, represent, and disseminate results are rarely taught in the institutions that generate the outputs in the first place (Shanley & Laird, 2002). Bridging this gap requires creativity, humility, and the willingness to engage with different ways of communicating that are relevant to local contexts (Shanley & Laird, 2002).

If I were to conduct this research again (and if some of the limitations I mentioned before were removed), I would make several improvements to this study. In terms of ecology, I would distribute the vegetation plots more widely across the landscape to capture greater ecological variation. Incorporating tree height measurements would also help to better understand the structural complexity of the ecosystem (and for this I would need a larger research team or more days in the field). Additionally, I would collect soil data at greater depths (and even recording soil depth at the different vegetation types), as this could provide more insights into the underlying factors influencing vegetation patterns. Furthermore, I would integrate structural metrics into the floristic analyses of the broader context, since structure is also important when defining vegetation types. I would also aim to improve the remote sensing models by utilising more advanced data analysis techniques, particularly regarding proxies for vegetation density and species composition, and in the case of fire dynamics, I would look deeper into ways to estimate burned area since the 1970s.

In terms of social science, I would place a stronger emphasis on adopting participatory, decolonising research approaches that centre local priorities from the start. This includes co-defining research questions with communities, recognising their knowledge systems on their own terms, and ensuring tangible benefits to participants (Marovah & Mutanga, 2023; Pritchard, 2017). Such approaches also require rethinking the project design, communication, and dissemination to build long-term, equitable partnerships beyond data collection.

My academic struggles

Beyond the struggles of the research itself, I struggled in my own academic journey, difficulties rooted in similar origins of power, coloniality, and dominant knowledge systems. I believe these personal and structural struggles have shaped not only the outcomes of my work, but the ways I understood and related to the process of knowledge production. Colonial legacies at the university are not abstract ideas for me, but rather they were lived experiences, embedded in the challenges I faced as a Mexican woman navigating academic spaces shaped by Eurocentric norms. My own positionality often led to moments of feeling out of place, where my contributions might have been dismissed or devalued. These experiences made me aware of the internalised hierarchies that continue to persist in academia, rooted in colonial histories and racialised structures of knowledge (Villenas, 1996; Sandoval et al., 2016).

For instance, expressing my ideas, writing, and presenting in a second language was a challenge. And my own experience of writing in a second language has made me more empathic towards others who navigate similar linguistic challenges in academic spaces, spaces where particular forms of expression and epistemologies are privileged, whilst others are seen as less credible or intelligent. Speaking English fluently is often treated as a baseline academic skill, yet is a sign of privilege and coloniality. The expectation to write and sound ‘like a native speaker’, or to be expected to frame my research within the strict boundaries of a specific academic field, whilst attempting for transdisciplinarity, reinforces hierarchies of whose knowledge is considered legitimate. Such linguistic and epistemological barriers shaped not only how others perceived me, but also how confident I felt in expressing ideas.

Through the realisation of this thesis, I learned that the academic journey is not a neutral nor an easy path. Like many student-researchers, I struggled to balance fieldwork, teaching, writing, working, and engaging in bureaucratic demands of an overseas student, often under conditions of financial precarity, isolation, or academic pressures. For those of us navigating these demands in a language and institutional culture not our own, the emotional and mental load is even greater. Added to this was the uncertainty of navigating across multiple disciplinary fields, without becoming a specialist in any, battling against distinct, and often opposing views, and risking falling into their contradictions. Recognising the limits of our time, energy, and capacity is not always easy, especially in academic environments where the expectations can feel overwhelming. On top of this, being challenged with the ethics of research and the [de]coloniality of knowledge production can feel like one more weight added to an already busy schedule. But this does not mean we can, or should, avoid these topics.

These tensions extended into the field, where I felt a lot of ambiguity around my own identity in terms of nationality, academic background, institutional affiliation, among other factors. This often left me unsure of where I stood, both academically and ethically. The being in-between, however, was for me a challenge as well as a space of possibility, which helped me to continuously question who holds the power to define knowledge, and which voices are centred or silenced in the process.

5.4 Recommendations for future research

There is still much to learn from this landscape. A more extensive investigation into the plant ecology of the region is necessary to fully understand its dynamics, focusing on more than just trees. Given the constraints of time and resources, I was only able to focus on the canopy layer, but the understorey is just as important, particularly in relation to vegetation dynamics and fire. A thorough study of the ecology of the understorey could also help reveal the key drivers of vegetation types in this area. Additionally, examining the role of topography in shaping vegetation could help answer questions about the factors influencing the distribution of vegetation. Moreover, expanding the number of vegetation plots, particularly in the more remote and densely vegetated areas towards the Zambian border would help understand the dry forests better. Establishing plots in locations further from human activity (if there are truly places with no humans in this area, which is unclear) could also shed light on the influence humans have on vegetation patterns, particularly shrublands, which seem to be found only around villages. It remains unclear whether shrublands naturally exist in this form or if they are a consequence of continuous cutting by humans.

One fundamental learning of this research is the lack of information about *Cryptosepalum exfoliatum* (at least in accessible English recent literature). Mapping its distribution and understanding its ecology would be an important next step. Despite being considered fire-sensitive, this species has a thick bark and, in my study area, also occurs (although does not dominate) in regions that regularly burn. Further research into the environmental conditions that allow this species to thrive or restrict its growth is needed.

In terms of fire, it is possible that the dense canopy in dry forests makes difficult to detect smaller fires via remote sensing. Thus, field-based approaches to research fire in the ground layer of dry forests are needed. Furthermore, given the significance of fire in this landscape, studying ecological succession in dry forests versus open canopies would also be important, especially in identifying which species thrive post-fire. Ground data on dense vegetation that burns (if such areas exist) could help us understand the role of fire in maintaining vegetation diversity.

From a historical perspective, it would be relevant to explore the impact of reduced fire activity on the expansion of dry forests during periods of war. As local peoples reported, the absence of fire led not only to denser vegetation but also to the expansion of forests over open savannas. Remote sensing techniques could be employed to assess changes in vegetation density and distribution, providing insights into the impact of war on environmental dynamics. Whilst war is often associated with forest degradation or deforestation, it can also result in afforestation. Investigating the spatial patterns of changes in fire regimes during the war in this area, to see if more remote areas exhibited even less fire, would also be relevant.

