Conservation of Threatened Plant Species in Makueni Through Community Mobilization

Technical Report submitted to the Rufford Foundation and National Museums of Kenya Library

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[1,*]Munywoki J. M, [2]Malombe. I, [3]Kathambi. V & [4]Munywoki G. N. (2021). Conservation of Threatened Plant Species in Makueni, Kenya, through Community Mobilization. Technical Report, East African Herbarium.

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Cover Photos: Thumbnails: From top anticlockwise

Millettia vatkei P.K. Lôc

Euphorbia friesiorum (A. Hassl.) S. Carter

Pavetta teitana K. Schum

Thunbergia napperae Mwachala, Malombe & Vollesen

Center-Identifying perceptions of the locals (top left), Residents of Ngutwa-Nzaui (Top right), Representatives of various groups within Ngutwa-Nzaui area (bottom).

Design & layout: J. M. Munywoki

Illustrations by: J.M. Munywoki unless otherwise stated

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Dedication

to

The late Daniel Mutio Ndutu (Mulevu) (1893 – 2013) (Grandfather to the first and fourth author) as a humble homage to a great hero, a man of valor in thought and deed, and whose life was a blessing to many

and

all the participants in the quest for a sustainable society.

Acknowledgment

Conservation work is never a product of one person's effort, and as such many people, either consciously or unconsciously, contributed to the production of this project report. A few of these are mentioned here; however, all those not, should feel that their role(s) were also crucial and appreciated.

Of particular mention and appreciation is the Rufford Foundation (United Kingdom) for providing funds for this conservation project. I also thank the National Museums of Kenya for facilitating this noble course by hosting the project and Kenya Forest Service (Makueni) for permitting entry to Nzaui Forest.

I owe special thanks to project team members Dr. Malombe for the guidance throughout the project, Mr. Eric Mwakavi, Jones Muindi and Dominic Masila for acting as conduits to the locals of the Ngutwa-Nzaui area. I sincerely thank Vivian Kathambi and Gilbert Munywoki for the great work and contributions towards the final project report. To my mentors scattered globally and my referees, Dr. S. Makindi, Dr. Kisangau, and Mohamed Hamdy Amar to whom my research interests were met, your invaluable contributions were the linchpin of the project.

My sincere appreciation goes to all the informants and representatives of the various community-based groups for offering unfailing support through in-kind contribution that made this project successful.

I do not have the words to express my immeasurable gratitude to my family for encroaching their time during project implementation. Your inspiration and concern not just for the family's wellbeing but for the project were unparalleled. To you all, I say thank you.

Also, the lead author is indebted to those at different points in the evolution of this project report, offered critique or new perspectives, and especially to Michael Ndadema for analysis of land use and cover changes within the Ngutwa-Nzaui area using Geographic Information system (GIS) and remote sensing.

Executive Summary

Even though trees and the forests they form represent a crucial part of Kenyan lives, little is known about the part of biodiversity consisting of the rarest and most threatened plant species. Threatened plant species across southeastern Kenya have received frustratingly low attention compared to Afromontane and coastal dry forests. This served as the source of motivation for the present study.

Land use and land cover within the Ngutwa-Nzaui have substantially changed from 1987 to 2020. The main land use/land cover in the area include 47% scrubland (186.06km^2), 21% cropland (84.55km^2), 14% barren land (55.21km^2), 12% forested land (46.42km^2), 5% built-up area (19.95km^2) and 1% water bodies (3.27km^2). Further, between 1987 and 2020, the area has experienced an exponential increase in built-up areas (3594%) and cropland (271%), perhaps leading to loss of forest and scrubland by 43% and 21%, respectively. Although water bodies have increased by 175%, bare lands have shown a slight increase of 3%. Among the three decades, 2000-2011 encountered the highest percent change occasioned by the prevalent drought incidences. Of importance to note here is an increase in forest cover within the last decade, highlighting the significance of devolved system of governance and the role played by the Makueni County Government towards the set national target of 10% forest cover and climate change mitigation.

The locals of Ngutwa-Nzaui perceive the provision of water, firewood, timber, poles, pasture, and charcoal production as their most important reward from their environment. According to them, these ecosystem goods and services will remain important in ten years as they are today. In terms of relative importance within Ngutwa and Nzaui areas, water provision is highly ranked at 15% and 20%, respectively. This observation underscores the role of water in the lives of both animals (people included) and plants in the area. An average of 5.3Km^2 water cover were created annually between 1987 and 2020, explaining the government's efforts in water provision to the locals as evidenced by a 175% increase for the same time window. The local's perception of cultural and support ecosystem goods/services as less essential, demonstrates their increased destruction of sacred groves and biodiversity habitats within the area. As an outcome of their perception and attitudes towards the ecosystem, the overall project threat rating was found to be very high. Similarly, crop farming, herbivory, and over-exploitation were rated very high, confirming their contribution to the target species' declining subpopulations. On a fine scale, threat summaries across targets indicate *M. vatkei* being very-highly threatened, similar to *T. napperae* and *E. friesiorum*. Besides, *P. teitana* is rated highly threatened. Because of these threats, the target species within the study area has declined, with only 7 *T. napperae*, 15 *E. friesiorum*, 15 *M. vatkei*, and 19 *P. teitana* subpopulations being recorded during the mapping exercise.

Adoption of modern technologies within the study area was found to be relatively low, with some locals still using traditional technologies or practices to raise and manage seedlings. Some of the documented traditional practices of relevance to the study included perforated basins sealed with

polythene film used as propagator, empty milk packets/tins (sleeves), mosquito nets (shade nets) among others. The study built upon these existing traditional practices and established a non-mist propagator made of poly-tunnels. This was appropriate to the locals' needs because it requires no electricity and minimizes water loss. Its use in the propagation of *M. vatkei* achieved 87% germination. At the time of this report, 2528 *M. vatkei* seedlings had been restored through enrichment, re-introduction, and translocation strategies. Additional 200 bare-root seedlings (from natural regeneration) were also used for similar efforts within the study area.

The locals' awareness of the target plant species was low, with most of the young generation unaware of the target species. The elderly appeared much informed than the youth especially on the local names and uses of the target species. Over 500 locals were sensitized on the importance of conserving biodiversity, with 106 of them trained on propagation protocols. The outcomes of *M. vatkei* propagation and restoration are crucial in implementing similar recovery efforts for *T. napperae, P. teitana*, and *E. friesiorum*. Further, there is the need for an increased intergenerational exchange as a way of encouraging environmental stewardship in schools and businesses. There is also the need to carry out resource mapping especially in sacred sites and socio-economic research on priority indigenous wild fruits (IWFs) in the area with high potential for economic and nutritional benefits. Also, a quick guide to the rare and threatened plants of the area including wild crop relatives and their cultural uses is crucial for enhanced awareness.

Preface

The tension between biodiversity and development within Makueni County has existed for long with historical habitat loss being the main threat. Much of the vegetation has been lost, and thus the existing endemic, rare and threatened plant species hangs by a thread. Conservation efforts are frustratingly low against a sustained tide of threats to this biodiversity. This study records some inspiring motivations for conserving threatened plant species by actively engaging the local community. Therefore, it showcases successful and inspiring stories applicable to the conservation of threatened plant species in semi-arid areas.

This report chronicles the remarkable journey throughout the project cycle and therefore it is a storehouse of experiences, lessons, and insights that may guide similar efforts elsewhere. It strives to give voice to dryland people whose perceptions and knowledge of their environment have often been neglected in decision-making processes. Drylands usually play an unsung role in the provision of ecosystem goods and services, and thus many perceive them as hotspots of land degradation, social conflicts, and poverty. They are the largest biome complex on earth, whose importance is traceable in the earliest civilizations. Although they cover 80% of Kenya's land area, they have attracted less attention compared to Afromontane and Coastal dry forest. This background serves as the source of motivation for the present study.

The past decade has seen a renewed interest among conservationists, donors, and researchers in drylands biodiversity. As many plants continue being threatened to extinction by climate change and other threats, many approaches have emerged in an attempt to arrest the situation. While some have yielded substantial success, others have miserably failed, eliciting fears of an accelerated species loss. These multiple experimental approaches towards conserving dryland's imperiled flora have been likened to "*opening Pandora's box*." Therefore, approaches to conserving threatened plants should be chosen with caution. Mapping threatened plant species has been viewed as a double-edged sword, facilitating conservation and at the same time motivating biopiracy and outlawed trade. Such challenges are not new within the Ngutwa-Nzaui area, which has witnessed increased *Aloe* species and East African sandalwood poaching. Engaging the local community who are aware of their surroundings and nature's resource users holds the key to conserving these threatened plant species.

This report is designed as a vehicle for sharing experiences from engaging the locals in the conservation of the target threatened plant species. I have always believed that the existence of a relatively large number of rare and/or threatened plant entities is partly due to people's cavalier attitudes and behaviours to their environment in the past and today. The approach adopted by this study best captures the words of William Lund "*We study the past to understand the present; we understand the present to guide the future*." Of interest is the section in this report that summarizes such experience through Geographic Information System (GIS) and remotely sensed data that helped understand contemporary situations and offered guidance for the future. Understanding the local community’s perception is another vital aspect of this conservation effort. Knowing what they do and incorporating some of such practices encourages fast adoption of the project activities.

Conservationists have always used multiple approaches when entertaining threatened plant recovery projects. In this regard, this study adopts a three-step strategy (reinforcement, re-introduction, and translocation) to maximize the survival success of the target species. Hidden under these strategies is an emerging paradigm of ‘*conservation-cum-restoration*’, which presents a compelling subtext of this project. Although many references are made throughout this report regarding the conservation of threatened plants, the restoration part tackles the subject head-on. The use of threatened plant species to restore partially degraded areas (conservation that meets restoration) is a hot topic whose application has sparked controversy. This idea is relatively new among conservationists and thus less used. Those flatly opposed to it term the approach as “*opening Pandora’s box*.” Those from the same camp express their fears of increased species loss occasioned by uncertainty.

However, the debate on which approach to use as a solution or an alternative adds another wrinkle to the conservation of threatened plant species within drylands. Virtually all conservation projects are fraught with challenges, so conservationists’ discretion is encouraged. This project report is a story of hope and inspiration, demonstrating that determination, knowledge, and local’s engagement can restore our natural heritage and reward the future generation a world as diverse and healthy as that bestowed on us by the past generation.

Lead Author,

Munywoki, Justus Mulinge.

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CHAPTER ONE: PROJECT ORIENTATION

1.1 Introduction

Biological diversity (simply *biodiversity*) is the variety of life on earth in all forms and interactions. It forms the web of life we rely on for survival (Cardinale *et al.,* 2012). McMichael *et al.* (1999) observe that biological diversity is the foundation of human civilizations. It is usually considered at three levels: ecosystem, genetic, and species diversity. At the ecosystem level, drylands are the least appreciated terrestrial ecosystems. Despite this, they are estimated to cover about 41% of the world's land area (Cherlet *et al.,* 2018) and include 35% global diversity and 20% of plant diversity hotspots (White & Nackoney, 2003; Davies *et al.,* 2012). Globally, drylands sustain an estimated 2 billion people, of which about 90% of them are in developing countries (F.A.O, 2019). In Africa, drylands account for 43% of land area, half of the population, 70% cropland, 66% cereal production, and four-fifth livestock holdings (Cervigni & Morris 2015). About 47% of the land (328 million hectares) in Eastern Africa is dryland, an equivalent of 5.3% of the global drylands (FAO, 2019). At a localized scale, more than 80% of Kenya's total land surface is Arid and Semi-Arid Lands, supporting more than one-third of her population (Barrow & Mogaka 2007).

Drylands sustain one-third of the global conservation hotspot areas and about 28% of endangered species; 71 endemic dryland species are critically endangered, 200 and about 500 dryland species are endangered and vulnerable, respectively (Davies *et al.,* 2012). Although it is widely believed that dryland communities have deep-seated knowledge of their environment and are better positioned to conserve threatened plants species and their habitats, their ability to do so is hindered. Developments projects in these areas are designed to suit the interests of the few elites rather than the local community's needs. Similarly, the roles of rare and threatened plant species in providing ecosystem goods and services have been questioned, and thus, fewer considerations in decision making and resource management policies.

Usually, rare, or endemic species are thought to play lesser functional roles than common species (Cardinale *et al.,* 2006; Naeem, 2012). As per mass ratio theory, rare species contribute less services because of their restricted geographic ranges and small populations. Although they may not grab much attention when viewed through this lens, they are the most targeted ones in biodiversity conservation (Garnett *et al.,* 2011). According to Lyons (2005), the contribution of rare species is crucial, yet it has attracted fewer studies. This lack of information concerning rare and endemic plant species has threatened their survival, especially in drylands where inhabitants solely rely on natural resources. Dryland communities have fewer choices of livelihoods; a problem worsened by limited access to markets. As a result, they have continued exerting more pressure on these resources for their income and subsistence needs. Indigenous knowledge plays a crucial role in conserving rare/threatened plants in drylands. Although information of threatened plant species in arid lands is limited, some of these plants are safely conserved through traditional land use and cultural practices. Traditional knowledge systems in arid lands have remained intact due to under-development and thus continue playing a pivotal role in conserving these rare and threatened plants. There is this perception among local communities that some conservation efforts conflict with their needs. Such challenges can be solved by empowering dryland communities to participate in decision-making processes. Reconciliation of these obviously competing uses is pegged on public policy decisions, but science also plays a crucial role.

Against this background, many conservation efforts fail, because they are initiated without the involvement of the local communities. Worse still, the locals are unaware of the importance of conserving biodiversity, especially the threatened ones, which they perceive to contribute less to ecosystem goods and services. Although it is undeniably true that threatened plants are safer in protected areas, there are glaring observable threats to those falling within private and communal lands. Although this study covered a protected area, it placed much focus on unprotected areas within the study area. Here, the suitable habitats have been degraded to a point where their conservation can only be part of an integrated approach to foster sustainable economic and social development. In many instances, the drivers of biodiversity loss are traceable to a history of well-intentioned yet misguided interventions and practices. Therefore, this study was hinged on past scenarios and thus approached the conservation of threatened plants in arid lands in a somehow similar and slightly different strategy that placed locals, the end-users of natural resources, at the center of its activities. It studied the past to understand the contemporary situation of the study area and that guided the future activities. Under the precepts of the Convention on biodiversity, sustainable conservation of drylands biodiversity heavily relies on our collective ability achievable by mobilizing the local community.

1.2 Research Objectives

Therefore, the study's main goal was to conserve threatened plant species in Makueni county by mobilizing the locals. The long-term goal is to maintain viable populations of threatened plants while at the same time having fair and equitable sharing of ecosystem benefits. However, under this general framework, the study was specific to the following threatened plant species; *M. vatkei, E. friesiorum, P. teitana*, and *T. napperae* occurring within Ngutwa-Nzaui landscape, a relic *combretum* wooded grassland in the Makueni sub-county.

1.2.1 Specific Objectives

(1) Collection of Baseline Information

A descriptive cross-sectional assessment of the study area and the target species was undertaken to gather more information on the status quo. This formed the information base against which project success or progress was tracked. Although the project used lumped targets of four focal threatened species, *M. vatkei, E. friesiorum, P. teitana*, and *T. napperae*, to pilot the study, its priority species was *M. vatkei*. To gather detailed information on the current situation of the area and the target species, the following assessments were done; -

(a) Assessment of land use and land cover changes (LULCCs) within Ngutwa-Nzaui area from 1987 to 2020 using geographic information systems (GIS) and remotely sensed data.

(b) Assessment of the local community perception of their environment. Here, the study sought not to examine their perception of the target threatened plant species in isolation but within a broader framework where their attitudes and preferences are relevant in devising sustainable conservation measures.

(c) Mapping the spatial distribution of *M. vatkei*, *E. friesiorum*, *P. teitana*, and *T. napperae* as well as documenting threat information, indigenous technologies, and practices used in propagating seedlings. This laid the foundation for the second objective of the project.

(2) Mass propagation and restoration of *M. vatkei.*

After studying the past and understanding the present (current situation), community-centered conservation of *M. vatkei* and its habitats was born. The study built upon already existing traditional technologies in the propagation of the *M. vatkei* and subsequent restoration.

(3) Creation of Awareness on the importance of conserving the target species and building the local capacity in plant conservation.

This sought to make the locals understand the importance of biodiversity. For sustainability, the study strengthened the local's capacity through training on the identification, seed collection, propagation, and, importantly, nursery management.

CHAPTER TWO: BACKGROUND INFORMATION

2.1 Conceptual Framework

Any human effort worth recognition should express the axioms upon which it is founded. Therefore, a critical aspect of biodiversity conservation is making good decisions backed by science (Cook *et al*., 2013). Today, conservation is under triage because of the various challenges associated with the allocation of the available resources. We are witnessing increasing efforts (deliberate or otherwise) abandoning imperiled species to extinction and channeling resources to species with higher survival probabilities. This has seen drylands suffer the most because they are perceived as wastelands. The proponents of conservation triage argue that some extinctions are unpreventable, and of importance is allocating limited and fully fungible resources based on return on investment (ROI). However, this view of conservation as an economic problem does not sit well with the opponents who firmly believe species recovery is possible regardless of how few individuals remain. Knowledge of which path to pursue on this crossroad of conservation triage is imperative.

There is significant uncertainty on which approach to use in decision-making and prioritization of conservation efforts. When such decisions entail conserving threatened species or key biodiversity areas, the confusion is even more remarkable. Coarse-filter and fine-filter concept (The Nature Conservancy, 1982) is one of such approaches available in the toolbox of conservation frameworks for the project. While coarse filter seeks to conserve higher-order aggregations of species (plant and animal communities), the fine-filter approach, on the other hand, focuses on the individual species. It was initially envisioned that 85-90% of the global species would be conserved by taking care of their communities in the coarse filter approach. Although most species were expected to be conserved, some would inevitably be overlooked and thus face threats that might lead to their extinction. A complementary approach, a fine-filter approach, was established to arrest the situation. Since its inception, the concept of coarse/fine filter has evolved to great applications in conservation planning today.

Coarse filter conservation approach to species assemblage has been recognized as a good way of using limited resources (Bottrill *et al.* 2008) because conservation of a single species has been perceived as expensive (Metrick and Weitzman, 1996). Protection was the oldest approach used in conserving species and their habitats; however, it does not guarantee long-term success (Hannah *et al.*, 2007; Heywood, 2015; Volis, 2015). Though passive restoration is crucial in maintaining natural processes, viable populations, and insulating species and habitats from human-induced disturbances (Volis 2015), it is not immune to climate and invasive species threats. Since the protection of habitats proved not safe either, conservation efforts have leaned towards species management planning (Heller & Zavaleta, 2009; Stein *et al.*, 2013). Prioritization on which species needs conservation is the first step in a fine-filter approach. Having identified the priority species, fine filter conservation proceeds to mitigate threats facing the target species. Therefore, conservation focusing on species may pursue both *in-situ* and *ex-situ* efforts. While *in-situ* efforts focus on conserving target species within their current distributional range, *the ex-situ* approach relocates target species into more suitable areas outside their current distributional range. Cognizant that *ex-situ* efforts may be misconstrued to human care in botanical gardens and zoos, this reference is made to keep them strictly in the wild (translocation). The traditional *in-situ* conservation of species relies on protected areas that may not necessarily meet some (if not all) of species' crucial requirements.