Finally, in any research, management, or conservation initiative, it is essential to engage local communities from the planning stage through to implementation and validation. Grounding these interactions in ethical engagement fosters trust and affirms the rights and knowledge of local peoples.

5.5 Concluding remarks

This study offers valuable insights into a lesser-known region of Angola, where limited research has explored the links between livelihoods and natural resources, particularly in rural and remote areas like the southeast of the country. In post-conflict landscapes such as this, adopting a socio-ecological lens and employing ground-based, mixed-method, ethical approaches is essential to understand how social and political spheres continue to shape both ecological and human systems.

These methods enabled me to describe different vegetation types, locate dry forests in my study area, and understand drivers of shifting fire dynamics. Participatory methods helped me reveal socio-ecological dynamics that conventional approaches frequently overlook, whilst local knowledge played a vital role in filling spatial and temporal gaps and in answering the 'why' of many of my ecology-centred research questions. Moreover, recognising convergences between local and scientific knowledge systems allowed for deeper insights into human–wooded ecosystem interactions and promoted a more integrated understanding of the landscape.

This thesis suggests that such integration must move beyond extractive practices to become a process of co-production, acknowledging local voices as legitimate sources of knowledge rather than passive data sources, and that is grounded in an ethic of listening, humility, and critical reflection (Staddon et al., 2023; Diver & Higgins, 2014). This approach challenges the often implicit human–nature divide, which can undermine the ways in which rural livelihoods actively shape and sustain ecosystems.

The learnings from this place can extend to other regions and to global nature-human dynamics. Many forest services, beyond being essential to local communities, benefit global socio-ecological dynamics (e.g., climate regulation). In many cases, these benefits emerge from long-standing interactions between people and forests, particularly where local users play a central role in maintaining biodiversity and forest cover. In the same sense, tensions between livelihood needs and conservation goals in marginalised settings might influence global dynamics. Bridging local experience with ecological research and management strategies is thus crucial for fostering more global, environmentally just and effective conservation efforts. In regions like southeast Angola, where state and market infrastructures are minimal, the agency and stewardship of local users becomes even more critical.

Whilst this work is grounded in academic research, I hope its insights extend beyond academia. Conservation and research are not neutral, they are shaped by colonial histories and contemporary power asymmetries. Whilst these dynamics cannot always be resolved, acknowledging and making them visible is a necessary step toward more just and context-sensitive approaches. In this sense, scientific work can serve as a bridge between conservation approaches and societal issues.

Finally, I believe that knowledge, of all kinds, should be valued and shared. Encouraging dialogue between ecological science, local practices, and policy can help bridge persistent divides. Ongoing research grounded in lived realities and respectful of diverse knowledge systems is thus essential in shaping more inclusive and equitable conservation futures.

Throughout this project, my journey has been one of both construction and deconstruction. Whilst building new understandings, I also had to question internalised assumptions about what constitutes legitimate knowledge and about what it means, to me, to do science. I am fortunate to continue, although in different ways, interacting with these communities and collaborating in conservation planning. This thesis, for me, serves as a reminder of my responsibility with them.

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Appendix 1.

A1.1a Participatory mapping, transect walks and surveys

Mapping

We draw a map

- a. On the ground (to get familiar with mapping). Can you draw:
    - i. The river
    - ii. The main road
    - iii. Your houses
    - iv. The church
    - v. Medical facilities
    - vi. School

VEGETATION COVER AND VEGETATION USE

- b. Using a blank piece of paper. Let's draw (as a group we will decide if we annotate the map with words, symbols, or colours):
    - i. The village
    - ii. The river
    - iii. Land cover types
    - iv. Other important features of the landscape
- c. Do you have any place for:
    - i. Recreation
    - ii. Ceremonies/traditions/sacred
    - iii. Burial grounds
- d. What are the local names for the land cover types drawn?
- e. Which of these land cover you use more frequently?
- f. Which of these you think are more important?
- g. Have these land cover types changed through time? Were there bigger, smaller or different in the past? (i.e., more or less savanna, more or less grassland, more or less water on the river)
- h. Now let's point. Where do you:
        1. Hunt
        2. Fish
        3. Collect firewood
        4. Harvest foods: Fruits, mushrooms
        5. Install beehives
    - ii. How long does it take you to get there by foot? (min)
    - iii. Why do you do these activities here? Is there anything special/unique about these places?
    - iv. Can you do these activities all year long?

WOODLAND COVER AND USES

i. Do you have different woodland types? *If yes*, what are the types of woodlands that you have? What are their local names?
j. Where are the boundaries of the woodland? How do the boundaries look like?
k. Which types of woodland do you use? What do you harvest from each type of woodland? Record type of woodland and characteristics of each type:
    i. In terms of tree species
    ii. In term of resources (provision services)
    iii. In terms of uses
    iv. In terms of state (burned, cut, diseased)
    v. Is that place able to provide what you need from it?
l. From all these places, is there one that you use more than the others? Why?
m. What would happen if one of these woodland types disappears? (point at the ones they have identified and record which ones they would be more affected if they disappear)
n. Do you think these places have changed through time?
    i. More or less trees/woodland (*size*)
    ii. More or less tree species (*diversity*)
    iii. More or less species for medicines, fruits, firewood (*resource provision*)
o. If there is not enough of a resource, what do you do? Where do you collect it?
    i. Firewood
    ii. Beehives
    iii. Hunting
    iv. Construction
    v. Charcoal
p. How do you take care of the woodland?
q. Does the woodland have all of the things you need to live?
r. If the woodland cannot provide enough resources anymore, why do you think is that?
s. Do you think there is anything you can do so the woodland will provide enough resources?
t. Is there any way that you can know that a woodland is productive? (i.e., by looking at the species present, by looking at how many big trees there are, etc).
u. Who makes the decisions about the woodlands?
v. Can everyone harvest what they need, whenever they need?
    i. In terms of quantity
    ii. In terms of frequency. *If not*, when can you harvest?
    iii. In terms of what can be harvested:
        1. Firewood
        2. Tree bark for beehives
        3. Wood for construction
        4. Hunting
        5. Foods
        6. Wood for artifacts/tools

With an aerial photograph. Localize each land cover type, including woodland types (I will record point locations on a digital map on a tablet). Discuss if there is anything they see on the aerial photograph that we have not talked before but that it is important for them.

WOODLANDS FURTHER AWAY.
Show them in the map woodlands that are less used by them.

- iv. Do you use these woodlands for any purpose?
- v. *If yes*, for what purpose? *If not*, why not?
- vi. Do these woodlands burn?
- vii. Are these woodlands different from the woodlands closer to your village?

<u>Transect walks</u>

With at least 3 key informants from each village, you will ask them to walk around the village's landscape and show different land cover types and resources. Whilst walking with them, questions will be asked.

Name: *Age:* *Female/Male:*
Occupation: *How many children do you have:*
For how long have you lived in the village:

With a GPS:

-Mark location of land cover/vegetation types
-Mark location of useful resources
-Mark location of borders between land cover/vegetation types

1. How did you acquire the knowledge about this place?

When finding different land cover types:

2. What are the main uses of this land cover?
3. What are the main characteristics of this land cover?
    a. In terms of resources. What specifically does it provide?
    b. In terms of physical structure. How can you identify this specific land cover?
    c. In terms of state (more/less used, burned, etc.)
4. What are the main uses of this land cover?
5. Has this land cover changed through time? How? Can it still provide enough resources? *If not*, what do people do to obtain what they need?
6. Is this land cover managed?
7. Are any land covers more valued than others by the people living in the village?
8. Are the boundaries between land covers clear? How to identify these boundaries?
9. Is land around the village managed? *If yes*. How is it managed?
    a. Are there any rules/restrictions for the different land covers?
    b. How are decisions made around land cover types?

Rapid survey

Sampling until saturation. Individual maps will be created, locating land cover types and uses with additional information to gain an understanding of interactions with woodlands.

Name: *Age:* *Female/Male:*
Occupation: *How many children do you have:*
For how long have you lived in the village:

VEGETATION USE

1. What activities did you do this week? What about last month?
2. *Using a map*. Where did those activities happen? Could you show me on this map?
    a. Why do those activities happen there?
    b. Could you do those activities in other places? Where?
3. Those activities are the same every day or do you do different activities each day?
4. How long does it take you to get to those places to do those activities?
5. Do those places have a local name? What are those names?
6. Do the things you can harvest from these places are different from one place to the other?
7. What is on those places that makes them different?
8. *Using the map*. Is there any place that you think is more important than the others? Why?

WOODLAND USE

9. What things can you harvest/do from the woodland? In which season?
10. What is the name for the woodland?
11. *If they have more than one name*. Why do the woodlands have different names?
12. *Using a map*. Where is each woodland type?
13. How do the boundaries between the woodlands look like?
14. *Using a map*. From which woodlands do you bring/do?
    a. Food.
        i. Mushrooms
        ii. Fruits
        iii. Insects
    b. Firewood
    c. Wood for honey production
    d. Construction materials
    e. Wood for charcoal production
    f. Agriculture
    g. Honey production
    h. Hunting
15. Why do you bring those products from there?

WOODLAND MANAGEMENT

16. Does the village have any organization on when and how to use the woodlands?
17. Do you take care of the woodland? How?
18. Can you use/take whatever you need from the woodland?

WOODLAND CHANGE

19. Has your ability to collect different products from the woodlands changed through time? Why?
20. *If yes.* What do you do if the woodland does not have the resources you need?
21. Do you think the woodland can still provide what you need for your livelihoods?
22. *If not*, do you think there is anything you can do so the woodland can provide what you need?

A1.1b Demographics of rapid survey

Table A1.1. Demographics of rapid surveys.

Village	Gender	Youth (≤25)	Middle-aged (26-50)	Elderly (>50)	Total
Sayoswa	Male	3	2	1	6
	Female	1	2	1	4
Tempue	Male	8	12	5	25
	Female	8	9	3	20
Sete	Male	7	8	7	22
	Female	7	8	3	18
Sassungu	Male	4	1	1	6
	Female	3	2	0	5
Samanunga	Male	3	1	0	4
	Female	2	1	1	4
Total		46	46	22	114