For this reason, protected areas established to protect species may not realize fine filter purposes but may act as avenues for species searching suitable habitats. At times, even with the established migration corridor, some species may not be able to "move" because of their restricted range, and in this case, *ex-situ* conservation falls in place. Through this, imperiled species are translocated outside their historical range into suitable habitats. These efforts are sometimes expensive as they may present undesired outcomes and therefore should be procured with caution. For example, plant translocations have resulted in the proliferation of invasive alien species in the receiving micro-sites. Therefore, one major problem of the fine filter approach to conservation is the uncertainty of how the target species might respond to the new habitat. Despite the wide adoption of the fine-filter conservation approaches, a growing number is embracing coarse filter conservation framework. While at inception, the coarse filter approach was intended to conserve community of species rather than individual species, the contemporary one has evolved to conserve unique sites for threatened species. Today, coarse filter approach is hinged on preserving certain environmental variables (say topography, elevation, geology, or soil) of a landscape that is crucial in determining species niche. Today's coarse filter approach to conservation is broadly classified into conserving land facets (Wessel *et al.,* 1999) and climatic variables. Conservation of land facets entails identifying critical geographical areas with similar topography and soil type, such as limestone karst outcrops (see Struebig *et al.,* 2009).

On the other hand, the climate approach to coarse-filter conservation prioritizes land conservation to sites of low climate velocities such as mountain-tops and some inselbergs in low-lying drylands. However, adhering to a coarse-filter approach in arid and semi-arid areas may present a suite of challenges: do we focus on climate-resilient sites even though they have been offered more protection, or do we invest conservation efforts in anthropized low-lying drylands that may have fewer refugia for species? Such conundrums hinder the utility of course-filter approaches in conservation. In this regard, a conservation effort that only pursues either coarse or fine filter may be doomed to fail. One may then ask, do we prefer conservation of plant community or an individual species or, more specifically, threatened plant species to their degraded habitat? In this sense, conserving the habitat of the threatened plant species is arguably as important as the target species themselves. As initially envisioned (Hunter *et al.,*1988; Noss, 1987), both coarse and fine-filter approaches may work synergistically by complementing each other. If an effort aims at conserving biodiversity, then the species and their habitat are both considered. Despite the widespread notion of choosing either of the two, conservationists are leaning towards a hybrid approach in their planning process. Such an approach is applicable in conserving threatened plant species within degraded but functioning habitats. This hybrid approach integrating coarse and fine-filter is equivalence for *'conservation that meets restoration,' sensu* Volis (2016). It entails conserving imperiled plant species by reclaiming their habitats and similarly restoring the environments using threatened plant species. Though seemingly paradoxical, this integration of conservation biology and restorative ecology has a place in conserving most of the threatened flora.

Ecological restoration (the Coarse filter approach) emphasizes on community or ecosystem processes. To the contrast, conservation biology (fine-filter approach) mainly focuses on the processes operating within the population of threatened flora. Creating a viable population of endangered plant species may entail removing the stressor, which usually means restoring their habitat (coarse-filter approach). Habitat restoration is becoming an integral part of conserving rare and threatened plant species (consider examples in Wiens & Hobbs (2015)). As stated by Volis (2016), the use of threatened flora to restore partially degraded habitats has not gained wide acceptance and is thus new among conservationists. Though the use of threatened plant species in restoring degraded but functioning habitats has elicited a lot of active debate, it is justifiable in the following sense. With the increasing habitat alteration necessitated by the exponential growth of the human population, restored lands will in future form critical habitats for threatened plants. Before using these imperiled plant species to restore degraded habitats, we should know which one presents the potential candidate and under what circumstances is it applicable. If these target plants are part of a specific plant category, (eg have key roles in restoring the integrity of the ecosystem), then knowledge of how to use them in restoring degraded habitat is crucially important. Unlike in traditional restoration, where priority is on the most degraded areas, the use of threatened plants in the land restoration approach prioritizes the least-altered habitats.

The application of coarse and fine filter approaches should not be perceived as alternative concepts but instead should be used complementarily. A sound conservation initiative may start with a coarse-filter approach in identifying priority areas for conservation at the regional level and then focusing on species-specific conservation efforts for each site. Since the coarse and fine filter approach emphasizes different entities (landscape versus species), do they present different conservation actions? For example, think of conservation project with a suite of threatened plants species in a less-degraded habitat. Do they focus on the threatened plants over restoration of the degraded habitat? Whether the prioritization approach is on habitat or the target species, the available options share some commonalities. Bearing in mind that not all habitats can be conserved and not all species can be saved, priorities must be set. What should be done first using the available resources should be identified in setting priorities. In such cases, prioritization does not focus on determining what should not be done but rather on what should be initiated first. Aware that not all threatened plant species or their habitats can be conserved, one ought to decide what of the two to let go. Areas and landscapes will always exist, although with more modification, and thus it is prudent that they can be conserved later when resources are available.

On the other hand, the uncertainty of prioritizing can drive a threatened plant species into extinction with no hope of recovery. With the highly changing world, conservation of threatened plant species will face many targets that change over time and space. Though prioritization may follow science's way, the decisions deeply lie in society's social values, and therefore community mobilization is essential. The attitudes and perceptions of the local communities to threatened species may vary over sites. Some see it as taking their land to preserve the imperiled flora, while others may see it as being denied the right of use. The contemporary conservation initiatives of threatened plants have begun engaging the locals throughout the project activities. Issues of how ecosystem services influence human values has saturated conservation fora. Conservationists are now thinking globally and acting locally and thus have started incorporating the locals' practices and ways of doing things, perceptions, and motivations in their conservation efforts. Therefore, the time is ripe for conserving threatened plants species by engaging the local community. Based on the above deliberations, this study adopted a two-tiered coarse to fine filter prioritization approach. This hybrid scale of action used a coarse filter approach in identifying priority areas at a local level and then on a fine-scale focused on species-specific conservation for the target species.

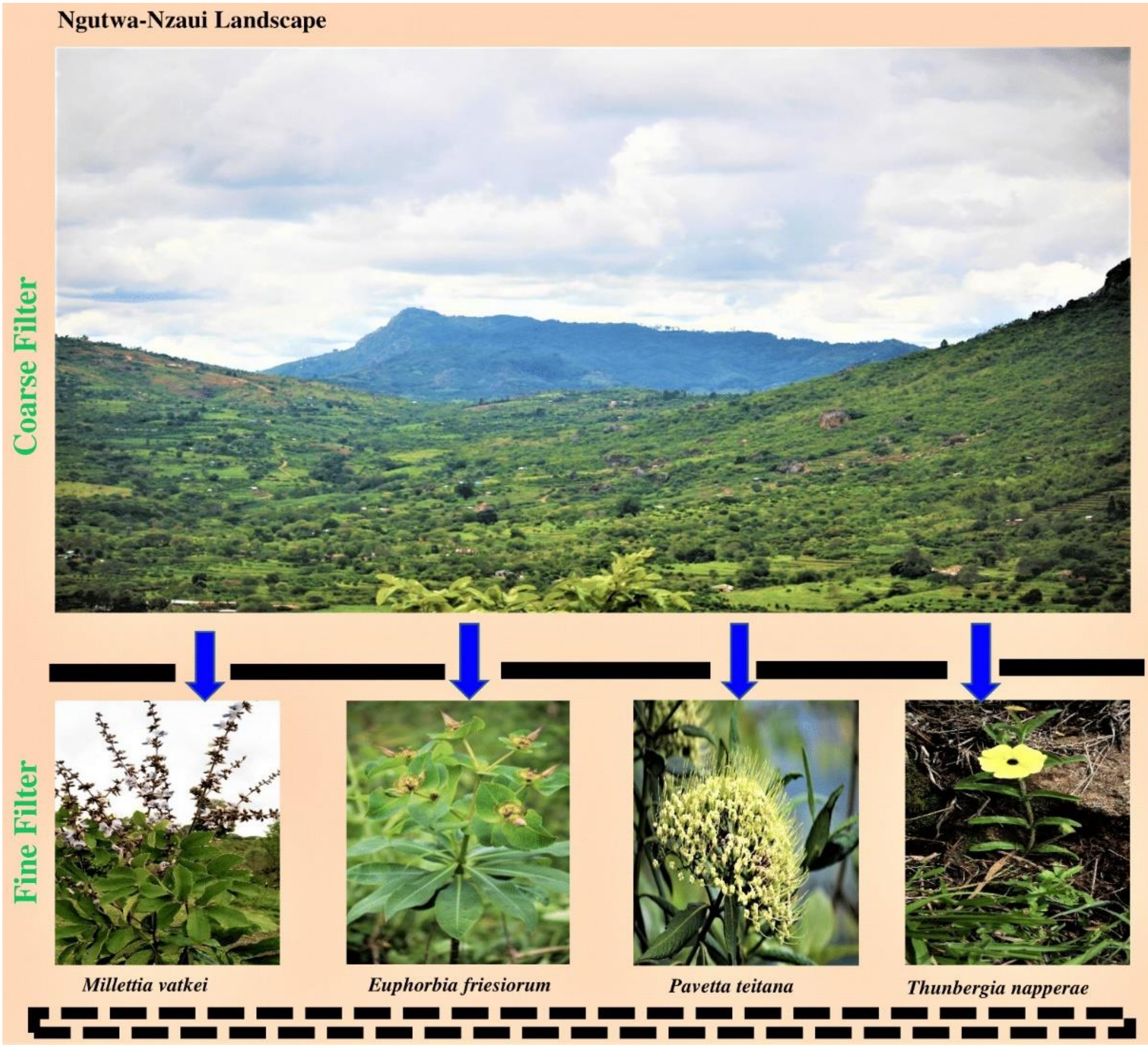


Figure 2. 1 Conservation model adopted by the study.

A modified illustration from Tingley *et al.,* (2014) applied in the present study in identifying the priority sites for conservation as well as conservation targets. Conservation of the extensive southeastern Kenya region, a *Combretum* wooded grassland and potential biodiversity "hotspot" (Kimeu *et al.,* 2020) play a crucial role in protecting unique biodiversity within Ngutwa-Nzaui landscape (Makueni county). Although the conservation of the whole area may positively impact many plants, some threatened plant species such as *M. vatkei, T. napperae, P. teitana*, and *E. friesiorum* may be overlooked in the coarse-filter conservation approach thus necessitating species-specific management prescriptions. Therefore, the study adopted a hybrid system, by starting with a coarse filter approach, in which the Southeastern Kenya region was identified as a priority area in need of conservation owing to the large number of endemic and threatened flora, and then proceeded on a fine-scale, conserving the four-target species within Ngutwa-Nzaui landscape (part of the larger lower eastern Kenya).

2.2 Study Site

Unlike Afromontane and coastal forests, drylands habitat has attracted fewer studies in Kenya (Beentje, 1990). Southeastern Kenya is one of the arid and semi-arid lands (ASALs) in Kenya with a vast dryland ecosystem punctuated by several inselbergs forming a transition zone between Somali-Masai and moist upland Afromontane vegetation (White, 1983; Lillesø *et al.*, 2011; Kindt *et al.*, 2011) and thus play a refugial niche function for species unsuited for higher and lower elevations (Malombe *et al.*, 2020). These inselbergs are characterized by wooded grassland and have established a semi-moist vegetation at their top. Young (1984) compares this area's biodiversity uniqueness and endemicity to the bio-diverse eastern arc mountains and the coastal dry forests. They have been found to host the highest plant diversity of about 4721 species in the country (Mwachala *et al.*, 2011). For example, floral surveys in the relic *combretum*-wooded grasslands in the Makueni sub-county report over seventy (70) endemic or rare plants majority of whom are threatened in the wild (Malombe *et al.*, 2015). Besides the floral diversity, the area hosts the threatened bird, Hinde's Babbler (*Turdoides hindei*), and of heritage interest since preliminary anthropology data indicate undiscovered rock art. Unfortunately, this potential biodiversity hotspot faces habitat fragmentation occasioned by increasing settlements and farmlands.

The study was carried out in the Ngutw'a-Nzaui area in the Makueni sub-county. The climate of the region is generally dry, showing semi-arid conditions. The seasonal shifts and the intensity of the Inter-Tropical Convergence Zone (ITCZ) and the El Niño Southern Oscillation (ENSO) influence the rainfall patterns of the Ngutwa-Nzaui. The area has a bi-modal rainfall distribution, with long rains between March to June and short rains from October to December. While the annual precipitation range is about 800-1200mm per year in the hilly areas and less than 500mm per year in the other regions, the average temperature is about 23℃. As one moves from Wote town (Makueni County headquarters), the altitude increases with lowering temperatures towards Ngutw'a-Nzaui landscape. The region is dominated by various inselbergs whose elevations vary from one to another, with Nzaui forest being the highest, tending to 2000m a.s.l. Besides, the area is generally dominated by dry *Combretum*-wooded grasslands and some Afromontane vegetation at the top of Nzaui hill. Unlike other inselbergs in the area, Nzaui hill (forested) is the only gazetted forest mainly dominated by *Eucalyptus* at the top and indigenous vegetation at the base. The main economic activity among the locals of Ngutwa-Nzaui includes crop farming, livestock keeping, sand mining, charcoal burning, brick making, among others. The crop farming is carried out in rain-fed systems with patches of irrigation in some localities. As a result, the study site is highly fragmented, with most natural vegetation receding to the hilltops. Kimeu and others (2020) term this occurrence of natural vegetation within farmlands as vegetation ''islands'' or relics.

2.3 Target species

Although the project used lumped conservation targets of four focal threatened plant species: *M. vatkei, E. friesiorum, P. teitana,* and *T. napperae* to pilot the study, its priority species was *M. vatkei.*

2. 3.1 *Millettia vatkei* P.K. Lôc (Endangered)

- **Taxonomy and nomenclature**

This species was previously known as *Millettia leucantha* Vatke but was found to be a homonym, and hence renamed *M. vatkei* P.K. Lôc. It belongs to the family Fabaceae, sub-family Papilionoideae, and genus *Millettia*.

Common name/ vernacular: Utw'aa/kitw'aa (Kamba).

- **Botanical description**

M. vatkei usually occurs as an evergreen liana, scandent shrub, or tree and (though rarely) as a semi-herbaceous plant. It is usually evergreen with their young twigs having pale brown velvety color and the older ones dark grey with white lenticels, and pods velvety with straight tip (Verdcourt, 1968). It has white and blue to violet flowers and can grow up to 12m in height (Beentje,1994).

- **Distribution, habitat, and ecology**

This species is endemic to central and southeastern Kenya (K4 and K6). Its estimated Extent of occupancy (EOO) is 15735 km², and the estimated area of occupancy (AOO) is between 24-60 km² and thus assessed as endangered (IUCN, 2019). Therefore, it is a rare species occurring as few clustered clumps in semi-evergreen forest remnant on rocky hills and has also been found to survive in secondary vegetation after clearance (Beentje, 1994). It does well in an elevational range of 1050m to 1700m (IUCN, 2019). Within the study area, the species is a palatable fodder for rock hyrax.

- **Botanical use**

This species is a source of dry season fodder, fuelwood, mulch and has medicinal properties. Similarly, it is used to produce fiber and timber for construction. Also, its flowers attract bees enhancing pollination within farmlands.

- **Conservation status**

The species is declared endangered and thus highlighted as a potential candidate for conservation concern (Beentje,1988;1994).

- **Propagation challenges**

M. vatkei can be propagated vegetatively and from seeds. Their seeds are orthodox and can be stored for an extended term without losing viability (Muthoka *et al.,* 2003). The seed coat is very hard and, therefore, a challenge to its germination. Another drawback is the ballistic seed dispersal in *M. vatkei*, which disperses the seeds over a short-range. However, long-range dispersal of *M. vatkei* is achieved through the aid of runoff and seed-eating animals (granivores), which include wild rodents (field mice) and ochre bush squirrel (*Paraxerus ochraceus*), which are common in the study area. Ngutwa-Nzaui area is characterized by unreliable rainfall, so drought is a common occurrence. Therefore, in such times of scarcity, these animals collect *M. vatkei* seeds and store them in caches a distance from the seed source. Although there is copious seed predation at such times, they are unable to deplete the stock before the onset of rains, and therefore some grow into seedlings.

Similarly, because of the high protein content in *M. vatkei* seeds, other animals also feed on them. An excellent example is the bean weevils (Bruchidae) which infest the dry pods and the seeds. Unlike the field mice and ochre bush squirrel, which feed and reciprocate by offering long-range dispersal for the fallen *M. vatkei* seeds, the bean weevils are of no benefit whatsoever to this species. *M. vatkei* seeds have evolved to contain toxic substances such as saponins, lectins, and trypsin inhibitors as a defense to these destructive insects and weevils. These toxic substances also adversely affect the granivores, though they do not reach lethal thresholds because of their larger body size. Another challenge to this target species is that locals carry their leaves as mulch and decayed leaves as manure and thus the carried fallen seeds end-up being lost and unavailable for germination. Seeds fortunate enough to establish themselves on the farm are soon uprooted as a weed.

2.3.2 *Euphorbia friesiorum* (A. Hassl.) S. Carter

- **Taxonomy and nomenclature**

This species belongs to the family Euphorbiaceae and genus *Euphorbia.*

Common name/ vernacular: Musilia (Kamba)

- **Botanical description**

It is a shrub and occurs less commonly as a tree, with a height of 1-5(10) m. (Beentje, 1994). Its branches are somehow succulent, leaves attenuate at the base and acute at the apex. Their reddish-green flowers are arranged in a long terminal cyme with bracts resembling a cup and have three-lobed fruits.

- **Distribution, habitat, and ecology**

This species is endemic to Kenya, and its distribution is restricted to the eastern region, in the counties of Makueni, Kitui, Meru, and Embu. It does well in dry bushland on rocky areas along rivers and deforested land. It has a restricted area of occupancy (AOO) of 40-100km^2 and an extent of occurrence (EOO) of 23,520 km^2 (Luke *et al*., 2018). Due to the continued threats facing this species, it is currently considered to grow in 5-10 locations. It is rare, and its populations are scattered in the above localities.

- **Botanical use**

The latex from this species is mixed with butter or ghee and used in cooking. It is used to cure rashes on human skin and treat cow glands. It is also used to treat toothache and mouth sores.

- **Conservation status**

The species is declared vulnerable and protected in international trade (listed on CITES Appendix II). Therefore, conservation measures a needed to rescue its declining populations.

- **Propagation**

It is propagated vegetatively and through seeds.

2.3.3 *Pavetta teitana* K. Schum.

- **Taxonomy and nomenclature**

P. teitana belong to family Rubiaceae and genus *Pavetta.*
Common name/ vernacular: Muthongoi (Kamba).

- **Botanical description**

This species occurs as a shrub or a tree ranging from 2-9 m tall. Its leaves are elliptic with an acute apex and cuneate base. While the flowers are cream or yellowish-green, their fruits are round and purple-black.

- **Distribution, habitat, and ecology**

The species is endemic to Kenya, with extant populations in Makueni, Machakos, Taita, and Kitui. Its occurrence in Kiambu is feared extinct because of severe habitat loss. While its small area of occupancy (AOO) ranges from 20 to 32 km^2, its extent of occurrence (EOO) falls between 8,602 and 18,911 km^2 and is thus known to occur in less than ten localities (Luke *et al.*, 2018). It has been found to thrive well between elevations of 650m to 1500m a.s.l (Luke *et al.*, 2018) in rocky areas along the riverine forests (Beentje,1994).