A1.2 Unsupervised classification with no fire, NDVI or TPI data layers

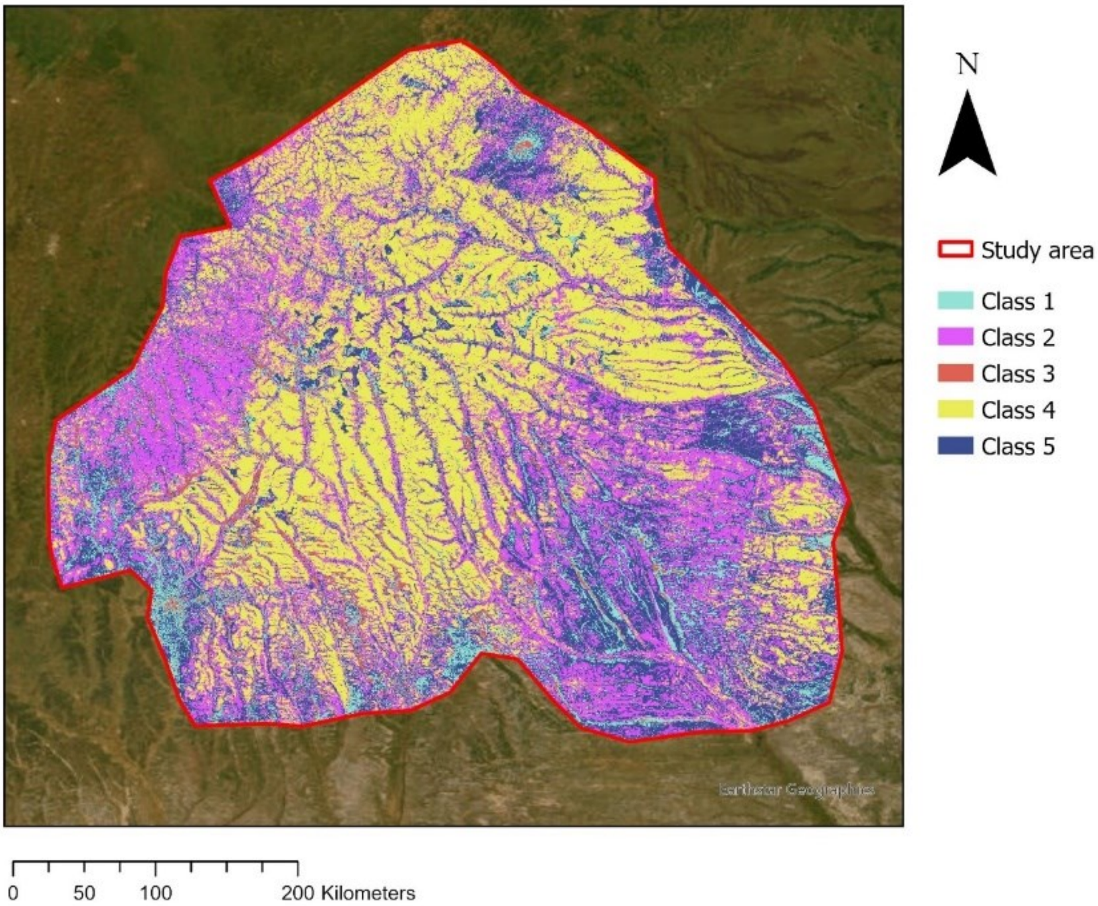


Figure A1.1. Unsupervised classification with no TPI, fire nor NDVI layers

A1.3 Graphs of relation between unsupervised and supervised classification

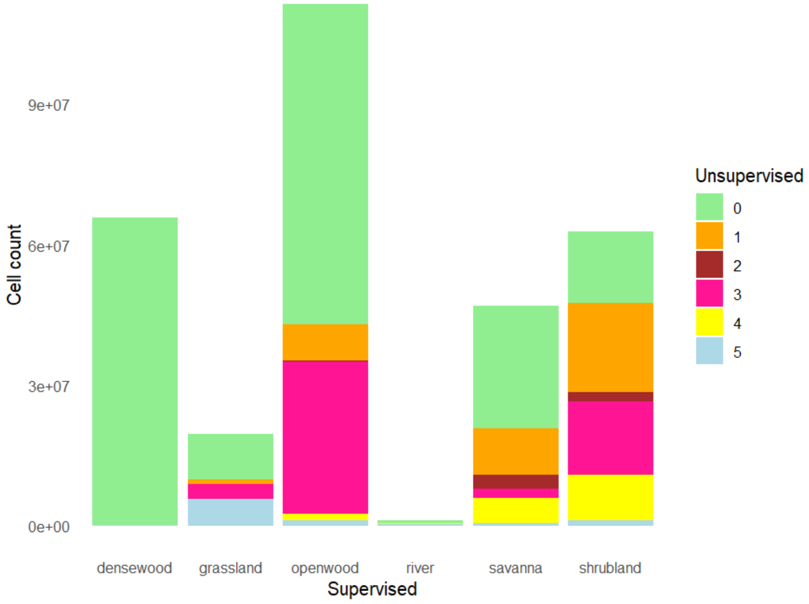


Figure A1.2. Correspondence of classes from the unsupervised classification with relation to the supervised classification

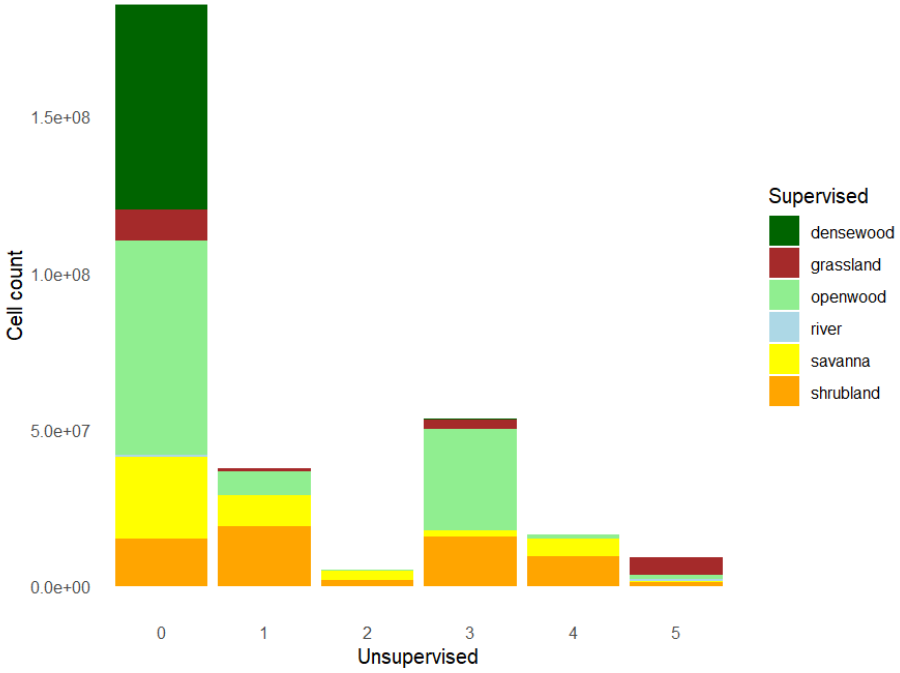
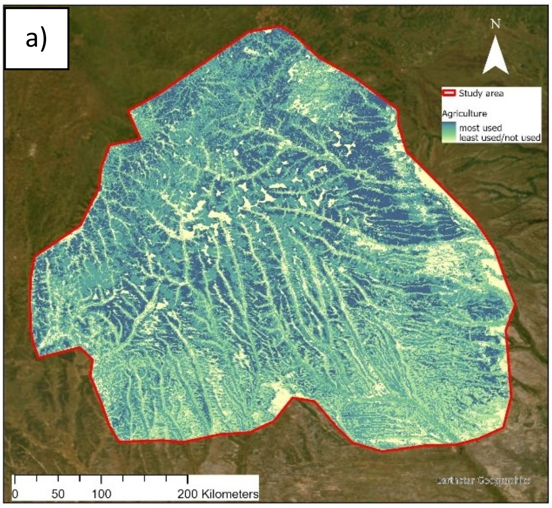
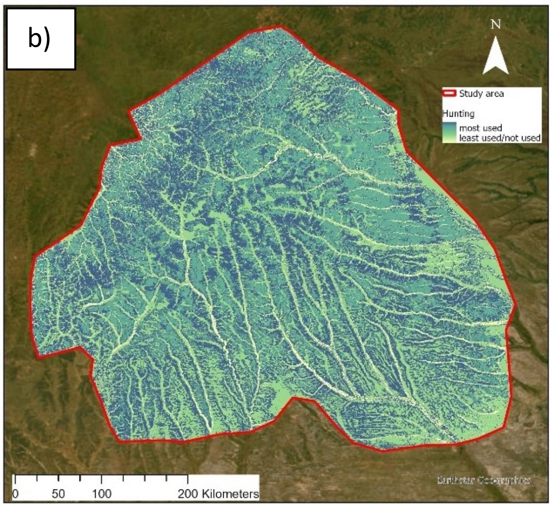
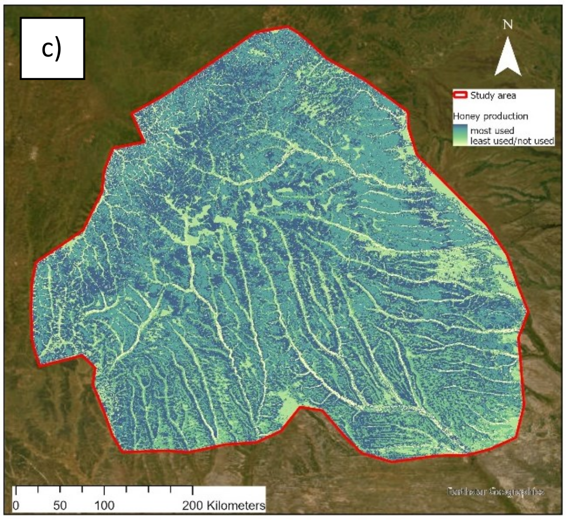