- **Botanical use**

This species is used to provide timber and twining materials for construction purposes. Similarly, it has medicinal properties and is thus used to treat oral lesions among children.

- **Conservation status**

Due to its decreasing population and occurrence in low frequencies, it is assessed as vulnerable and in need of immediate conservation.

- **Propagation**

It can be propagated through seeds and cuttings.

2.3.4 *Thunbergia napperae* Mwachala, Malombe & Vollesen

- **Taxonomy and nomenclature**

Belongs to family Acanthaceae and genus *Thunbergia*
Common name/ vernacular: Unknown

- **Botanical Description**

T. napperae is a prostate to ascending perennial herb with a woody rootstock of about 0.5m tall, bright yellow petals, and a dotted tube or purple striata.

- **Distribution, habitat, and ecology**

Occurs in *Acacia-Combretum* wooded grassland or *Acacia* bushland and along roadsides within an altitudinal range of 1400-1800m above sea level.

- **Botanical use**

No known botanical use

- **Conservation status**

The species is assessed as vulnerable and thus of conservation concern.

- **Propagation**

This species is propagated vegetatively and through seeds.

CHAPTER THREE: MATERIALS AND METHODS

This section is divided based on the specific objectives of the project, collection of baseline information, mass propagation and restoration of *M. vatkei*, and creation of public awareness on the importance of conserving the target species (as well as biodiversity in general) and building the local capacity in plant conservation.

3.1 Collection of Baseline Information

3.1.1 Assessment of Land Use and Land Cover Changes (LULCCs) in Ngutwa-Nzaui

(a) Data Collection

Two sources of data were used for the study; -satellite imagery and ancillary data. Cloud-free Landsat images were mainly used for quantifying change for the past three decades at a ten-year sequence. Unfortunately, it proved impossible to sequentially secure images for the area of interest due to either poor quality images necessitated by more than 10% cloud cover or missing information. Satellite imageries used to evaluate the land use and cover changes in the Ngutwa-Nzaui area included 1987 Landsat 5, 2000 Landsat 5, 2011 Landsat 7 and 2020 Landsat 8, which were obtained from the United States Geological Survey (USGS) database. The digital image processing was done in a Geographic Information System (GIS) environment with tools for processing remotely-sensed images. Also, the time when the image was captured was considered. Images used were captured during dry seasons since, at such times, cloud cover is less to guarantee data precision. Similarly, human activities within arid and semi-arid areas such as (Ngutwa-Nzaui) are at their peak during dry seasons. Following this criterion, all the images secured were multispectral and had a spatial resolution of 30m. This filtering ensured the download of atmospherically corrected images ideal for land use/land cover studies as training sites could easily be done. Also, auxiliary data for the analysis was gathered using Global Positioning System (GPS) for ground-truthing.

(b) Data Processing

The processing of the Landsat data involved loading the cloud-free imageries, creating composites, training sites, and finally classification.

1. **Loading the imagery**

The imageries were loaded into ArcGIS software for processing. While Landsat 5 and Landsat 7 imagery contained seven bands, Landsat 8 had 13 bands. The images were then subset to the Region of Interest (ROI) which involved clipping our imagery to the area of interest (AOI), which was enabled by coordinates of extends around the Ngutwa-Nzaui area (Study area) in Makueni County. The data clipping was done using the data management tools in the Arc toolbox, using the raster processing tools. The output was a raster image with extents of the area of interest.

2. **Creating composites**

Creating composites involved combining bands to help bring out different features in the imagery. This band manipulation process helped pick training samples by highlighting the features in the image. For example, in Landsat 5, a composite of bands 4, 3, 2 was a false-color composite that helped highlight vegetation in red. Also, a composite of bands 7, 4, 2 helped highlight the different variations in vegetation, thus being able to distinguish forest, croplands, and scrublands. These different band combinations enabled the realization of different LULC classes.

3. Creating training sites

This involved using the image classification, which involved picking like pixels based on color and proximity to each other and merging them as a class of features to help in the supervised classification process. The different color composites aided this. The sample classes included; built-up area, water, bare land, forested land, cropland, and scrubland. Several training sites were picked for each class to ensure better accuracy and representation of the desired land use during classification. Determination of the training sites heavily relied on ground-truthing and the researcher's personal experience of the Ngutwa-Nzaui area.

4. Land use and land cover Classification

Maximum likelihood algorithm was used to classify the data using the training samples acquired. The training samples were based on the researchers' experience of the study area. According to Shalaby and Tateishi (2007), the maximum likelihood algorithm is a widely used classification approach when accurate training data is used. It assumes that the pixels near each other most likely share the same properties, and thus similar. This classification process resulted in several classes as per the training sites.

(c) Post-classification Processing

After classifying the data, land use/land cover maps for 1987, 2000, 2011, and 2020 were obtained, and post-processed to attach meaning to the results by showing the change in the various classification classes. Some of the processes included;

- Adding fields in the attribute table for the class name and area acreage to help identify the features and show the area.
- Converting the results from raster to polygon using the conversion tool.
- Dissolving the polygon data into unique feature classes to help conveniently calculate area.
- Calculating area in hectares using the geometry tool.
- Exporting the data in dbase format for further analysis in Excel.

It also entailed using ancillary data to differentiate scrubland, forest, cropland, and other land cover classes.

(d) Accuracy assessment

An accuracy assessment was done to verify the classification reliability and quality. Ground-truth data collected during fieldwork on land use, land cover, spatial location, and topographic characteristics was used. Visual interpretation and Google Earth images were also used to assess accuracy.

(e) Change Detection Analysis

To quantify the change for each land use/ cover class from 1987 to 2020, the following method was used; -

$$\text{Percentage change } (\%\Delta) = \frac{\textbf{Area change (for example 2020- 1987 etc)}}{\textbf{Original area (1987)}}$$

This formula was also used in calculating decadal percentage changes for 1987-2000, 2000-2011 and 2011-2020.

Similarly, annual rates of change for the various cover types between different years was calculated as follows; -

$$\text{Annual rate of Change} = \frac{\textbf{Areal coverage at } t_2 \textbf{ -Areal coverage at } t_1}{(t_2 - t_1)} \times 100$$

Whereby t_1 and t_2 is the year of the older and recent image capture respectively.

3.1.2 Assessment of Local Community Perception towards Biodiversity Conservation

To understand the perceptions and attitudes of the locals of Ngutwa-Nzaui towards biodiversity conservation, an interactive scoring exercise (Pebble Distribution Method) (Colfer *et al.* 1999a, Sheil *et al.* 2002, 2003) was used. This flexible and straightforward diagnostic scoring technique does not require prior training and thus was appropriate for gathering information from the locals. Through this, we sought to assess the local's relative importance of various ecosystem goods and services they received from nature. The relative weight placed on the multiple ecosystem goods and services by the community was used in the determination of relative importance value (RIV) for each product or service (Lynam *et al.*, 2006). The following formula was used in calculating the relative importance value for each good/service; -

$$\textbf{Relative Importance Value (RIV)} = \frac{\textbf{Relative weight (Pebbles)}}{\textbf{Total weight (Pebbles)}}$$

Materials

1. Categories to be scored (ecosystem goods and services) identified by locals.
2. Cards with various ecosystem goods named in local dialect and drawings (illiterate).
3. 100 Counters of equal size (match-sticks)
4. Datasheets

Method: Pebble Distribution Method (PDM)

The facilitator introduced the objective of the focused group discussion and answered any questions from the group members. They were then asked to identify the various goods and services they received from the ecosystem. Discussions occurred amongst the members as they tried to settle on multiple categories. Once there were no further discussions, the facilitator read all the listed ecosystem goods and services for all to approve. There being no dispute, the cards were shared among the locals to make illustrative drawings for the identified ecosystem goods and services. All the illustrations were named in the local language (Kikamba).

Once again, the facilitator explained all the labeled cards with illustrations of the various biodiversity uses identified by the local people and placed them on the ground where everyone could see and access them. Similarly, 100 matchsticks were bundled at the center of the group. Each good or service was comprehensively discussed and offered a clear description as possible. The facilitator demonstrated how they were supposed to distribute the matchsticks among the various categories and the implications of the scores. What was perceived least necessary was assigned one matchstick, and all other uses were scored relative to that one. For example, if six pebbles were placed on the 'water' card and three on the 'fodder' card, it was explained that water is twice as important as fodder. If three matchsticks were placed on 'firewood' and one on 'honey' card, then firewood is three times as important as honey. Similarly, it was also explained that if ten pebbles were placed on the 'food' card and ten on 'water,' water was equally important as food. Additionally, assigning a zero score for any use that they attached no importance at all was acceptable. Before scoring started, the facilitator ensured that the labels (in local dialect) and illustrations on the cards were clear and the procedure well understood by everyone.

The next step was to score the identified ecosystem goods and services. The group was welcomed to distribute 100 matchsticks on the cards based on their perceived relative importance. The facilitator did not intervene until such a time when the group or a member sought clarification. When all the matchsticks were distributed, the assessor read all the cards and assigned sticks before allowing the group to approve. Sometimes this sparked a debate that saw some matchsticks being redistributed. Exciting and relevant remarks were noted as the discussion progressed. When consensus was reached, the scores for each card were counted and the final tally recorded on the datasheet. The facilitator also welcomed the group members to score the importance of the various goods and services ten years from the present. They were supposed to indicate which of the identified goods and services would be significant in a decade. After all was done, the facilitator confirmed if all the matchsticks added up to 100, and verbally presented the results to the group, and welcomed any clarification or question. To understand the local's perception of certain ecosystem goods and services, more explanations were sought from the group members. A similar process was followed in the identification and scoring of threats.

3.1.3 Mapping the local indigenous technologies and distribution of target species

- **Indigenous technologies practised by the locals**

The study recorded the local's practices in 5 of the ten villages initially earmarked for the survey located within the Ngutwa-Nzaui area. A semi-structured questionnaire was devised to interview the most receptive locals about their propagation techniques. Similarly, data was also collected through opportunistic sightings during the mapping exercise.

- **Spatial distribution of target species**

The study employed a suite of methods, including primary and secondary data sources. A desk-based method was used to review the literature on the target species and the study site in both peer-reviewed and grey literature. Also, a more targeted inventory employing an intuitive meander survey technique was adopted. As the name suggests, this method describes the path taken by a researcher in maximizing the probability of detecting rare and threatened plants within a locality. During a meandering search, the researcher covers a larger geographic area than other techniques such as transects. This approach has been recommended for many inventory protocols (Alberta Native Plant Council, 2012; Johnson-Groh, 2004; Wisconsin Department of Natural Resources, 2015). Because of the patchy distribution and small population size of *M. vatkei*, *T. napperae*, *P. teitana*, and *E. friesiorum* within the Ngutwa-Nzaui area, an intuitive meander survey is justified.

The study used a stratified sampling plan, whereby the whole of the study site was divided into three strata of high, medium, and low probability habitats. Guided by intuition, the investigation team focused much of their survey efforts on the high probability areas. The team used deductive (knowledge-based) and inductive techniques to model the distribution and determine the best route. Since many threatened plant species show uneven distributions and cryptic character (Thompson 2004; Garrard *et al.*, 2015), the survey efforts were intensified to ensure all high probability habitats were adequately surveyed. According to Garrard *et al.* (2015), the detectability of plants is hinged on total time searched rather than the frequency of site visits. Lancaster (2000) adds that conducting fieldwork twice per flowering season is the minimum requirement for a defensible rare plants survey.

Importantly, to minimize the occurrence of bias, the team also used other floristic inventory approaches such as a general walk-over survey (Filgueiras *et al.*, 1994) and a modified plotless sampling method (Hall and Swaine, 1981) in exploring lesser value areas (medium and low probability habitats). In some instances, the target species' subpopulations consisted of few individuals that could not permit an ethical collection. In such cases, the team took photos to document such observations. As advised by Pavlovic *et al.* (1992), caution was observed not to exhaust extremely small subpopulations. To achieve this, the team adhered to the '1 in 20' rule as per Wagner (1991), whereby no specimen was collected from a population of lesser than 20 individuals.

3.1.4 Documentation of Threat Information

(a) Threat Classification System

The study adopted a standardized threat assessment of the IUCN–CMP Classification of Direct Threats Version 3.2 (Salafsky *et al.*, 2008) for consistency in comparison. This unified classification system is hierarchical and categorized into three levels-starting with coarse to fine scale. The first level identifies 11 broad threat categories with specific threat types being given in level 2. In attempt to further describe level 2 threats, a finer third-level is established mainly containing illustrative examples of level 2.

(b) Threat identification

The study used two approaches to identify direct threats to biodiversity within the Ngutwa-Nzaui landscape.

(i) Expert Knowledge-based Threat Assessment

A detailed expert-based threat assessment approach was developed specifically for use by experts during the mapping exercise. They were supposed to identify direct threats, rank, and prioritize current and future threats impacting the target species and their habitat within the Ngutwa-Nzaui area. The assessors (experts) used modified classification by Salafsky *et al* (2008) while documenting threats to the target species. They were supposed to use a second-level threat type from this classification scheme. Also, they assessed and recorded contributing factors and indicators of threats within the study area.

(ii) Simplified Threat Assessment Tool

A simpler, interactive, and complementary approach that does not require prior taxonomic knowledge was used among the locals of the Ngutwa-Nzaui landscape. This encouraged a more inclusive threat assessment permitting a broad range of stakeholders. In the pebble distribution method (as discussed in detail elsewhere in this report), the locals were asked to identify threats facing goods and services they received from nature. Similarly, they were asked to rank them from the most to the least significant and project future impact.

(c) Threat Ranking system

The feedback from both experts' knowledge-based and simplified threat assessments was consolidated and presented in a table. A simple threat rating system (Conservation Measures Partnership) was adopted for the study. Besides rating the impact of direct threats on the targets, the system provides a prioritized list of direct threats affecting each target. The system offers three types of summary rating: a summary for the overall rating of each threat across all targets, a summary of the overall threat rating for each target, and finally, a summary of the threat rating for the entire project. The summary ratings were not entered directly but involved some calculations.

- **Criteria for Ranking Direct Threats**

After identifying direct threats to the targets, they were combined using an appropriate scoring algorithm. Although the arithmetic procedure is relatively simple, the study used a rule-based threshold procedure with several rules on how different threat parameters should be combined or rolled up. This scoring algorithm was preferred for the arithmetic approach because combinations could be tailored to reflect real-world threshold effects. Threat ratings were calculated by combining the scope, severity, and irreversibility.

(i) Scope of a Threat

For the study, the scope meant the proportion of the target species that would be affected by the threat within ten years if the current circumstances and trends (both existing and potential threats to the target) continues. Rating the scope of the identified threat on the target species used the scale below.

Table 3. 1 Scope of a threat.

Scale	Scope of threat scoring
Very High	A pervasive threat with potential of affecting 71–100% of the target species population or occurrences.
High	A widespread threat likely to affect 31–70% of the target species population or occurrences.
Medium	A restricted threat with potential of affecting 11–30% of the target species population or occurrences
Low	A very narrow threat likely to affect 1–10% of the target species population or occurrences
Negligible	A threat likely to affect a negligible (< 1%) proportion of the total population or occurrences

(modified from Corrado *et al.*, 2018).

(ii) Severity of a Threat

Within the scope of the threat, severity was used to mean the level of damage caused by the threat to the targets as the current circumstances and trends continue. For the study, rating the severity of the threat was not done for the whole area, but only within the scope that the threat impacts. The following scale was used to rate the severity of the identified threats on the target species.

Table 3. 2 Severity of a threat.

Scale	Scoring severity of threats
Very High	Within the scope, the threat with a potential of reducing the target occurrences by 71–100% within ten years.
High	Within the scope, the threat likely to seriously reduce 31–70% of the target in ten years’ time.
Medium	Within the scope, the threat has a potential of moderately reducing the target species population by 11–30% within ten years.
Low	Within the scope, the threat likely to cause slight reduction of the target occurrence by 1–10% within ten years.
Negligible	Within the scope, the threat is likely to negligibly decrease the target species by < 1% in ten years.

(modified from Corrado *et al.*, 2018).

(iii) Rating the irreversibility of the Threat

Irreversibility (alternatively permanence) is the degree to which threats' impacts can be reversed and the target's populations restored. Simply, it refers to how difficult it is to reverse the stress inflicted on the target species by the threat. Irreversibility ratings are crucial in prioritizing potential threats. For example, it is essential to prioritize a potential threat expected to cause irreversible damage on target than on a threat that has already occurred. The following scale was used in rating the irreversibility of the identified threats;

Table 3. 3 Irreversibility of a threat.

Scale	Irreversibility rating
Very High	An irreversible threat impact that can take more than 100 years to restore the target species.
High	The impact can technically be reversed, taking 21-100 years of conservation efforts to restore the target species.
Medium	The effects can be reversed and the target restored between 6 to 20 years of reasonable resource commitment.
Low	Easily reversible threat impact whereby the target species can be restored at relatively low cost within 0-5 years of conservation efforts.

(modified from Corrado *et al.,* 2018).

(d) Calculation of Threat Rating Summaries

After completing ratings for the threats based on scope, severity, and irreversibility, the following rule-based system was used to sum up the threat ratings across targets, threats themselves, and the whole project.

(i) 3-5-7 Rule

This rule was used for summing up multiple threats to individual target species and multiple target threat scores.

- 3 High rated threats are equaled to 1 Very High-rated threat;
- 5 Medium rated threats are equivalent to 1 High-rated threat; and
- 7 Low rated threats are equal to 1 Medium-rated threat

(ii) 2-Prime Rule

After applying rule (i) above, the 2-prime rule was used to sum the threat rating for a target species, a threat, or the whole project. In this, it requires the equivalence of two rating scores at a certain level for the result to be that level. For example, at least two 'Very High' ratings resulted to a 'Very High' total score. Similarly, an equivalent of at least two 'High' scores led the global rating to be 'High' (High category).

(iii) Majority Rank Override Rule

This rule was used in determining the overall project rating by summing up the threat ratings using the 2-prime and 3-5-7 rules. Therefore, majority override ensures that the overall project ranking is not reduced too much by the rules mentioned above. If most of the target species have a rating higher than that summed-up, then that majority rating is used instead. For example, if a project is rated Medium based on the 3-5-7 and 2-prime rules, but three out of the four target species have at least one High (or very high) rating, then using the majority override rule, the overall project would now be rated High. Similarly, if the majority of the targets (<50 %) was affected by threats ranked 'very high', 'high', or 'medium', then threat status for the overall project would be, respectively, 'very high', 'high', or 'medium'.

3.2 Mass-propagation and restoration of *M. vatkei* within Ngutwa-Nzaui

3.2.1 Establishment of a Propagation System

The study used a non-mist propagation system consisting of poly-tunnels (polypropagator). Three (3) sunken beds for the tunnels, each measuring 1m x 6m, were established with a 0.5m path between the sowing beds. Two of them were used for sowing target species' seeds, while one held the potted seedlings after germination. The sowing beds were made by digging a trench of 1m (width) by 6m (length) and 15cm (deep). The bottom of the trench was leveled with a rake and lined with 500-gauge black polythene plastic sheeting to avoid excessive water loss and prevent roots from penetrating the soil. The trench was then filled with a germination media-a mixture of wood ask and river sand that had been sun-dried for 48 hours. After leveling the media to a uniform depth of 15cm, wooden planks were then placed at the edges of the sowing beds to control water flow and minimize soil erosion.

A half-dome wooden frame (tunnel) made of *Lantana camara* was erected on top of the sowing bed with hoops placed at 1m intervals along the beds to support polythene sheeting. *Lantana camara* was used because it is locally available and permits machinability. The hoops were curved into a semi-circular arc to allow rainwater run-off from the surface of the polythene sheeting. They were also set 50cm above the top of the sowing media or the potting tubes. An external wooden frame measuring 4m x 6m with semi-circular roofing was constructed, enclosing the beds and their paths, and allowing anyone to walk along the beds. This frame served as a support frame for the 70% black shade net.

3.2.2 Seed Collection Planning

Collecting high-quality seeds is the first step in ensuring quality seedlings to conserve threatened plant species. The study adopted a seed collecting scheme by the Center for Plant Conservation (1991) in collecting seeds for the target species (Which species to collect from, how many/which populations and individuals, and how many and what kind of propagule, etc.). Before seed collection, a reconnaissance was conducted to determine the number of subpopulations with mature seeds for collection. Based on elevation, three strata within the target species range were demarcated; on the lowest elevation of the three was Ngutwa, followed by Kathuma area falling between Ngutwa and the third region on the highest elevation (Nzaui). We engaged the locals living within the three strata to gather as many seeds of the target species as quickly and cheaply as possible. Before the collecting exercise, the locals were trained on the basic procedures.

A proportionate stratified random sampling was used in determining the number of subpopulations to collect seeds from in each of the three strata. The following formulae were used in determining the stratified sample in each stratum.

Proportionate Stratified Random Sampling Formula: $n_x = (N_x / N) * n$

Where n_x= Sample size for x^{th} stratum

N_x= Population size for x^{th} stratum

N = Size of entire population

n = Size of entire sample

Although great focus for the collection was on *M. vatkei*, the team also collected mature seeds from the other three plant species targeted by the project.

Some of the rock crevices within the study area are thought to host venomous snakes that hunt down rock hyraces for food. Therefore, throughout such exercises, the teams were guided by local knowledge, which has it that fresh hyrax droppings symbolized the absence of such snakes. Where there were no fresh hyrax droppings were used as an indicator of snakes' presence and thus avoided. Though this was not a guarantee for maximum security, the teams observed caution and the local guides led the team members throughout the exercise.

3.2.3 Seed collection methods

A bulk collection of *M. vatkei* pods/seeds was done in August and September (2020) within the study area with the help of the locals. Standing trees with easy access from the ground formed a good seed source for propagation. However, those very close to the ground were avoided since they are believed to contain fewer seeds, possibly due to inadequate pollination. As a result, the groups focused on fruits (pods) falling within the middle of the crowns. Branchlets with mature pods at arm's length were hand-picked while those out of reach were pulled closer using a hooked stick and then plucked by hand. Branches with a good load of mature and dry pods were also agitated to facilitate falling. The team also collected seeds that had fallen on the ground after natural dehiscence. After collecting the seeds and pods, they were loosely filled in khaki bags which were then labeled inside and outside and stored separately as maternal lines.

3.2.4 Seed Processing

Before extracting the seeds, the pods were cleaned of twigs, leaves, and other impurities. Though the debris consumed needless space, it was necessary to remove them since they may harbor fungal spores. For *E. friesiorum*, the fruits were sundried to remove the sticky exudate (resin), which is thought to cause blindness by the locals. Since some fruits were collected in the near-maturity stage, precuring was done to ensure appropriate fruit drying and achievement of peak maturity. In this, the seeds/pods were spread thinly (one seed/pod deep) in ambient conditions. At regular intervals, they were turned and stirred using a rake. The pods were cut on one end to spill the seeds when fully dry. After seed extraction, a hand-sorting procedure was carried out to reduce bulkiness, remove infested seeds, those with detached structures and leaf particles. These inert materials were removed to avoid uneven stocking in germination beds and reduce incidences of diseases during germination. The cleaned seeds were sorted by a floatation technique whereby poor-quality seeds (especially those infested) floated on the water while the viable ones remained below the water. While the poor-quality seeds were discarded, the viable ones were dried and stored in loosely packed khaki bags. However, discretion was exercised not to clean the seeds below a certain level since this could lead to the loss of some viable seeds.

3.2.5 Seed Germination

Before sowing, the seeds were exposed to hot-water scarification with great caution not to boil them. Also, the germination media (mixture of wood ash and sand sun-dried for 48hrs) was leveled and watered slightly. Drills of 5cm deep were made at intervals across the sowing beds. A total of 2520 seeds were sown in the two-sowing beds, and 383 were planted in containers (improvised germination chambers). During sowing, the *M. vatkei s*eeds were gently pressed into the drill and a thin layer of sand leveled on top of the seeds such that none was visible. The bed was then watered with a fine spray to avoid exposing the sown seeds. The semi-circular tunnel on top of the germination beds was then tightly sealed with a 250-gauge clear polyethylene sheeting stretched taut across the *Lantana camara* hoops. The soil was piled on the edges to keep the polythene sheeting in place and to maintain soil moisture and high atmospheric humidity. Watering was done in the morning and evening. Germinated seeds were recorded on the last day of every week until no further germination was observed. The viability of the sown seeds was also estimated in terms of germination percentage, whereby the following equation was used.

$$\textbf{Germination Percentage (\%)} = \frac{\textbf{Germinated seeds}}{\textbf{Total seeds sown}} \times 100.$$

3.2.6 Restoration of the *M. vatkei* Population

A three-step approach was used to recover declining *M. vatkei* within the Ngutwa-Nzaui area, including reinforcement (enrichment), re-introduction, and translocation. Through reinforcement strategy (also augmentation), more individuals to the already existing *M. vatkei* subpopulations were added through planting. In the second approach (re-introduction), the study sought to re-establish *M. vatkei* subpopulations in areas where this species was known to occur. The third strategy used was translocation, whereby individuals were intentionally planted in areas without *M. vatkei* but within its known historical range.

3.3 Creation of Awareness on Importance of Biodiversity Conservation

To create awareness among the locals on the importance of conserving target species and their habitat, training workshops were organized within Ngutwa and Nzaui areas. Because of the restriction to hold large gatherings, the study undertook several groups of minimal individuals. At times, this entailed under tree meetings as a ware of reaching maximum number under minimal risk. Further, to evaluate the effectiveness of the training, the study assessed the opinions and attitudes of the trainees at the end of the training sessions. To gather more information about the trainees' perceptions on the taught topics, a 5-point Likert scale was used. The trainees were presented with ten subjective statements, each seeking to measure a certain aspect of the overall training workshop. The aspects of the training assessed included training organization and planning, communication (information delivery), instructional methods, and outcomes. A continuum of five possible responses (strongly agree, agree, neutral, disagree, and strongly disagree) was provided in each statement. Also, to analyse the data quantitatively, the study assigned a numerical score to each of the responses in the following order, Strong agree 5, agree 4, neutral 3, disagree 2, and strongly disagree 1.

3.3.1 Determination of Relative Importance

Therefore, the Relative Importance Index (RII) was calculated using the following formula;

Relative Importance Index =(∑W/A*N) x 100

Whereby W is the weight accorded to each item, ranging from 1-5 (1-strongly disagree and 5 - strongly agree).
A is the highest weight (5 in the 5-point Likert scale)
N is the total respondents.

Therefore, Relative Important Index = $$\frac{5n_5+4n_4+3n_3+2n_2+1n_1}{5 * N}$$

Where n_5 is the number of respondents who ‘strongly agree’,
n_4 for ‘agree’,
n_3 for ‘neutral,
n_2 for ‘disagree’,
n_1 for ‘strongly disagree.’

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Collection of Baseline Information

4.1.1 Assessment of Land Use and Land Cover Changes (LULCCs) in Ngutwa-Nzaui

Detecting change in land use and land cover over time offers a better understanding of the relationships between human and natural phenomena and guides resource use and management decision-making. The use of multi-temporal datasets in detecting temporal effects of a natural phenomenon has been recommended. Geographic Information System (GIS) and remote sensing have proved practical tools for analysing land use/cover changes. A geographic Information system has been used in measuring changes between two or more periods. It uses many data sources such as classified images, hydrological, soil, and topographical maps to detect change over a particular locality. On the other hand, remote sensing uses satellite imagery to detect land surface changes. Space-borne sensors' repetitive coverage of an area is crucially vital in identifying such changes. Geographic information systems and remote sensing have gained wide acceptance in detecting changes in land use and land cover. The ecosystem and landscape patterns in the Ngutwa-Nzaui area (Makueni county) have been modified by various land uses. Knowledge of the dynamics of these changes is crucially essential in devising sound planning and management policies.

Table 4. 1 Land use/ land cover categories and their descriptions

Land cover	Definition
Forest	Areas with evergreen trees either planted or natural and reserved on the hills and along the rivers
Scrubland	Areas within the study area dominated by shrubs, including scattered trees, herbs, and grasses
Bareland	Describes area with no vegetation cover such as rocks, excavation sites, abandoned farmlands, denudated areas, earth and sand land in-fillings and weathered road surface
Water	Defined as areas under water either a river, constructed earth dam, ponds and filled sand dam
Cropland	These are areas within the study area under crops such as oranges, mangoes, maize, beans, green grams irrespective of either irrigated or rain-fed
Built-up area	These involved areas covered by human settlement, commercial, residential buildings, transport and other man-made infrastructures both in rural and urban

Table 4. 2 **Land use/land cover classes of the study area**

Land cover	**1987 (km^2)**	**% Area**	**2000 (km^2)**	**% Area**	**2011(km^2)**	**% Area**	**2020(km^2)**	**% Area**
Forest	82.01	20.74	64.21	16.24	45.05	11.39	46.42	11.74
Scrubland	235.39	59.52	233.87	59.14	188.88	47.76	186.06	47.05
Bareland	53.57	13.54	57.3	14.48	72.08	18.23	55.21	13.96
Water	1.19	0.30	1.29	0.33	2.44	0.62	3.27	0.83
Cropland	22.76	5.76	37.01	9.36	80.43	20.34	84.55	21.38
Built-up area	0.54	0.14	1.78	0.45	6.58	1.66	19.95	5.04
Total	**395.46**	**100**	**395.46**	**100**	**395.46**	**100**	**395.46**	**100**

Table 4. 3 **Annual rate of change for the various land use/ land cover within Ngutwa-Nzaui**

	Percentage (%) Change				Annual rates of change			
LULC	**1987-2000**	**2000-2011**	**2011-2020**	**1987-2020**	**1987-2000**	**2000-2011**	**2011-2020**	**1987-2020**
Forest	-21.7	-29.84	3.04	-43.4	1.7	2.7	0.3	1.3
Scrubland	-0.65	-19.24	-1.49	-20.96	0.1	1.8	0.2	0.6
Bareland	6.96	25.79	-23.4	3.06	0.5	2.3	2.6	0.1
Water	8.4	89.15	34.02	174.79	0.7	8.1	3.8	5.3
Cropland	62.61	117.32	5.12	271.49	4.8	10.7	0.6	8.2
Built-up area	229.63	269.66	203.19	3594.44	17.7	24.5	22.6	108.9

Table 4. 4 **Decadal percentage change in land use land cover within the study area**

	Forest	Scrubland	Bareland	Water	cropland	Built-up area
1987-2000	-21.7	-0.65	6.96	8.4	62.61	229.63
2000-2011	-29.84	-19.24	25.79	89.15	117.32	269.66
2011-2020	3.04	-1.49	-23.4	34.02	5.12	203.19
Overall 1987-2020	-43.4	-20.96	3.06	174.79	271.49	3594.44

The assessment identified six (6) land use/land cover classes: forest, scrubland, Bare land, water, cropland, and built-up areas. Based on the 2020 land use/land cover map, scrubland, cropland, and bare land covered the most significant portion of the study area with 186.06Km^2 (47%), 84.55Km^2 (21%), and 55.21Km^2 (14%), respectively (see figure 4.1). Forest covers a moderate proportion of 46.42Km^2 (12%), with built-up areas and water bodies being the least at 19.95Km^2 (5%) and3.27Km^2 (1%), respectively (Figure 4.1).

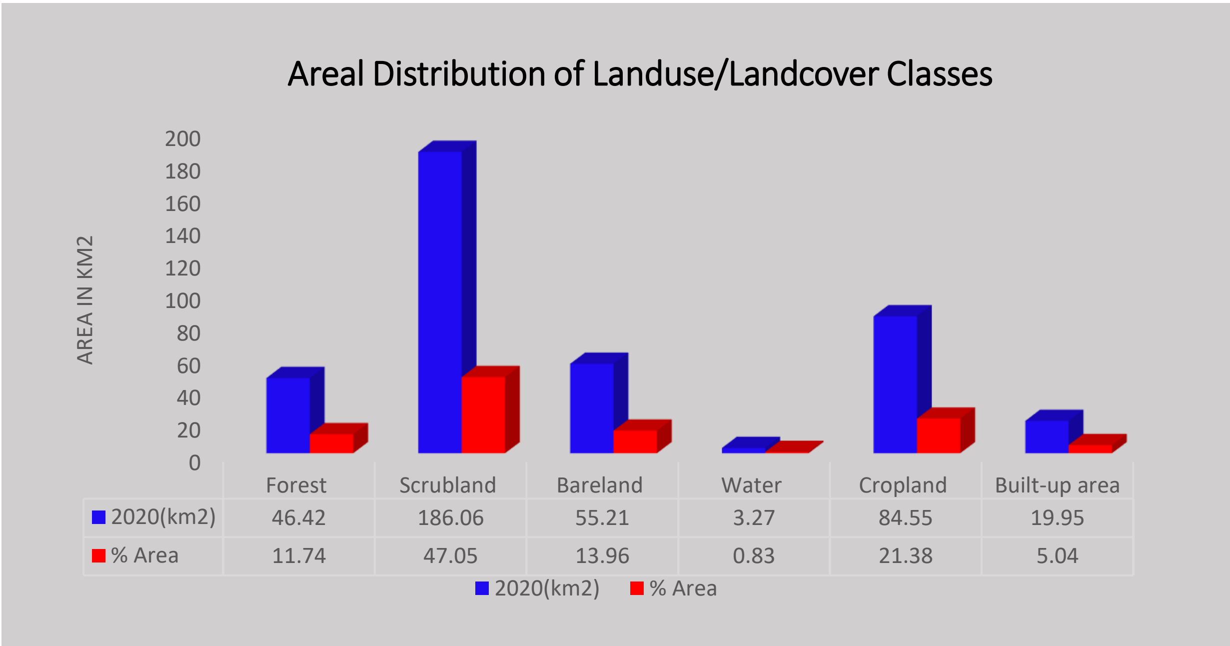


Figure 4. 1 Graphical representation of various land uses and cover within Ngutwa-Nzaui

Spatial-Temporal Changes in Land use/Land Cover within Ngutwa-Nzaui (1987-2020)

The areal coverage of the six (6) land use/land cover types (Table 4.2) shows that they have undergone substantial modifications from 1987 to 2020. Within this window, built-up areas and cropland increased exponentially, with water showing a steady increase over the years. Bareland remained relatively stable over the years, with a significant reduction in bareland witnessed within the last decade (Table 4.4). Areal coverage under forest and scrubland decreased significantly from 1987 to 2020. Generally, the major gains in coverage by the various land use and land cover included built-up areas, cropland, water, and bare land. On the other hand, forest and scrubland reported net losses for the last three decades. Although built-up areas cover the least space they have undergone the greatest increase from 1987 to 2020 (refer to table 4.4).

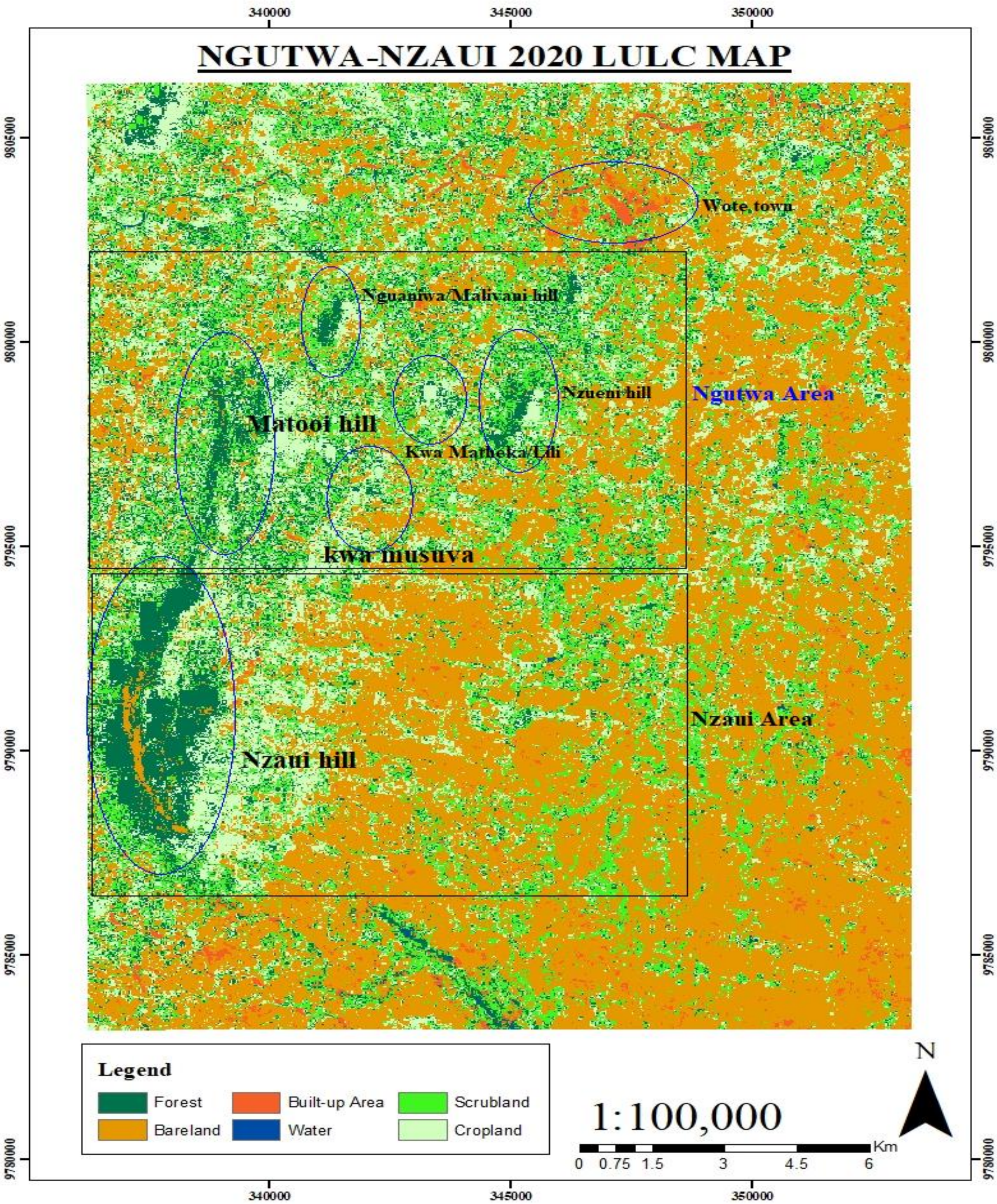


Figure 4. 2 Key biodiversity sites within Ngutwa-Nzaui area

Though vegetation in these sites occur as relics, they play an important role in the conservation of the target threatened plant species. Worthy noting is that some locals have kept large tracts of indigenous vegetation intact and thus have immensely contributed to this conservation efforts.