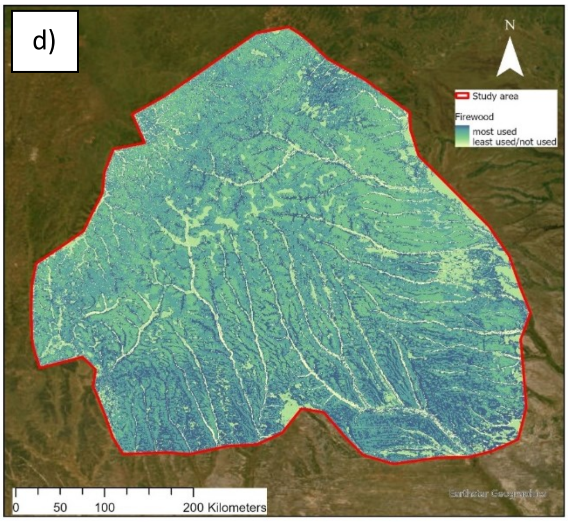
Figure A1.3. Correspondence of classes from the supervised classification with relation to the unsupervised classification

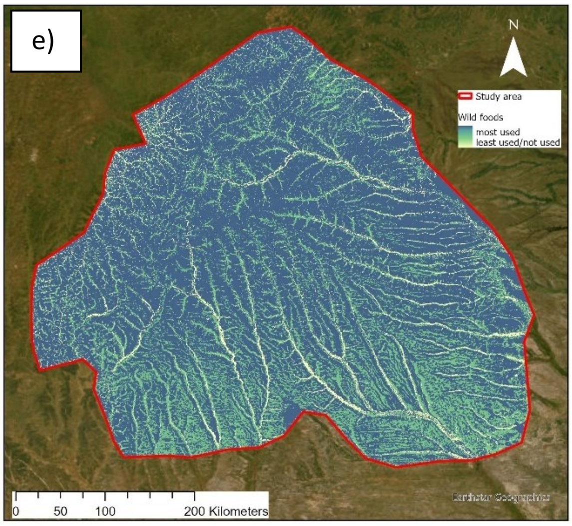
A1.4 Maps of vegetation used for each livelihood activity

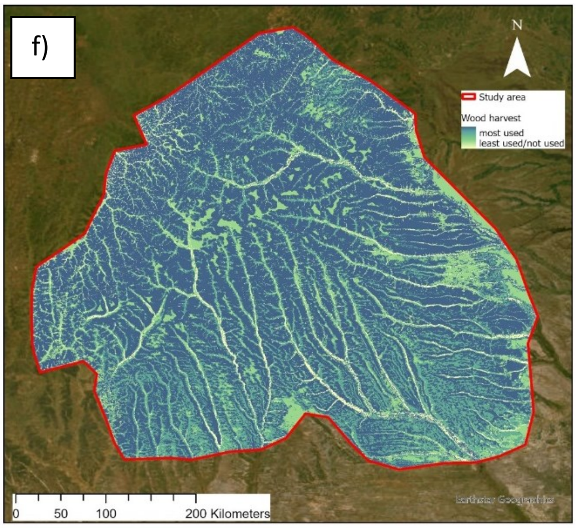












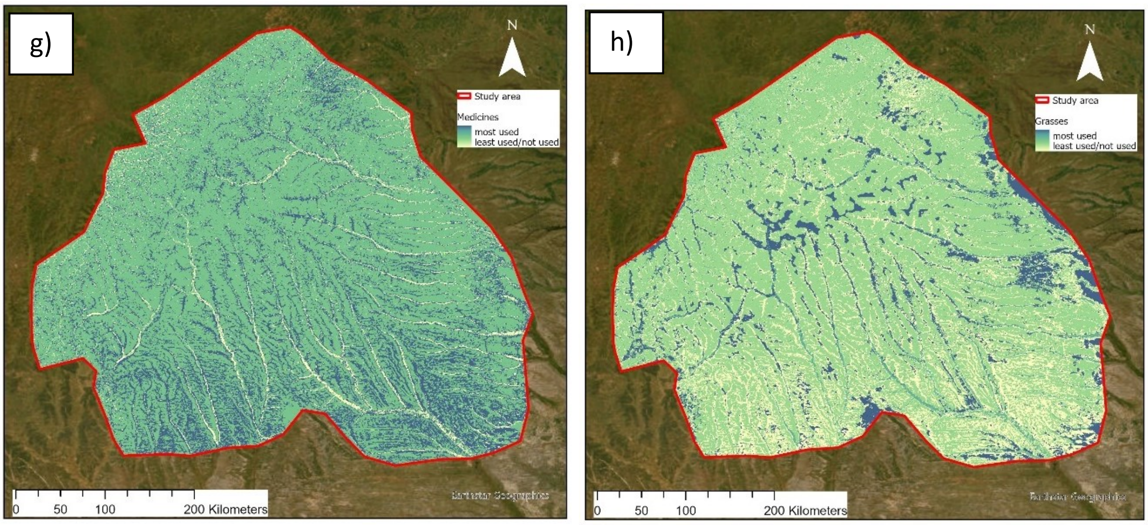


Figure A1.4. Vegetation types from most to least used for a) agriculture, b) hunting, c) honey production, d) firewood collection, e) wild food collection, f) wood harvesting for construction, artefacts, and tools, g) medicines, and h) grasses for construction.