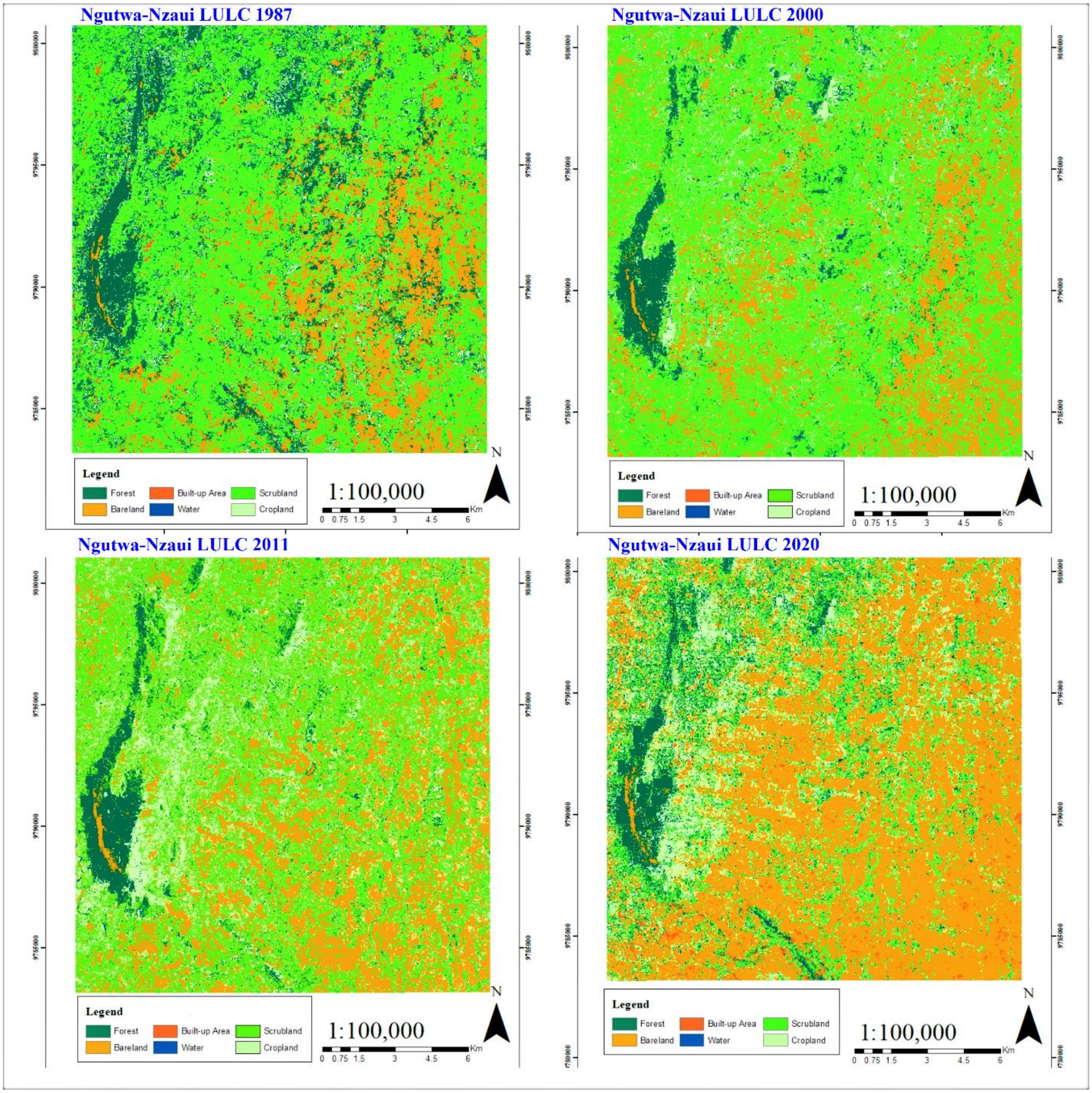
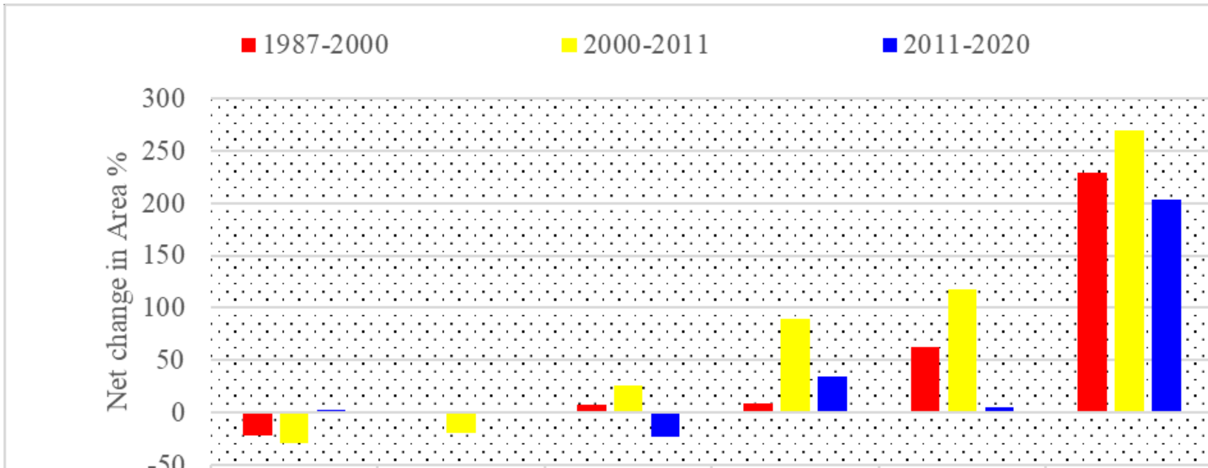


Figure 4. 3 Ngutwa-Nzaui Land Use Land Cover Changes for 1987, 2000, 2011 & 2020

Comparing Land Use Land Cover map for 1987 and 2020 (see figure 4.3) shows great change in built-up areas, cropland and bareland within the study area.



	Forest land	Scrubland	Bareland	Water	Crop land	Buit-up area
1987-2000	-21.7	-0.65	6.96	8.4	62.61	229.63
2000-2011	-29.84	-19.24	25.79	89.15	117.32	269.66
2011-2020	3.04	-1.49	-23.4	34.02	5.12	203.19

Figure 4. 4 Decadal net changes (%) for the six LULC categories within Ngutwa-Nzaui

From the results (Figure 4.4) the built-up area accounted for the most significant net gain in areal coverage with 3594.44%, followed by cropland (271.49%), water (174.79%), and bare land (3.06%) across the three decades. On the other hand, forest land accounted for the largest net loss of 43.4%, followed by scrubland with 20.96% between 1987 to 2020.

Changes in Forest Land

Within the Ngutwa-Nzaui area, most of the forest land is concentrated around Nzaui forest hill, Matooi hill, and shrinking pockets of natural vegetation in Nguaniwa and Nzueni hills (Figure 4.2). Among all the identified land use/land cover types, forest land has experienced the greatest disturbance (43.4% loss from 1987 to 2020). Decade to decade analysis indicates that 2000 – 2011 recorded the highest forest loss of 29.84%, which means an average of 2.7km^2 of forest were lost every year between 2000 and 2011 (Table 4.3). The decline in forest land between 1987 to 2011 within the Ngutwa-Nzaui area is consistent with the national decline in forest cover from 7.9% in 1990 to 5.9% in 2010 (Muhati *et al.*, 2018). From the land use/land cover maps of 1987 (Figure 4.3), a relatively dense and closed forest is concentrated on hilly areas of Nzaui, Matooi, Nguaniwa, and Nzueni, marked by an increased disturbance in 2000, 2011, and 2020. In 1987, about 80% of the study area was covered by forest and scrubland, with fewer areas settled by people and cultivated. In 1987, most locals were concentrated on the low-lying areas at the base of the hills; however, as the population increased and weather conditions became drier, they started settling on relatively higher elevations causing disturbances on vegetation established on hills. Increasing human population heightened the demand for more land to settle and cultivate as depicted in land use/land cover maps for 2000, 2011, and 2020 (see figure 4.3).

This forest decline is blamed on a nature of factors both nationally and locally, such as prolonged drought, agriculture, overexploitation, among others. According to UNEP, 2000, Ngaira, 2004; KRCS,2005; OCHA, 2009) Kenya has recently received drought incidences in the following years; - 1987, 1991-1992, 1994-1995, 1999-2000, 2004-2006, and 2008-2009. At a local scale, Mutua *et al.* (2016) observe that Makueni has encountered meteorological droughts in 1997, 2003, and 2011 will less severe forms of food shortage in 1999, 2000, 2001,2004, 2005, 2006, 2007, 2008, 2009. This is a clear indication that droughts have frequently visited Makueni county over the last three decades. Therefore, overexploitation of forests resources as an alternative source of income in time of such droughts could have contributed immensely to the loss of forest cover within the study area between 1987 to 2011. While between 1987 and 2000, only four occasions of drought were recorded, more occurred between 2000 and 2011. Therefore, it is hereby assumed that these droughts were accompanied by a famine that forced most of the locals to engage in destructive forest activities such as charcoal burning, illegal logging as an alternative to crop farming. Similarly, this is consistent with the highest increase (117.32Km^2) of land under crop compared to 62.61Km^2, 5.12Km^2 in 1987-2000 and 2011-2020, respectively. The onset of that decade (2000-2011) was marked by a severe drought (1999-2001) that saw 4.7 million Kenyans slide to an urgent need of food support. According to Kirumba (2019), this was the worst drought to be experienced in 37 years, whereby about 23 million Kenyans were directly or indirectly affected through crop failures and livestock deaths, with more food shortages experienced in arid and semi-arid lands. In an attempt to arrest such food shortages within the study area, the locals left their farmlands under fallow and established new farms, possibly in forested areas where soils are fertile and less eroded. This observation concurs with the highest increase in bareland (25.79%) between 2000 and 2011.

Unlike all this worrying trend of decreasing forest cover, the last decade has witnessed (though slight) positive change (3.04%) in areal cover under forest. These climate shocks have forced the locals of Makueni county to embrace some on-farm adaptation strategies. They include conservation agriculture, agroforestry, water harvesting, and afforestation. According to Kitinya *et al.* (2012) and GoK (2014), planting trees has become a common on-farm adaptation practice among many locals in Makueni. This increase in forested land by (3.04%) between 2011 and 2020 is attributed to the Makueni county government's efforts to encourage the planting of trees through its greening programmes in schools and public areas. Some of the drought-tolerant tree species used in this greening effort include *Mellia volkensii*, *Thevetia peruviana*, and *Euphobia tirucalli*. These adaptation strategies have also led to the conservation of water and soil. Some locals have also started commercial forestry by establishing *Eucalyptus* and *Grevillea robusta* plantations. Another critical element of County Integrated Development Plans (CIDP) for Makueni county (2018 – 2022) is water resource management, by conservation of water towers and wetlands, either through institutionalized or individualized tree planting (Government of Makueni County, 2018).

Wood fuel continues to be the primary source of cooking energy in Kenya's rural settings due to its high calorific value, accessibility, and affordability as compared to other non-wood-based fuels. As the demand of firewood has increased, this has, in return, contributed to forest loss; however, the locals' agroforestry and other afforestation activities have reduced the impact as evidenced by positive change (+3.04%) in forest cover between 2011 and 2020.

Population pressure is a key driving force to forest fragmentation, which involves resources extraction, conversion of forests to pave the way to human settlement and agriculture and its related infrastructural development (Crooks *et al.,* 2011). Forest fragmentation by human-related activities presents more detrimental consequences than nature-related factors (Wade *et al.*, 2003). The human population in Makueni county has increased from 636,825 in 1989 to 987,653 in 2019, an increase of 55.09%. According to Kenya Population and Housing Census (2019), population density in 2019 was 121 from 86 in 1989. At the local level, the Makueni sub-county had a human population of 116,110 in 2009 and increased to 130,375 in 2019 (Government of Makueni County, 2020).

Changes in Scrubland

This land use/land cover occupied an area of 186.06Km^2 as of 2020 after undergoing a loss of 20.96% from 1987. Further, decadal analysis shows the highest loss (19.24%) was experienced between 2000 and 2011, whereby an average of 0.6Km^2 of scrubland was lost annually between the same time gap. This land use/land cover is believed to have suffered the same threat as forest. Some of the major contributing factors to the loss of scrubland include conversion to farms, human settlement, and most importantly grazing fields which are common in the study area. Climatic variability in Makueni county has replaced some palatable grass species such as *Cenchrus ciliaris, Enteropogon macrostachyus,* and the *Chloris roxburghiana* with low-palatability ones which include *Sporobolus africanus* (MoALF, 2016). Other herbs that serve as fodder but are lost include Oxalis and *Leucaena leucocephala*.

Since the study area is more of *combretum*-wooded grassland, grazing is one of the economic activities. Overgrazing, as identified as one of the significant threats facing the target species, leads to excessive nibbling and trampling causing soil erosion and loss of herbs and grass-main elements of scrubland. The Makueni county government has enhanced feed and fodder production in gullied and denuded landscapes such as Nzaui, Kibwezi, and Kilome (Government of Makueni County, 2018). In this effort, the county government is introducing drought-tolerant grasses and fodders and in others encouraging low-cost systems of pasture conservation such as silage and hay bailing among the locals.

Changes in Bareland

Ngutwa-Nzaui area, just like other areas of Makueni County, has its share of barren land. Although percentage change in bareland from 1987 to 2020 presents a slight increase (3.06%), decadal analysis demonstrates otherwise. In 1987, 13.54% (53.57Km^2) of land within Ngutwa-Nzaui was bare, which later increased to 18.23 % (72.08Km^2) in 2011. This means that between 1987 to 2011, on average 0.8Km^2 of bare land was being created every year. A befitting justification for the increase in bare land between 1987 to 2011 is poor land management practices such as slash and burn, farm abandonment, and increased soil erosion. It is also worthy to note that the increase in bare land (35%) from 1987 to 2011 corresponds to a decline in forest cover by 45% during the same time. (Though this comparison in changes in land use/land cover is insightful, transition rates between the various land use/cover categories will yield a more precise estimate). However, this phenomenon underscores the role of anthropogenic factors in land degradation. Climate change is also believed to contribute to the increasing barren land within the study area.

However, over the last decade, the proportion of bare land has decreased within Ngutwa-Nzaui from 72.08 Km^2 in 2011 to 55.21 Km^2 in 2020, an equivalence of 23.4% decrease. This is attributed to the afforestation and reforestation campaigns through the greening initiative by the Makueni county government. Similarly, soil and water conservation measures through climate-smart initiatives such as conservation agriculture and minimum tillage. Besides, gradual colonization of these bare land by vegetation such as shrubs, grasses, and bushes due to soil and water conservation measures instituted by the Makueni county government and the locals.

Changes in the area under water

Makueni County is generally arid and semi-arid land with inadequate water supply as its locals travel a relatively long distance to access water. This acute shortage is attributable to prolonged drought, drying water sources because of forest degradation, and uncontrolled sand harvesting. The locals of Ngutwa-Nzaui source their water from seasonal springs, rivers, wells, boreholes, and earth dams, and in times of drought, water becomes a rare commodity. Generally, the areal coverage of water has steadily increased over the last three decades. In 1987, the area under water was 1.19 Km^2 (0.3%) which increased by 8.4% to 1.29 Km^2 (0.33%) in 2000 and 2.44Km^2 (0.62%) in 2011which later increased by 34.02% to 3.27Km^2 (0.83) in 2020.

Further, decadal analysis shows that between 2000 and 2011, there was the highest increase in area under water by 89.15%. Contrastingly, this decade was marked with frequent drought incidences which arguably led the Kenya national governments to invest in water provision in drylands through the construction of earth dams and sand dams. After the promulgation of the 2010 Kenya constitution, crucial water and sanitation functions were devolved, and the Makueni county government has established several water projects to that effect. The county government invested significantly in water harvesting, storage, and distribution for 2013-17. According to the government of Makueni county (2018), locals who could access potable water rose from 21% to 35.6% between 2013 to 2017. Similarly, the locals' distance to fetch water decreased from 8km to 5km during the same period (Government of Makueni County, 2018). In this line, it has established the Makueni County Climate Change Fund Board, which has led to a 2% increase in forest cover from 2013 to 2017.

Within the study area, these efforts by the Makueni County government are evident. It has constructed either earth dams, sand dams along rivers, or boreholes in almost every village within Ngutwa-Nzaui. It has also strengthened rainwater harvesting and subsequently enhanced the storage capacity among the locals. In similar efforts, farm water harvesting has been improved in the design and construction of earthen roads (road cut-off drains) in the study area and throughout the county. Other county government water and soil conservation measures include conservation agriculture through zai pits, cover cropping, farm ponds, and terracing, which are common with the Ngutwa-Nzaui area.

Further, to ensure sustainability in water management, the county has built the local community capacity for sound water management through education. It has also enacted various regulations to enhance water governance. One such effort includes the Sand Conservation and Utilization Act of 2015, enforced by the County Sand Authority (CSA), and aims at equitable and sustainable utilization of sand (GoK, 2015).

Changes in cropland

Crop farming is the primary source of livelihood for the locals of the Ngutwa-Nzaui area, and as such, the area under cropland has increased with growth in the human population. In 1987, 5.76% (22.76Km^2) of land within the Ngutwa-Nzaui area was covered by crops, which progressively increased by 271.49% to 84.55Km^2 (21.38) in 2020. Further, a decade to decade analysis shows that the highest percentage change in cropland was between 2000 and 2011, where areal coverage increased by 117.32%. This means that, on average, 10.7Km^2 of cropland was created each year during the same period. Although more droughts were encountered within this decade, it appears that the locals increased their farms arguably to maximize food production. Contrary to what was previously envisioned, this did not increase output, perhaps because of unreliable rainfall and poor agronomic practices. One farmer had this to say, '*Between 2000-2011, there was frequent drought and famine, and therefore I cleared more vegetation to get more food; unfortunately, I realized I could not take proper care of the crops, some even dried young.*' It appears that the locals invested a lot of effort in extensive farming than intensive farming, possibly because of the inaccessibility of farm inputs and extension services. After Kenya ushered in a devolved system of governance in 2013, most of the agricultural functions were transferred to the devolved units (counties), where they are within reach of many farmers. This increased local engagement in decision-making processes. According to the Government of Makueni County (2018), agriculture, water, and environment were ranked the most pressing needs among many locals. Since its inception, the Makueni county government has invested in increasing water availability and agricultural production by embracing appropriate and modern technologies.

Through the increased support from the Makueni county government, the locals transitioned from extensive to intensive farming, as evidenced by the slightest change (5.12%) in cropland between 2000 and 2020. Only 4.12Km^2 were created for crop farming compared to 14.25Km^2 and 43.42Km^2 in 1987-2000 and 2000-2011, respectively. With increased extension services from the Makueni county government, more production from a relatively small areas of land were achieved as shown in figure 4.5.

Table 4. 5 Field size and production of various crops in Makueni sub-county from 2015-2019

Crop	2015		2016		2017		2018		2019	
	Field size (Ha)	Crop production (MT)	Field size (Ha)	Crop production (MT)	Field size (Ha)	Crop production (MT)	Field size (Ha)	Crop production (MT)	Field size (Ha)	Crop production (MT)
Maize	32,802	49,260	31,240	36,600	31,450	42,560	31,245	36,560	32,150	48,457
Sorghum	3,360	3,815	3,200	3,650	3,210	3,601	3,180	3,598	3,240	3,667
Millet	500	374	476	340	486	280	485	275	500	300
Beans	4,662	5,872	4,440	5,520	4,435	5,501	4,230	5,380	4,500	5,540
Cow peas	18,480	19,129	17,600	18,950	17,200	18,800	16,800	18,750	17,800	18,820
Green grams	25,562	14,790	24,345	14,500	23,453	14,651	23,545	14,680	24,345	16,685
Pigeon peas	27,090	21,670	25,800	21,245	25,500	20,750	25,450	20,135	26,456	21,345
TOTAL	**112,456**	**114910**	**107,101**	**100,805**	**105,734**	**106,143**	**104,935**	**99,378**	**108,991**	**114,814**

Source: Department of Agriculture, County government of Makueni

Various crops grown within the Makueni sub-county include Maize, sorghum, millet, beans, cowpeas, green grams, and pigeon peas, as shown in table 4.5. Of these crops, maize, cowpeas, green grams, and pigeon peas are grown on a large scale.

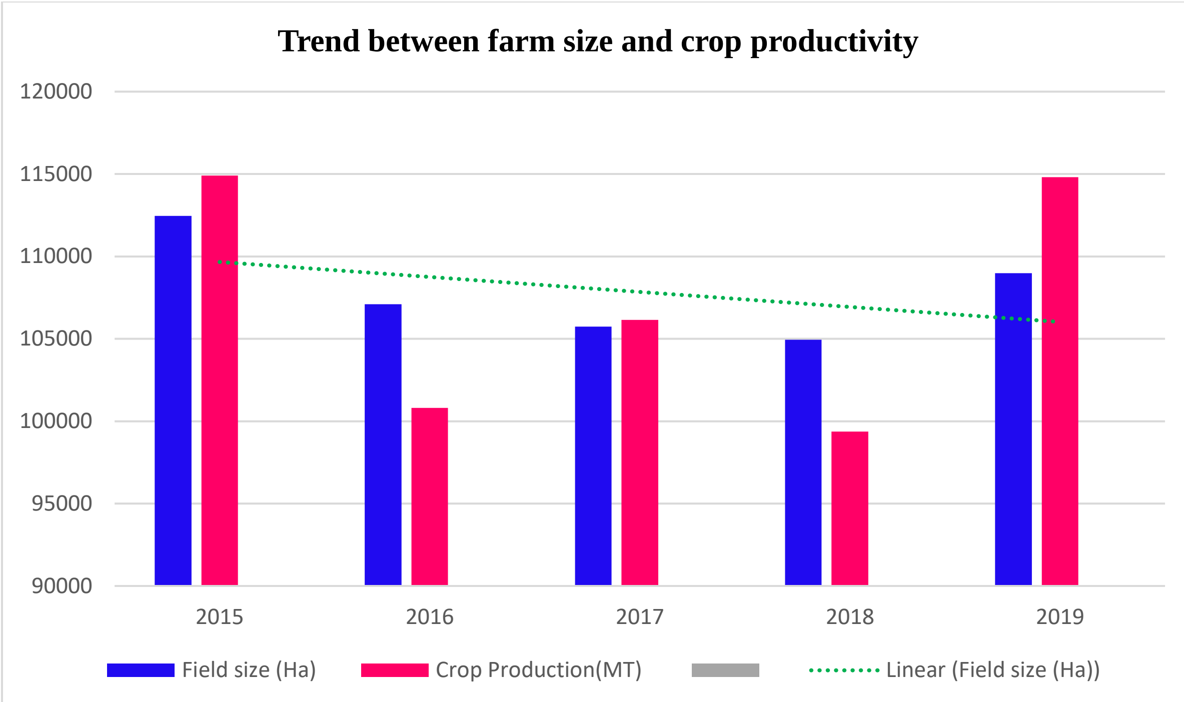


Figure 4. 5 Trend between farm size and crop productivity within Makueni sub-county from 2015-2019

There is a general decline in farm size from 2015 to 2019 (Figure 4.5) among the locals of Makueni-sub-county. As already discussed, this trend is attributable to the adoption of good agronomic practices within the Makueni sub-county (Ngutwa-Nzaui included). Against a backdrop of climate change, there has been a growing emphasis on using less land to produce higher yields while reducing environmental impacts.

Changes in built-up areas

According to the 2019 Kenya population and housing census, the Makueni sub-county (Ngutwa-Nzaui included) is the second most populated sub-county in Makueni after Kibwezi, with 130,375 people spread out in 34,479 households (Kenya National Bureau of Statistics, 2020). While in 2009, the human population in this sub-county was 116,110, there are 130,375 individuals according to the last census (2019), an increase of 12.3% (Kenya National Bureau of Statistics, 2020). This burgeoning population does not only cause increasing demand for more food but also shelter. Table 4.4 shows that the built-up area exponentially increased by 3594.44% from 0.54Km^2 (1987) to 19.95Km^2 in 2020. According to the tabled statistics (table 4.3), on average of 108.9km^2 of land was either converted to human settlement, commercial building, or a transport infrastructure between 1987 to 2020 within the Ngutwa-Nzaui area.

Further, a decade to decade analysis shows between 2000 and 2011, there was the highest percentage change in built-up area. This corresponds to the highest loss in both forest cover and scrubland. Built-up areas led to the loss of vegetation and increased impervious land surfaces that encouraged surface run-off and soil erosion. The presence of the target species alongside roads and human settlement indicates the impact of these infrastructures on biodiversity. With the devolved system of government, many earthen roads have been established by the Makueni county government within the Ngutwa-Nzaui area. Therefore, it is believed that this development has replaced a substantial level of vegetation, including the target species.

4.1.2 Community Perception Results and Discussion

The local people are assumed the best judges in determining what is of importance to them, and therefore the study engaged them in assessing their attitudes towards their environment.

Figure 4. 6 Locals using Pebble Distribution Method in determining relative importance values.

Two separate focused group meetings were held throughout the study area, one at Ngutwa and the other at the Nzaui area. While the informant group in Ngutwa consisted of 20 people (9 men, 7 women, and 4 youth), 25 people in the Nzaui area attended, including 10 men, 7 women, and 8 youth. Attendance between the two separate focused group meetings showed that patriarchal norms influence roles and responsibilities in the study area. Notably, this rigid construction of gender roles is weakened as female attendees almost equaled their male counterparts in both group meetings. Further, this explains an increasing active involvement of women in decision-making processes. Youth attendance between the two regions sharply contrasted as there were twice as many youth attendees in Nzaui as there were in the Ngutwa area. As discussed in the recommendation, this strengthens the bid to establish a youth ecotourism venture in the Nzaui forest and its environs. On the other hand, there is the need to increase awareness among the youth in Ngutwa area.

A total of sixteen (16) ecosystem goods and services were identified by the locals of the Ngutwa-Nzaui area (see table 4.6). While the locals of Nzaui identified fifteen (15) ecosystem goods and services vital to them, those of Ngutwa identified sixteen (16).

Table 4. 6 Identified Ecosystem goods and services and their relative importance values.

Ecosystem Type	Ecosystem good and service	Relative Importance Value (RIV)			
		Present		After 10 years	
		Ngutw'a	Nzaui	Ngutw'a	Nzaui
Provisioning	Provision of water	0.15	0.20	0.16	0.22
	Firewood	0.13	0.12	0.12	0.11
	Timber and Poles	0.12	0.14	0.12	0.14
	Fodder/pasture for livestock	0.10	0.09	0.10	0.06
	Charcoal production	0.09	0.08	0.09	0.06
	Herbal medicine	0.07	0.07	0.05	0.04
	Fruits and vegetables	0.06	0.05	0.04	0.03
	Manure	0.05	0.03	0.04	0.03
	Fencing (live)	0.05	0.03	0.02	0.01
	Honey production	0.04	0.05	0.05	0.06
	Wild meat	0.04	0.02	0.03	0.01
Cultural	Aesthetic/ Ornamentation	0.03	-	0.03	-
	Cultural sites (Sacred groves)	0.03	0.03	0.02	0.05
	Tourism	0.02	0.06	0.04	0.07
Regulative	Purification of Air	0.01	0.02	0.05	0.06
Supporting	Home for plants and animals	0.01	0.01	0.04	0.05
Total		**1.00**	**1.00**	**1.00**	**1.00**

It is evident that the locals easily identified ecosystem goods and services that offered direct use value, and therefore perceived them to be very important. Provision of water was ranked highest across the two areas, Ngutwa (15%) and Nzaui (20%), and would remain equally important in ten years. With the two ecosystems located in dryland areas, water is a life-sustaining resource in cultivating crops, which is the main economic activity in the area. Water is also an indispensable resource for human and animal use. From the table 4.6, water ranks highest (20%) in the Nzaui landscape due to its proximity to the Nzaui water tower, which has 16 springs (Kenya Water Towers Agency, 2020).

Figure 4. 7 Some of the sources of water for the locals of Ngutwa-Nzaui area.

In the figure, (a) shows a water collection point in Nzaui hill, (b) Water holding point before being distributed to around five villages within Nzaui area.

Unlike in the Ngutwa area, the Nzaui area has a reliable water supply, as evidenced by various permanent springs in the area. These permanent springs source water from Nzaui hill, a forested area accorded legal protection and thus minimal human disturbance. Out of 16 springs within the Nzaui water catchment area, only three seasonal springs (Kithoni, Itaa, and Ngutwa) are within the Ngutwa area (Mumbuni location). In this case, there is no permanent spring within the Ngutwa area, and therefore during dry spells, the locals fetch water from constructed earth dams, boreholes, and wells dung along dry river beds. Makueni country government has, over the past few years, intensified its efforts in reducing water shortage through the construction of earth dams, sand dams, boreholes, and rock water harvesting.

The provision of firewood, timber, and poles was also perceived important among the locals of the Ngutwa-Nzaui area. While in the Ngutwa area, firewood is more critical than timber and poles, the locals of the Nzaui region attach more weight to timber and poles than firewood, possibly because of illegal logging from the Nzaui forest. This was evident during the mapping exercise whereby the team identified various tracks where illegal lumberjacks transport timber and poles. In 2018, the government of Kenya imposed a forest harvesting moratorium on logging in public and community forests which came with socioeconomic implications (Kagombe *et al.,*2020). This has led to illegal harvesting of poles and timber from the forest. Firewood is the primary energy source for cooking and space heating due to its availability. Besides, firewood is relatively cheaper than alternative energy sources such as electricity, liquid petroleum gas (LPG), and kerosene. In a 2015/2016 baseline survey, it was estimated that 84.3% of rural households in Kenya and 77.9% of rural households in Makueni county use firewood as the main source of cooking fuel (KIHBS, 2018). According to the Kenya Water Towers Agency report (2020), over 90% of locals within the Makuli-Nzaui area use firewood and charcoal for cooking and heating. This clearly demonstrates the importance of the ecosystem in providing firewood, timber, and poles.

In ten years, the locals perceive a slight drop in the demand for fire energy sources. This could be explained using alternative and clean sources of energy such as liquefied petroleum gas which is gaining popularity in some rural households within the study area. Secondly, there is a likelihood of 'fuel stacking' phenomena (Nyambane *et al.,* 2014) within the study area for the next ten years. There will be no complete shift from firewood but a combination of two or three fuel sources. Wood is a key building and construction material within the study area whose value is not expected to fall as clearly evidenced in table 4.6. Both the locals of Ngutwa and Nzaui believe that poles and timber will remain important in ten years as it is today. A rise in demand for timber will cause increased afforestation initiatives, whether individually or collectively. A similar effect was witnessed in the 2018 forest moratorium while led to increased afforestation efforts in both public and private lands (Kagombe *et al.,* 2020).

Other ecosystem goods and services relatively crucial between the two areas are pasture, charcoal production, medicine, fruits, vegetables, and manure. Though herbal medicine is equally important in both Ngutwa and Nzaui areas, its relevancy among the locals is expected to decrease. Currently, health care provision in the area is scarce as the locals are forced to travel at least four (4) kilometers to the nearest health center. This usually forces them to use traditional herbal medicines as their first choice before going to health centers. In devolving health services delivery, the Makueni county government, through its county-level health insurance scheme (MakueniCare), has seen many of her residents access affordable healthcare services. Similarly, dispensaries and other healthcare facilities have been increased in wards and sub-wards in an attempt to ensure accessible healthcare to the locals. As this continues, the reliance on herbal medicine among the locals is expected to decrease in years to come, as portrayed in the table 4.6**.**

Air quality and habitat for both plants and animals were lowly ranked with average relative importance values of 1.5% and 1%, respectively. A probable explanation for this could be, processes such as air quality needs a more profound understanding, and these services do not have direct household consumption. As noted elsewhere by Cifuentes-Espinosa *et al.* (2021), some regulations and supporting ecosystem services are complex to identify. However, appreciation of the two ecosystems as sources of quality air and biodiversity habitat is projected to increase in the next ten years, a consistent observation made by Kisiwa *et al.* (2020) that most regulative and supportive services are expected to appreciate in value.

Worth noting is the role played by cultural services in the lives of Ngutwa and Nzaui locals. Though cultural sites (sacred groves in particular) are equally important at present between the two areas, Nzaui locals see more importance (0.05) in their cultural sites than Ngutwa residents (0.04) in ten years. Again, the study tried to determine why the locals held such attitudes to sacred groves within their area. Most of those from Nzaui singularly referred to a famous cultural site in Kithoni (within the Nzaui area) that has continuously served the locals with water even in the driest of months. This observation strengthens their perception that the provision of water will be more important (0.22) to them in ten years. Contrarily, the Ngutwa area attaches lesser importance to her sacred groves, as evidenced by increased destruction to pave the way for agriculture and developments. A similar observation is made on the limited knowledge of the locals (average 0.01) on their ecosystem as habitats for both plants and animals. Though seemingly unknown by the locals, sacred groves play a critical role in biodiversity conservation. Some of the mapped subpopulations of the target threatened plant species existed in sacred groves that have, over time, enjoyed protection from traditional beliefs. Due to erosion of cultural values among the current generation, this is being lost as portrayed by locals of Ngutwa (0.02). Though tourism is lowly ranked within the two sites, it will be more important in Nzaui than Ngutwa within ten years. This is perhaps because of more cultural and scenic places in Nzaui than in Ngutwa (see more in the recommendation section herein), highlighting the potential for eco-tourism activities in the area.

Perception of biodiversity threats by the locals of Ngutwa and Nzaui area

Before developing conservation strategies, it is recommended that the stakeholders fully understand the local community’s perception of the ecosystem services (ES). Kisiwa *et al.* (2020) note that a critical driver to forest degradation is the lack of appreciation for the values derived from ecosystem goods and services. The scoring exercise assessed the relative magnitude of biodiversity threats in Ngutw’a and Nzaui ecosystems. Primary threats to biodiversity were identified, and their relative importance values are tabulated in table 4.7.

Table 4. 7 Relative magnitude of biodiversity threats as perceived by local communities in Ngutwa-Nzaui.

Threats	Relative Importance Value (RIV)	
	Ngutw'a Area	**Nzaui Area**
Encroachment (agriculture and settlement)	0.34	0.32
Overexploitation/overharvesting	0.19	0.25
Prolonged Drought	0.14	0.13
Soil erosion	0.12	0.11
Fire	0.08	0.12
Road development	0.12	0.06
Invasive species	0.01	0.01
Total	**1.00**	**1.00**

Ecosystem encroachment (agriculture and human settlement) was perceived to contribute significantly to biodiversity loss in Ngutw'a and Nzaui areas, with relative importance values of 34% and 32%, respectively. This is consistent with land use/land cover changes (LULCs) results where areal land under cropland and buildings has increased by 271.49 Km^2 and 3594.44 Km^2 respectively for the last thirty-three years. Agriculture is the main economic activity in the Ngutw'a-Nzaui landscape, with maize, beans, and fruit crops (oranges and mangoes) being predominant. As the human population increases, more land for agriculture and settlement heightens, leading to forest degradation or fragmentation and subsequent biodiversity loss. Unsustainable use of natural resources through overharvesting of timber and poles, illegal logging, firewood, and charcoal burning, among others, is also perceived to significantly contribute to loss of biodiversity in both Ngutw'a (19%) and Nzaui (25%). In Nzaui, over-extraction of timber and illegal logging is believed to cause more harm because of its proximity to the Nzaui forest. Logging reduces land cover exposing the soil to agents of erosion and high temperatures, which adversely affect biodiversity. Charcoal production in both ecosystems is an alternative source of income and fuel, affecting indigenous trees more than exotic ones. Herbivory and continued trampling by large herds of goat, sheep, and cattle reduce grass cover and other herbaceous plants that prevent the soil from agents of erosion.

Prolonged drought ranks third in importance value as a threat to biodiversity in Ngutw'a and Nzaui ecosystems, with 14% and 13% respectively. The two ecosystems lie in arid and semi-arid lands of Southeastern Kenya, where recurrent drought conditions are prevalent. Drought leads to a decline in the quality and quantity of water discharge from water sources in these two ecosystems leading to drying up of vegetation and loss.

Either from slash and burning or wildfires, fires are also a significant factor in biodiversity loss. A striking variation in relative importance value shows Nzaui is more prone to these fires (12%) than Ngutw'a. This implication is consistent with the Kenya Water Tower Agency report (2020), which indicated that wildfires are a recurrent phenomenon, especially during the dry season. These fires may be caused by sparks from traditional flaming torches during honey harvesting, charcoal burning, or instigated by unscrupulous timber enterprises. Road construction and invasive species are other low-ranking factors perceived by local community members to threaten the provision of ecosystem goods and services. The locals think invasive alien plant species pose less harm (1%) because of a lack of adequate information about them. Because of this information gap, some locals have intercropped crops with alien species with allelopathic tendencies, such as *Eucalyptus* species.

4.1.3 Mapping Distribution of Target species and their uses

Mapping the distribution of threatened plant species is a demanding task because they occur in small and patchy distributions that are not easy to locate. Due to this and other reasons, information about threatened plant species is limited and thus poorly known, as evidenced by many youths unaware of target species compared to their older counterparts. Some locals within the Ngutwa-Nzaui area expressed their fears on the study's mapping exercise, citing increased biopiracy as their as one of the reasons. Further research showed that the study area experienced *Aloe* poaching sometime back and currently East African sandalwood (*Osyris lanceolata*). Because of the study's targeted mapping, others feared that such efforts were geared towards drug discovery. Cognizant of all these challenges, the study adopted an approach based on cooperation with reciprocal benefits. Throughout the project cycle, the study engaged the locals in all the activities and shared the results of the project activities. They were also trained on basic procedures of great importance to them, such as establishing poly-tunnels.