Appendix 2.

A2.1 Stem size distribution of vegetation in the highlands of Moxico

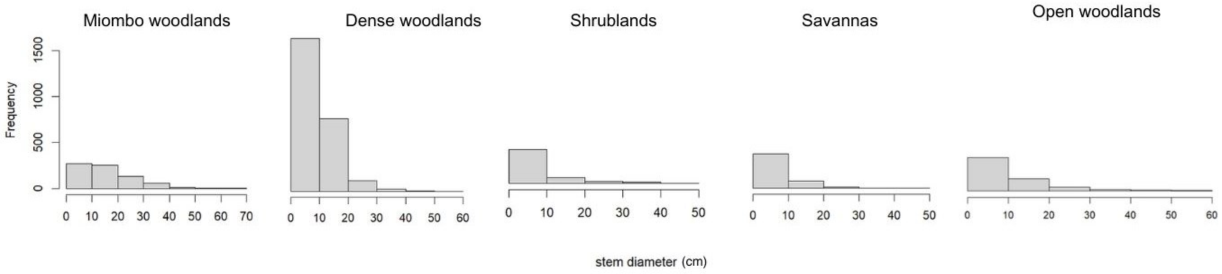


Figure A2.1. Stem size distribution plots of all five vegetation types. Miombo has the highest relative proportion of larger stems.

A2.2 Mean diameter at breast height of each vegetation type

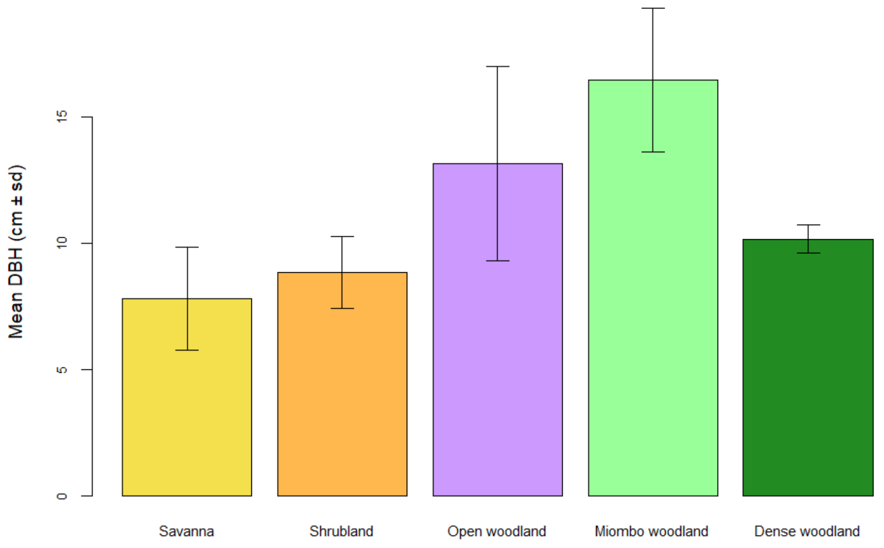


Figure A2.2. Mean DBH (cm ± sd) on each vegetation type

A2.3 Stumps and termite mounds for each vegetation class

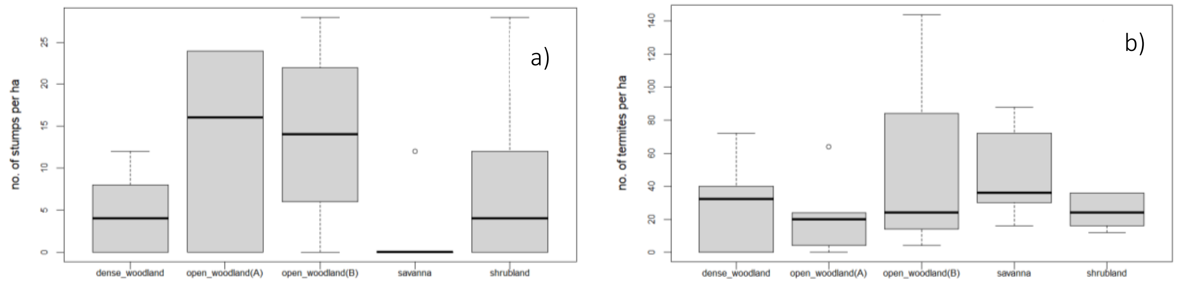


Figure A2.3. A) Number or stumps per hectare on each of the local vegetation classes. B) Number of termite mounds per hectare on each of the local vegetation classes. No significant differences among vegetation types were found

A2.4 Soil parameters of each vegetation class

Table A2.1. Soil parameters of each vegetation type.

Vegetation type	Mean sand % (±sd)	Mean silt % (±sd)	Mean clay % (±sd)	Mean pH H2O (±sd)	Mean pH KCl (±sd)	Mean nitrogen(±sd)	Mean carbon(±sd)
Savanna	95.7±1.6	1.58±0.6	2.6±1.1	4.14±0.09	3.9±0.2	0.03±0.01	0.46±0.3
Open woodland	94.2±1.6	1.85±0.5	3.9±1	4.5±0.5	3.7±0.2	0.05±0.01	1.01±0.3
Shrubland	95.3±1.1	1.34±0.5	3.4±1	4.4±0.1	4±0.14	0.03±0.004	0.47±0.06

Miombo woodland	95.7±0.8	1.32±0.6	2.9±0.8	4.4±0.2	3.9±0.2	0.036±0.01	0.63±0.3
Dense woodland	95.8±0.4	1.5±0.4	2.7±0.2	4.2±0.2	3.6±0.2	0.043±0.01	0.75±0.2