To enhance consistency, objectivity and comparison across widely different taxa, IUCN guidelines and definitions were adopted in the study. While the word population in the common biological usage may be misleading, its usage under the IUCN Red List Categories and Criteria means total number of the individuals of a species. According to IUCN (2001 and 2012b), subpopulation means geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange. The operational approaches of determing the number of subpopulations differs substantially between taxon and strict adherence to this definition considers subpopulation as spatially distinct subset of the population encountering insignificant exchange from other subpopulations. Although subpopulations exhibit minimal exchange, they are not completely isolated. According to IUCN (2003; 2012a), subpopulations assessed under the above criteria (possible exchange with other subpopulations) must follow regional guidelines.

Although it may be used as subset of global data at regional, national, and local level, IUCN criteria is majorly designed for global species assessments. In this case, a global category may not be the same as national or even local category for a particular species. A taxon, (such as *M. vatkei*) categorized based on its fast-global decline in numbers or range as endangered may not meet the criteria of being endangered at local level where populations may appear stable or decreasing at a lower rate. Although IUCN criteria may be applicable to geographical scale, its usage within very restricted geographical areas (such as the study area) may be inappropriate. In small area such as the study area (Ngutwa-Nzaui), the target taxa may frequently exchange individuals with neighboring areas, resulting to unreliable assessment under IUCN Red List Criteria (IUCN 2012a). However, national application of the IUCN criteria in the assessment of endemic taxa (*M. vatkei*-endemic to southeastern Kenya, *E. friesiorum* and *P. teitana* both endemic to Kenya) are regarded as global assessments.

The determination of the subpopulation's size considers numerical thresholds and mature individuals only. According to the IUCN Standards and Petitions Committee (2019), mature individuals are those known, estimated, or inferred to be capable of reproduction. For the re-introduced individuals (such as some individuals of *E. friesiorum* within the present study), they are counted as mature individuals only if they have produced viable offspring (IUCN 2001, 2012b). Similarly, suppressed, senescent, juvenile, and low-density individuals are not counted as mature individuals as they may never produce new recruits. The interpretation of mature individuals differs quite substantially in estimating individuals known, estimated, or inferred to be able to reproduce. Reproduction should not be used to mean just mating or exhibiting reproductive behaviour but being able to produce viable offsprings. In determining which individual can reproduce, insights on the target taxa's biology is crucial in making the right judgement.

Due to less floristic studies within the study area, adequate information about the distribution of the target threatened plant species is scarce. Therefore, extant localities of the target species were mapped at the finest spatial scale available. Mapping at finer scale shows more localities in which the target species is unrecorded compared to coarse scale mapping which reveals fewer unoccupied areas. Additionally, it was necessary to upscale to obtain estimates of subpopulations at reference scale represented by 2x2 km grid as recommended by IUCN Standards and Petitions Committee (2019). The subpopulations were standardized to a reference scale (2x2 km scale (4 km2)) to ensure parsimony with the IUCN Red List Criteria.

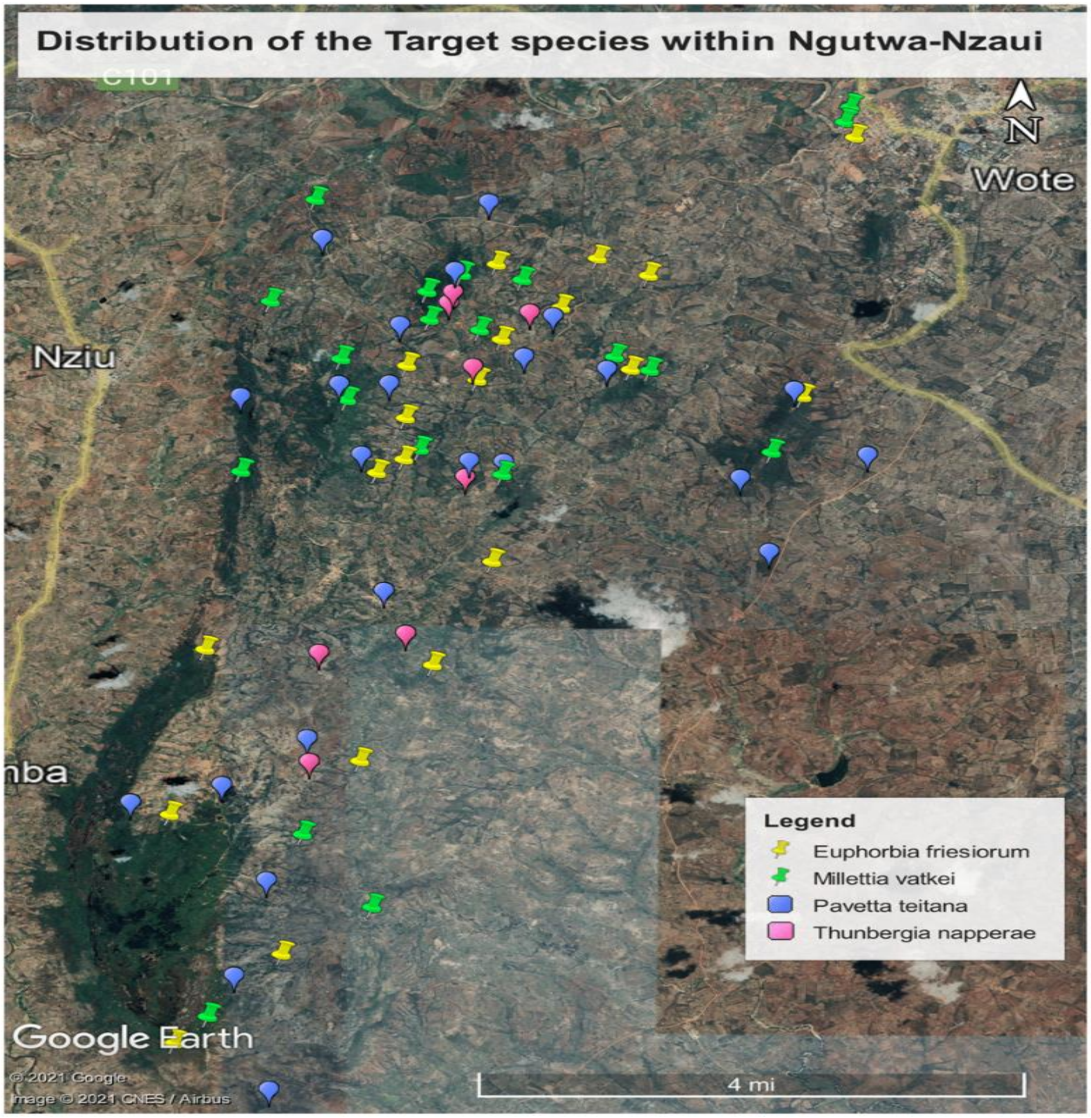


Figure 4. 8 **Spatial distribution of the target threatened plant species within Ngutwa-Nzaui area**

Mapping the distribution of threatened plant species is the first step to their conservation. Therefore, as a prerequisite to the conservation of *M. vatkei*, *T. napperae*, *P. teitana,* and *E. friesiorum,* the study determined the spatial distribution of the above-imperiled flora. Throughout the mapping exercise, the study identified fifteen (15) subpopulations of *M. vatkei* with an estimated size of about 300 mature individuals. Fifteen (15) subpopulations of *E. friesiorum* were mapped with about two hundred (200) mature individuals. *P. teitana* recorded the highest number of approximately 500 mature individuals spread across 19 subpopulations within the study area. *T. napperae* was the rarest with the least subpopulation size among the four-plant species. Seven (7) subpopulations of this species yielded less than hundred (<100) mature individuals. The target threatened plant species representation by their subpopulation sizes is as in the figure 4.9. All the species were in their flowering and fruiting phenology at the time of mapping.

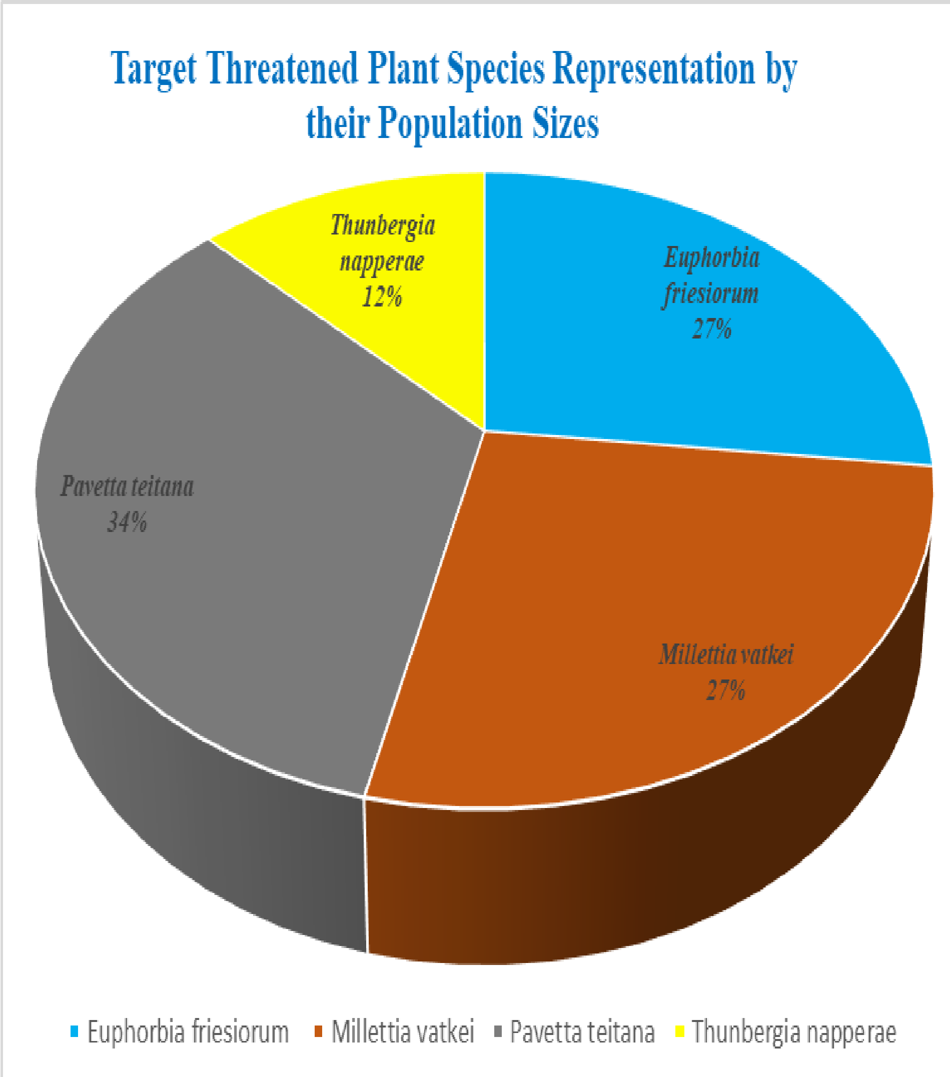


Figure 4. 9 Representation of target threatened plant species by their subpopulations.

- **Uses of the Target Threatened Plant Species to the Local Community**

While all the four-target species were of great importance to the local community, this varied from one species and household to another. The uses ranged from herbal medicine for various diseases, construction materials, livestock fodder, boundary demarcation, and both manure and mulch for crops. The study also found that the methods used to harvest these species in part or whole were unsustainable.

1. *Millettia vatkei*

This species was found to have multiple uses among the locals of Ngutwa-Nzaui. One of the common ones is a source of dry season fodder for their livestock. *M. vatkei* is green throughout the year and thus appropriate feed for animals during the dry season. The tender parts, especially young twigs with their buds, are cut and fed to the animals through the cut and carry system. An alternative is tethering the animals within close range to the *M. vatkei* stands. When pasture is inadequate, this results in stripping of barks from their stems. Besides, this species has a potential for animal alimentations as seeds are consumed by granivores in times of food shortage. *M. vatkei* is commonly used in constructing structures among the locals of Ngutwa-Nzaui. Its stems are pliable and thus often used in building traditional houses (walls and roofs), grain storage silos, among others.

Figure 4. 10 A traditional grain storage silo among the Kamba community.

A traditional grain storage silo (locally known as 'Kiinga') among the Kamba community. Made from *M. vatkei* stems and fastened with fibers from the same species. (Photo: Akamba cultural center and Museum).

M. vatkei played a crucial role in the Akamba basketry industry before the introduction of the sisal. Its soft inner bark contains fibers used to make strings for hand-woven baskets (Nthungi/kyondo). The strings were chewed to soften them before weaving the baskets. Besides, the process of chewing aided healing of body pains. The fibers were used to make ropes for various purposes. For example, the ropes served as plugs for gourds, fastening firewood after collection and piles of grass during traditional house-thatching. Also, the locals used these ropes to tether animals in the grazing fields.

Figure 4. 11 Ropes made from *M. vatkei* fiber used as plugs for gourds

(Photo (a): Akamba Cultural Center and Museum).

M. vatkei remains vital in the Akamba traditional therapeutic arsenal. It is used in the treatment of body pains. While leaf and stem bark decoction were used to treat mild body pains, feverish aches, and general tiredness, root bark decoction was preferred for severe forms of pains. The mode of usage involved washing the whole body with the decoction, and at times steam bathing was used. While some traditional practitioners among the local community used a single species therapy, others used combined species therapy involving *M. vatkei* and *Uvaria scheffleri* in the treatment body pains.

Additionally, this species plays a significant role in agroforestry systems. Being legume, they fix atmospheric nitrogen, thus improving soil quality, possibly the reason they are considered in agroforestry. The locals of Ngutwa-Nzaui use *M. vatkei* within their farms in several ways. Firstly, they collect the dry and fallen leaves and use them as manure during farming. Secondly, they use the same dry leaves as mulch for their cultivated crops. These two uses are linked since the mulch decay forming manure rich in nitrogen for their crops. It was found out that the locals usually collect these leaves during the dry season before the rains. Within the study area, logging for charcoal production is intense during the dry season, and since *M. vatkei* remain evergreen, their leafy branches are used in traditional earth kilns whereby they support the soil during the sealing of the cut logs.

Figure 4. 12 Dry *M. vatkei* leaves used as mulch-cum-manure

2. *Euphorbia friesiorum*

It is locally known as *Musilia* (Kamba). Interestingly, out of all the *E. friesiorum* subpopulations mapped, most of them were found at the edges of homesteads or less than 20 meters from the compound. They are usually discarded after their use during treatments from where they re-establish themselves. Like other *Euphorbias*, it is locally used to demarcate boundaries and as a live fence around homesteads and farmlands. Since the study area is relatively dry, the locals have demonstrated their preference for this species in boundary demarcation because of its ability to withstand such dryland conditions. Similarly, because of the caustic latex, they have escaped herbivory by animals and other natural enemies, perhaps the reason they have persisted in live fences within the study area. The latex is poisonous and can cause conjunctivitis when it gets into the eyes, and as a result handling of this plant has been accorded some care.

Although the latex is vesicant, it has some beneficial uses as well. It is mixed with butter or ghee and then used in cooking. Also, it plays an essential role in folkloric medicine for the treatment of various ailments. It is used to cure rashes on human skin and toothache whereby the milky resin from its fruit is applied to the aching tooth. The possible mode of action is to 'kill' the tooth to minimize pain. Besides, the stem is burned, and the ensuing charcoal is grounded and mixed with milk or porridge, then drank for the treatment of coated tongue (*Kivuti*-Kamba) or any other sores along the gut. The latex is also used to extract a thorn lodged in flesh whereby it is applied to the point of entry to corrode the flesh holding it. Also, its stems are used in making a traditional bee smoker for use during honey harvesting. The strong irritant smoke harms the bees, and therefore it is sometimes mixed with thin sticks from other plant species to produce a cool smoke used to subdue the bees without negatively affecting them. Fully-dried stems of *E. friesiorum* are used as firewood. Because of its good agronomic characteristics such as drought resistance, *E. friesiorum* is an excellent candidate for afforestation and re-forestation initiatives in drylands. Its various uses are an added advantage to its adoption as a hedge crop, ornamental, medicinal herb, and other agroforestry purposes.

3. Pavetta teitana

Within the study area, it is locally known as '*Muthongoi*.' Because of its straight stem, it is used as timber and twinning poles for construction purposes. Besides, it has medicinal properties as leaf decoction is used to treat body pains. They can also be dried and ground to powder that is mixed with water and drank for treatment of urine retention. The stem is burnt, and the ensuing charcoal used to treat tooth sores (*Mutata*-Kamba) among children. The leaves can also be chewed in the treatment of the above health conditions. In combined therapy, it is mixed with *Plectranthus cylindraceus* (Kio kinini) for the treatment of body pains and head ache.

4. *Thunbergia napperae*

Most of the locals were unaware of the existence of this species. It had no local name, possibly because of its rarity. Besides, no use was attached to it perhaps due to the abovesaid reason.

• Documentation of Traditional Technologies and Practices

A conservation initiative that builds upon intimate indigenous practices usually benefits from wider acceptance by the locals within where the outcomes of such efforts are utilized. Indigenous communities have always passed a tested knowledge of their developments and traditional technologies of resource utilization, a type of knowledge that rivals modern science. Therefore, conservation efforts must pursue the goals of those pushing them and should be cumulative and adaptive through the inclusion of the local communities' aspirations. According to Los and Timmer (2005), though good for enhanced production, new knowledge is most applicable when used together with technologies like those of the inventor. Therefore, transferring technology may fail to take root in the target area and thus prove unsustainable. In respect to this, appropriate technology should be built upon already existing technological knowledge of the local community. In the quest for sustainable ways of conserving biodiversity within any given locality, the local's ways of doing things should form the foundation for carrying out such initiatives.

Local communities in Kenya's arid and semi-arid lands (ASALs) have accumulated a wealth of indigenous knowledge about their environment (plants and animals included). Disregarding such ideas is a detachment from their lived experiences and may attract less project acceptance and thus failure to achieve desired goals. Therefore, empowering indigenous knowledge of the dryland rural communities of the Ngutwa-Nzaui area formed the bedrock for sustainable conservation of *M. vatkei, T. napperae, E. friesiorum,* and *P. teitana.* Transformative homegrown and grassroot-based ingenuity in traditional agriculture among these locals was accorded a special place in this study. Therefore, the study incorporated existing indigenous practices in conserving the target threatened plant species within the study area. It started by exploring the basic tenets of the local's ingenuity and then proceeded to use some of the technologies in the study.