Vegetation type	Mean Mg mg/kg (±sd)	Mean Ca mg/kg (±sd)	Mean Na+ mg/kg (±sd)	Mean Al mg/kg (±sd)	Mean K mg/kg (±sd)	Mean eCEC (±sd)
Savanna	1.52±0.8	2.82±1.8	0.13±0.01	20±3.8	7.1±2.2	2.7±0.4
Open woodland	4.3±1.9	12.45±10.6	0.13±0.05	25±10.5	15.2±4	4.2±0.5
Shrubland	2.2±1.6	3.06±2.3	0.11±0.04	17.2±1.6	9.5±3.6	2.5±0.3
Miombo woodland	6.7±5.7	15.6±10.7	0.11±0.03	14.6±3.7	9.4±2.2	3.2±0.8
Dense woodland	3.02±1.1	3.9±1.2	0.17±0.16	20.1±3.4	10.9±3.6	2.9±0.5

A2.5 Tree species found in my study area

Table A2.2. Species found in plots in the Angolan highlands. Stem diameter and basal area are the mean of all stems with standard deviation. Number of stems per hectare is the calculated mean of the number of stems in one hectare, extrapolated from the 50x05 plots.

Family	Species name	Mean stem diameter ± sd (cm)	Basal area ± sd (m^2/ha)	N stems	N stems/ha
Annonaceae	*Xylopia tomentosa*	5.9 ± 1.6	0.03 ± 0.04	11	11 ± 11.49
Apocynaceae	*Diplorhynchus condylocarpon*	12.3 ± 7.2	0.31 ± 0.4		62.59 ± 87.01
Cesalpiniaceae	*Erythrophleum africanum*	9 ± 4.1	1.16 ± 0.8	414	72 ± 43.50
Chrysobalanaceae	*Parinari curatellifolia*	13.5 ± 7.5	0.66 ± 1.01	66	24 ± 37.35
Clusiaceae	*Garcinia huillensis*	15.2 ± 10.3	0.06 ± 0.07	16	8 ± 9.80
Combretaceae	*Combretum collinum*	11.2 ± 5.5	0.06 ± 0.04	42	12 ± 10.05
	Combretum molle	19.3	0.23 ± 0.36	19	19 ± 22
	Combretum indet 4	9.3 ± 5.5	0.43 ± NA	1	4 ± NA
	Combretum indet 5	7.7 ± 3.2	0.06 ± 0.07	4	8 ± 5.66
	Combretum zeyheri	5.1 ± 0.2	0.06 ± 0.06	22	11 ± 7.33
	Pteleopsis anisoptera	7.7 ± 2.8	0.28 ± 0.30	23	30.67 ± 29.48
	Terminalia brachystemma	10.8 ± 5.5	0.17 ± 0.24	78	24 ± 29.21
Dipterocarpaceae	*Monotes africanus*	15.8 ± 11.1	0.29 ± 0.28	107	38.91 ± 45.05
	Monotes dasyanthus	8.9 ± 4.3	0.57 ± 0.7	59	19.67 ± 15.11
	Monotes indet 2	7.3 ± 3.7	0.05 ± 0.04	9	7.20 ± 7.16
Ebenaceae	*Diospyros batocana*	7.3 ± 2.7	0.84 ± 0.94	178	47.47 ± 34.47
	Diospyros pseudomespilus brevicalyx	7.5 ± 2.6	0.29 ± 0.22	60	60 ± 37.95
Euphorbiaceae	*Maprounea africana*	8.8 ± 4.4	0.02 ± 0.02	6	8 ± 6.93
Fabaceae	*Albizia adianthifolia*	11.4 ± 13.1	0.01 ± NA	1	4 ± NA
	Albizia antunesiana	6.9 ± 1.8	0.44 ± 0.56	10	20 ± 16.97
	Baphia massaiensis	10.7 ± 6.2	0.24 ± 0.18	91	60.67 ± 45.78
	Bobgunnia madagascariensis	9.7 ± 3.7	0.18 ± 0.17	59	15.73 ± 8.61

	Brachystegia bakeriana	10.9 ± 6.5	0.76 ± 1.26	89	89 ± 141.28
	Brachystegia longifolia	18.8 ± 12.4	0.89 ± 0.78	159	70.67 ± 74.03
	Brachystegia spiciformis	9.6 ± 7.6	3.48 ± 3.6	175	87.50 ± 91.80
	Burkea africana	7.8 ± 2.6	0.73 ± 0.69	355	61.74 ± 85.31
	Copaifera baumiana	9.9 ± 4.8	0.01 ± 0.004	3	6 ± 2.83
	Cryptosepalum exfoliatum	11.7 ± 9	4.49 ± 5.4	1635	467.14 ± 634.85
	Dalbergia spp.cf.	6.5 ± 0.8	0.07 ± 0.11	14	11.20 ± 13.97
	Dialium englerianum	12.5 ± 8.3	0.51 ± 0.46	139	29.26 ± 21.38
	Guibourtia coleosperma	7.1 ± 2.7	0.64 ± 0.58	67	24.36 ± 21.50
	Julbernardia paniculata	6.6 ± 1.9	3.75 ± 3.20	221	98.22 ± 54.37
	Pterocarpus angolensis	8.9 ± 2.9	0.11 ± 0.1	93	20.67 ± 20.59
Hypericaceae	*Psorospermum febrifugum*	5.3 ± 0.4	0.009 ± NA	1	4 ± NA
Lamiaceae	*Vitex madiensis*	6.9 ± 1.7	0.024 ± 0.01	7	3 ± 1
	Vitex doniana c.f.	7.5 ± 2.2	0.01 ± NA	1	4 ± NA
Loganiaceae	*Strychnos cocculoides*	8.9 ± 4.3	0.090 ± 0.117	28	14 ± 16
	Strychnos pungens	10.1 ± 3.8	0.026 ± NA	2	12 ± NA
Melastomataceae	*Warneckea sapinii*	6.1 ± 1	0.036 ± 0.027	24	11.50 ± 9.67
Myrtaceae	*Syzygium guineense*	8.3 ± 4.7	0.273 ± 0.509	37	29.60 ± 48.46
Ochnaceae	*Ochna pulchra*	11.8 ± 1.6	0.090 ± 0.092	59	16.86 ± 15.78
Phyllanthaceae	*Hymenocardia acida*	19.49 ± 10.3	0.260 ± 0.564	98	56 ± 125.28
	Pseudolachnostylis maprouneifolia	5.4	0.387 ± 0.357		20.44 ± 11.04
Picrodendraceae	*Oldfieldia dactylophylla c.f,*	16.6 ± 8.8	0.089 ± NA	2	8 ± NA
Polygalaceae	*Securidaca longipedunculata*	8.3 ± 3.6	0.078 ± 0.059	20	16 ± 12
Rubiaceae	*Psydrax kraussioides*	6.5	0.198 ± NA	22	88 ± NA
	Psydrax indet 2	9.9 ± 4.7	0.013 ± NA	1	4 ± NA
	Rothmannia engleriana	6	0.041 ± NA	3	12 ± NA
	Vangueriopsis lanciflora	6.9 ± 1.8	0.071 ± NA	1	4 ± NA
Sapotaceae	*Chrysophyllum bangweolense*	28.1 ±	0.029	1	4
Uapacaceae	*Uapaca nitida*	15	0.122 ± 0.190	16	10.67 ± 9.00

A.2.6 Diversity metrics for the vegetation classes

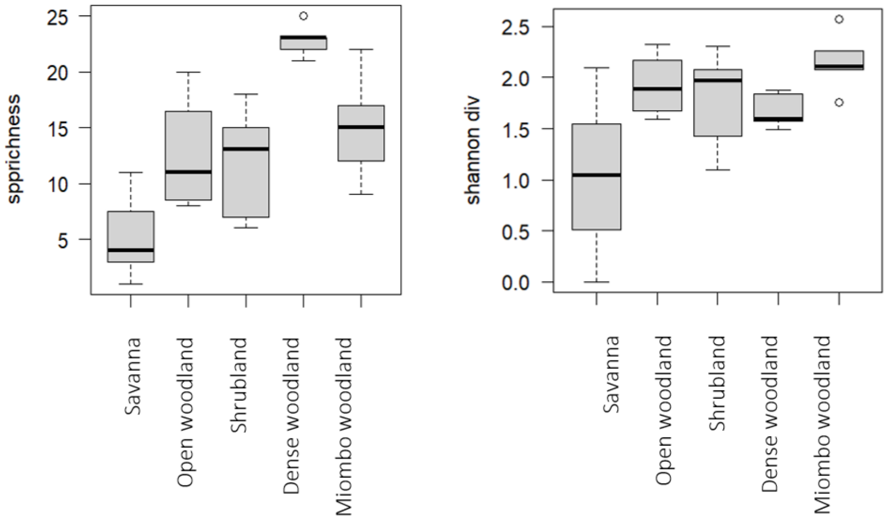


Figure A2.4: A) Species richness and b) Shannon diversity of vegetation classes. Dense woodlands have the highest species richness but miombo woodlands the highest Shannon diversity.

Appendix 3.

A.3.1. Data validation between MODIS and AVHRR-LTDR datasets

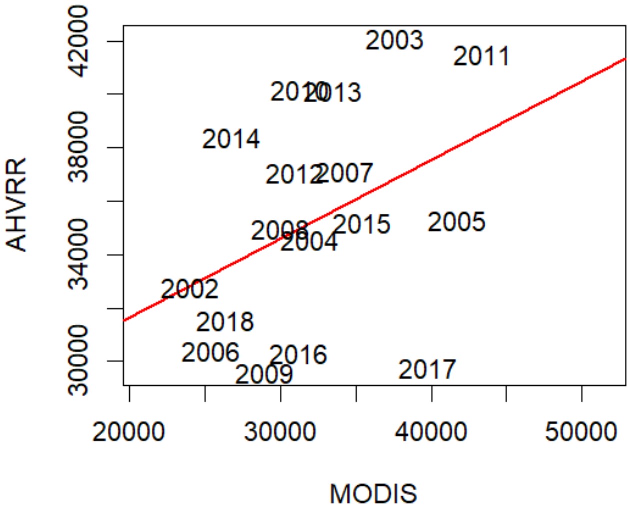


Figure A3.1. Data validation between MODIS (Giglio et al., 2021) and AVHRR-LTDR (Chuvieco et al., 2020) datasets.

A.3.2 Interviews with elders regarding past and present fire use

Personal Information

What is your name?
How old are you?
Where are you from? Were you born here?

Experience with Fire

Have you had any direct experience with fire?
Are there different types of fire in the area where you live? What do you call them?
Are there different types of fire at different times of the year?
Have you noticed any changes in fire patterns in recent years? If yes, why do you think this has happened?
Is the population growing? Does the increase in people in the village result in more fires?

Thinking About the Past

Have you always lived in this area? If not, where did you come from? Why did you move here?
Were you here during the war?
Were people and communities displaced or forced to flee during the war?
What kind of military forces were present in this territory, and when? What did they do?

Reconstructing Key Historical Moments with Participants

Portuguese colonial rule
War of Independence (First war)
Post-independence civil war (Second war)
Civil war after the Bicesse Agreement and 1992 elections (Third war: UNITA-MPLA)
End of the civil war (2002)
Were there changes during these periods in how people used fire or managed natural resources?
Was fire used as a military strategy (e.g., bombings, intentional fires by government or UNITA forces)?
During the war, were some of the fires caused by military activity (bombs, intentional fires set by enemy forces or UNITA)?

Traditional vs Current Fire Practices

In the time of your grandparents, was the way people used fire different? How?
How did you learn to use fire in the landscape?
If fire use has changed since your grandparents' time, why do you think that change has happened?
What do people use fire for today in your community (e.g., agriculture, honey collection, hunting)?
Are there any community rules or agreements about when and where fire can be used?
Do you think fire is still important today? Why or why not?

Local Names and Classifications

What are the names for different kinds of fires in Luchaze?
Do you still make firebreaks?
What about fires at the beginning of the dry season?
Fires in the middle of the dry season?
Fires at the end of the dry season?
Why do these fires have different names?
Do people still carry out all these types of burning?

Understanding Fire and Displacement

Where did people flee to during the war?
Where did people still burn during the war?
Where was burning no longer possible?
In which areas were fire practices different during the war compared to now?