Although there was an increased rate of adoption of modern methods of raising seedlings among a few organized groups, most of the locals within the study area were still using traditional methods and practices. For example, in table 4.8, the study documented and drew comparisons between some local traditional technologies and their modern scientific surrogates. For instance, during interview with some locals, it was evidently true that cold-water soaking was an old-age practice among them, especially during planting seasons whereby some soaked their seeds overnight before planting the following day. Unfortunately, hot-water soaking was not practiced because of the fear of boiling the seeds. During the training, the locals were taught about hot water pre-soaking and the types of seeds pre-treated through the method. Hot water scarification plays an essential role in seed germination, especially the hard-coated ones. This method softens the hard seed coat and controls seed-borne diseases that damage seedlings (Muniz, 2001; Singh, 2020). It prevents not only surface seed infections but also deep-seated ones. Another contested discussion among the locals was the length of soaking before planting. This depends on the temperature of the water used; hot water calls for a reduced time of soaking while warm water soaking duration can be extended. Following this, *M. vatkei* seeds were soaked in warm water overnight before planting the following morning

4.2.3 Documentation of Existing Indigenous Technologies within Ngutwa-Nzaui area

Table 4. 8 Comparison between traditional practices within the study area with modern scientific technologies

s/no	Traditional Indigenous practice	Image	Modern scientific technology	Image
1.	Bottle gourd (*Lagenaria siceraria*) fitted with perforated metallic tin on the mouth (locally known as *ivungu*) and used for watering seedlings. Such gourds have a punctured hole on their side through which water is poured into it. The gourd is large enough to contain about 10 liters of water.		Watering can	
2.	Perforated washing basins and Jerican cut in half and tightly covered with a transparent polythene film. They are tightly fastened with a rubber-band to hold the sheet in place.		Non-mist propagator or Humid germination chamber	
3.	Used milk packets, plastic tins, and bottles used as sleeves. With the recent ban of single-use plastics by the Kenya government, many locals within the study area have turned to re-using milk packets, used metallic and/or plastic containers/ bottles as potting tubes.		Potting tubes/sleeves They come under different gauges and sizes based ones need.	
5	Mosquito nets Some locals used mosquito nets to shield their seedling beds. They used them to protect their young seedlings from crickets, birds, chickens etc		Shade net They come under different densities based on the climatic conditions. High-density shade nets (70-80) are applicable in hotter areas and low-density ones (50-60) in colder areas. However, farmers can use both eg depending on the crops and the desired shade conditions. They can use high-density ones on the roof and a lower density shade on walls.	

6	Crop residue as mulch Some locals used crop residue such as dry grass to cover their seedling beds from excess sunlight. It was also used to prevent excess water loss through evaporation.		Plastic mulch Though concerns have been expressed about the use of plastics, researchers are designing biodegradable and non-plastic mulches that are friendly to both the farmer and the environment. (Photo by Leahy, 2019).	
7.	Use of 'dead' fence Some locals used rows of cut thorny branches of *Acacia mellifera* piled around the small plants to keep browsing animals such as goats away from them.		Wire-mesh welded cage for protecting small plants from being eaten by animals such as goats, cows, rabbits	
8.	Grain storage silo locally called '*kiinga*'. Alternative to this and commonly used even today within the study area is the gourd and plastic containers. The grains were mixed with wood ash and pepper and the put on the gourd or containers which when full were sealed with cow dug at the 'mouth'. This approach deprived the weevils of oxygen.		Hermetic storage bags Most people today rely on organic-hermetic storage. They prevent metabolism of the organisms (eg weevils) inside the grains by creating a low oxygen modified environment inside hermetic storage bags. Reduction of oxygen levels in the grain to 5-10% stops any activity by the organism and they die. (Photo by Bibwe *et al.,* 2017))	
9.	Optimizing pesticidal plants Some locals planted tobacco within their nurseries to repel pests from their seedlings. Similarly, wood ash was used by the locals as a termicide. They mixed it with the growth media.		Termicides and insecticides such as Fipronil- based insecticides	

4.1.4 Documentation of Threats

The four conservation targets for the project are faced with a suite of threats that continue to challenge their existence. Therefore, identifying which threats to address may be difficult. The ranking of threat is an appropriate way of determining which threat to address first to meet the desired objectives. Using a set criterion of extent (scope), severity, and irreversibility to rank the priority of threats enabled the project team to focus its efforts on conservation actions urgently needed to reduce threats to the target species. Throughout the threat documentation exercise, the study quantified the extent to which various factors were a threat to the existence of the target species and their habitat. A coarse-scale examination identified the following level two threats; housing & urban areas, annual & perennial non-timber crops, wood & pulp plantations, livestock farming & ranching, roads & railroads, gathering terrestrial plants, logging & wood harvesting, fire & fire suppression, dams & water management/use, invasive alien species and droughts. Further, it undertook a fine-scale analysis to capture the local situation and better the understanding. In this, the study merged related level 2 threats and divided others based on the real situation within the study area. Surprisingly, this merger and division effort yielded a list almost similar to that developed by the locals during simplified threat assessment (weighted scoring). Therefore, the following threats were found to be adversely affecting the existence of the target species within the Ngutwa-Nzaui area; habitat loss (occasioned by agriculture, overexploitation, herbivory, soil erosion, infrastructure development, and fires), the introduction of alien (non-native), and invasive species and finally droughts.

1. **Habitat loss**

Within the Ngutwa-Nzaui area, destruction of natural habitat through degradation or fragmentation was found to be posing the greatest threat to the survival of the target species. Human activities are rapidly altering habitats, and every single day, there are fewer spaces left for them. The following indicators of disturbance were documented; -

(a) Herbivory

Overgrazing/browsing by animals was found to be contributing to the decline of the target threatened plant species. *T. napperae*, which occurs mostly on glades within the study area (figure 4.13d) was heavily impacted by livestock grazing. Those sheltered by other larger species were healthier and taller than those within the glades, most of which were nipped-off by animals (see figure 4.13c). Similarly, *M. vatkei*, which remains evergreen, forms a good fodder for domesticated and wild animals. When fodder is inadequate during the dry season, locals feed their animals with this species (see figure 4.13 a and b). Because of the limited number of other green fodder during the dry period, the animals consume the leaves, the pods, and at times the barks.

Indigenous knowledge and personal observations show that *M. vatkei* forms a good nesting site and fodder for rock hyraces and ochre bush squirrel because of their dense-matted characteristics. Rock hyraces are gregarious diurnal herbivores that live in rock crevices near *M. vatkei* stands.

Because of the limited studies or lack thereof, the relationship between *M. vatkei* and rock hyraces within the study area is poorly understood, and therefore their preference for this species largely remains anecdotal. Although they are secretive and shy to people, the study validated the local's knowledge of their feeding behavior through inferences. It thus explained the rock hyraces' preference for *M. vatkei* in several ways; - Both *M. vatkei* and rock hyraces prefer rock outcrops as their suitable habitat. Due to the heat stress prevalent in drylands, the humidity retained within rock crevices helps these animals survive in such areas. They usually forage less than 50m for their dens because of thermoregulatory and denning requirements. Since *M. vatkei* thrive well in rocky habitats, it forms a convenient food for these animals. They also feed on grasses and herbs, which die-back in the dry season, forcing the hyraces to rely solely on the evergreen *M. vatkei*. Besides, domesticated animals shift to browsing on *M. vatkei* during dry seasons, exerting more pressure than during wet seasons. These herbivores prefer young leaves, new shoots, and buds to more woody portions, and at times of acute shortage, they are forced to consume coarser parts such as pods or even debark the stems.

Figure 4. 13 Herbivore pressure on *M. vatkei* and *T. napperae* within the study area.

From the figure, (a) shows heavily browsed *M. vatkei* (b) a cow tethered on *M. vatkei* stands (c,) nipped-off *T. napperae* regenerating (d) a glade with surviving *T. napperae* on the periphery sheltered by a bush (e) *P. teitana* on an overgrazed area.

The frequency of feeding among rock hyraces is another interesting characteristic. They usually forage in groups of 10 to 50 individuals. This strategy offers several advantages, such as vigilance and dilution effect during predation. Rock hyraces have a larger surface area exposed to their volume and therefore lose more heat per unit volume than larger animals such as cattle. They thus recover the lost heat by feeding more over a short time in the morning after sunrise, late in the evening before sunset, and at times on moonlit nights. *M. vatkei* offers a safe foraging site because of the sub-vertical stems that make climbing easy for them.

An increased conversion of *M. vatkei* subpopulations to farmlands was observed during field investigation. Therefore, the fast-declining *M. vatkei* subpopulations will lead to increased herbivory rates occasioned by perhaps constant or increasing hyrax populations. Also, it's worth noting that hyraces' preference for *M. vatkei* forms an interesting topic that can serve as a source of motivation for further studies.

(b) Agriculture

Agriculture is the main economic activity among the locals of the Ngutwa-Nzaui region. As the human population continues to increase, the locals have also intensified the conversion of forested lands into farmlands. As observed during mapping exercise, the locals are currently encroaching on natural vegetation in higher elevations which were previously avoided. Within the study area, more *M. vatkei* subpopulations are concentrated on higher altitudes than low-lying areas saturated with human settlements. Luckily, a few disturbed *M. vatkei* individuals were encountered on the edges of such cleared areas. They were completely defoliated, and fire scars were all evident from their stems. On the cleared *M. vatkei* habitat were finger millet with some young seedlings of *Eucalyptus* species scattered all over.

Figure 4. 14 A forested land cleared to pave way for finger millet farming within Ngutwa-Nzaui.

As mentioned elsewhere, natural vegetation within the Ngutwa-Nzaui landscape is highly fragmented and only occurs as '*islands'* in farmlands (see figure 4.15). What was once continuous natural vegetation is now sub-divided by people's farmlands punctuated by small forest patches serving as a haven for the target species.

Figure 4. 15 'Islands' of natural vegetation within cropland within the study area.

Because of the continued land fragmentation, some individuals of the target threatened plant species were found within abandoned farmlands and on the edges of forest fragments. For example, figure 4.16 (a & b) shows a surviving *E. friesiorum* in a fallow land on the edge of a mango orchard within the Ngutwa-Nzaui area. Similarly, in figure 4.16 (c) shows a regenerating young *M. vatkei* within a newly established farm.

Figure 4. 16 Effects of agriculture on the Target Threatened Plant Species' habitat within Ngutwa-Nzaui.

In the figure, (a) shows a *E. friesiorum* individual growing on edge of a mango orchard, (b) sprouting *E. friesiorum* in a fallow land, (c) *M. vatkei* re-growing in a newly established farm within the study area

Additionally, it was found out that the locals usually collect humus under *M. vatkei* stands for their crops (4.17-a). Rock hyraces usually use communal latrines collecting large amounts of fecal pellets in one place. For example, during field investigation, the locals showed the project team one such midden (latrine) that serve as a source of manure, and which was about 5m deep (see figure 4.17-b). These dens often occur in *M. vatkei*-shaded areas within rock formations and seeming uninhabitable nooks on sheer cliff faces (refer to figure 4.17-d). For this reason, the locals clear this dense-matted *M. vatkei* to access these middens easily. Figure 4.17(c) shows a *M. vatkei* branch that possibly survived disturbance during manure collection. These twin threats (clearance during manure collection and herbivory by hyraces) were found to contribute to the declining numbers of *M. vatkei* within the study area.

Figure 4. 17 A rock hyrax midden surrounded by *M. vatkei* used as source of manure.

In the figure, (a) shows a local collecting manure in a midden beside a rock crevice, (above) a dry *M. vatkei* branch circled in red (b) rock hyrax communal latrine (c) a surviving *M. vatkei* branch (d) a seemingly uninhabitable nook on a rock cliff face.

(c) Soil Erosion

The Ngutwa-Nzaui landscape is a dryland ecosystem characterized by high temperatures and low, unreliable rainfall. These conditions favor the establishment of glades with loose soil particles, which make the soil susceptible to wind and water erosion (see figure 4.18-a). All the mapped subpopulations of *T. napperae* occurred within these unsheltered glades. Indicators of soil erosion were evident from various rills witnessed during the mapping exercise (Figure 4.18-c). As evidenced by cattle tracks (see figure 4.18-b), grazing by livestock within these open spaces worsened the effects of erosion on the target species. When it rains, the run-off water exposes the plant's roots (see figure 4.18-d) or even wash away the whole plant.

Also, *M. vatkei* was encountered along eroded streams and rivers, with some individuals submerged in sand. Unlike the other three target species, *M. vatkei* roots hold soil particles together, minimizing the chances of being washed away by water. This supports the information gathered from the locals that '*M. vatkei is a difficult plant which is hard to uproot or eradicate once it establishes itself on your farm.'* Therefore, this, too, explains why some locals disapproved planting it within their farms. Importantly, these expressions demonstrate the suitability of *M. vatkei* in restoring partially degraded areas. A substantial number of the *M. vatkei* population were safer in deep gullies where disturbances were minimal. Through this detained observation, the study chose these gullied landscapes as appropriate receptor sites for enrichment and translocation efforts for the following two reasons. Firstly, such area denies frequent human entry and therefore experience less human interference. Secondly, the use of *M. vatkei* in such partially degraded areas controls further soil erosion.

Figure 4. 18 Indicators of soil erosion within Ngutwa-Nzaui area.

In the figure, (a) is an eroded glade hosting a *T. napperae* individuals (b) cattle track and (d) exposed roots of *T. napperae* by run-off water.

(d) Infrastructure Development

With the devolved system of governance, Makueni county has witnessed various projects such as road construction and maintenance, water development, and erection of housing structures among others (see figure 4.20). As discussed elsewhere in this report, the built-up area increased significantly from 1987 to 2020 within the Ngutwa-Nzaui area. These new developments have come with both direct and effects on the area's flora. The construction of earthen roads in the region has had the highest impact not only on the target threatened plant species but also on the general vegetation. Some subpopulations of threatened plant species have been lost, with others occurring as extremely small subpopulations of less than five individuals on either side of the road. The existence of these imperiled individuals on roadsides exposes them further to herbivory from the passing animals and dust from vehicles which hinder pollination.

Increased human settlement has also eliminated or interfered with these target species within the study area. Although some *E. friesiorum* individuals were planted within homesteads because of their medicinal values (figure 4.19-a), others were adversely impacted by such settlements. For example, figure 4.19 (b) shows a young *E. friesiorum* in an abandoned site possibly regenerating after the threat was eliminated.

Figure 4. 19 Effects of settlement on the target threatened plant species within the study area.

In the figure, (a) shows a house (background) erected beside a *E. friesiorum* individuals, (b) an abandoned house with a young *E. friesiorum* (foreground), (c) A young *T. napperae* regenerating after having been buried by sand piled in a construction site within Ngutwa-Nzaui area.

Other effects of settlements on the target species are shown in figure 4.19(c) whereby a young *T. napperae* is seen regenerating after the sand burying it in a construction site was used. This can also be blamed on the lack of awareness on the target species among the local community.

A relatively high number of target species was observed along roads and paths within the study area as in figure 4.20 (a, b, c & e). Occurrence of *E. friesiorum* along roads and paths could be explained in several ways; the development of the roads has unintentionally transferred parts of *E. friesiorum* with soil to other sections where they re-established themselves. Within the study area, most paths are by design established between two different land ownership, and this boundary is usually demarcated by drought resistant plants species such as sisal and *Euphorbias* e.g. *E. friesiorum.* Since the area is arid, the Makueni county government has also invested substantially in water harvesting through the construction of pans, earth, and sand dams (4.20-d). Though these have benefitted the locals in the provision of water, it has come with loss or fragmentation of crucial plant species.

Figure 4. 20 Impacts of infrastructure development on the target plant species within Ngutwa-Nzaui landscape.

(a) *T. napperae* individual (Indicated by red arrow) growing beside an earthen road (b) young *E. friesiorum* in a roadside, (c) *E. friesiorum* growing in a roadside cliff after road maintenance, (d) a recently constructed dam by the Makueni county government within the study area, (e) a road dividing a *M. vatkei* population into two within the study area.

(e) Overexploitation

All except one of the target species have high utility within the Ngutwa-Nzaui area as they serve as either timber, dry season feed, or have medicinal properties. As mentioned somewhere else herein, *M. vatkei* is used as a dry season pasture, used for construction, and has medicinal properties. With the increasing population, these species are overharvested, leading to a decline in their numbers. Similarly, the methods of harvesting are not sustainable, leading to more mortalities. For example, *M. vatkei* stems are stripped of their inner bark to make strings and herbal medicine. Since this species is ever-green, the locals commonly use it in the cut-and-carry system whereby young twigs, together with their buds, are cut and fed to the animals. *P. teitana* is used for construction by the locals as it forms good timber. Over-extraction brought about by the increasing human population is threatening this species' existence.

Figure 4. 21 Indicators of overexploitation within the study area.

In the figure, (a) shows a red pod *Terminalia* harvested as pole for construction purposes, (b) pile of firewood witnessed with the study area.

Both *E. friesiorum* and *P. teitana* are used by the local people as a source of medicine. While *P. teitana* is used by the locals to treat body pains, *E. friesiorum* is used to cure toothache, coated tongue, and cow glands. The medicinal purposes attached to these species create demand and open more doors for their continued over-extraction. Besides, the approaches used to extract them destroy the mature individuals.

Firewood/charcoal is a cheap energy source for locals of the Ngutwa-Nzaui area. All except *T. napperae* are used as wood fuel for cooking. As the human population continues increasing, so is the pressure to extract more in the form of firewood and charcoal. It was found out that the locals collect not only dry stems as firewood but also cut live branches and pile them in bunches for them together to dry (see figure 4.21-b).

(f) Fire

Though fire is used as a management tool in forest conservation, it poses a great threat to the existence of plants when out of control. The study established that prescribed burning was used (though on a small scale) in converting forested land into farmlands. At times, the fire is uncontrollable and thus destroys unintended vegetation nearby. During the field assessment, incidents and effects of uncontrolled fires were noticeable within the study locality. Some surviving individuals of *M. vatkei*, *P. teitana*, and *E. friesiorum* species were encountered with fire scars. Incidences of fire differed substantially between protected areas (Nzaui forest) and unprotected areas (Ngutwa). In unprotected areas, fire is usually used by the locals in preparing their farms, while in the protected area (Nzaui forest), fires ignition results from the illegal honey collection, charcoal burning, and retaliatory from the locals.

Fortunately, the frequency of fire occurrences within Nzaui forest has substantially decreased. In interview with the Kenya Forest service (KFS) area forester, the study established that involvement of the local community in the forest management greatly contributed to low fire frequencies. The community has played a key role in policing and in putting off fire when it occurs.

Figure 4. 22 Effects of fire on *E. friesiorum* and other vegetation types in the study area.

In the figure, (a) shows a section of Nzaui forest regenerating after fire incident, (b) surviving young *E. friesiorum* individual after uncontrolled fire in Ngutwa area, (c) postfire stumps in Nzaui forest indicating occurrence of fire, (d) charred tree trunks within Ngutwa area and (e) establishment of dense secondary vegetation dominated by giant ferns after fire incident in Nzaui forest.

2. Introduction of alien (non-native) and/or invasive species

Invasive species is the second main threat to biodiversity after habitat loss. Ngutwa-Nzaui has witnessed an increasing single-species introductions of exotic timber species such as *Eucalyptus* species (see figure 4.23-a). Habitats for the target species has been cleared to pave way for such plantation farming. In one of the *Eucalyptus* plantations, the allelopathic effects were evident as what was previously known as the largest population of *T. napperae* was reduced to few individuals (refer to figure 4.23-c). Similarly, before the establishment of the plantation, the area was densely populated with *M. vatkei* stands but currently only few individuals of this species are found restricted to rocky outcrops on the edge of the plantation. As shown in figure 4.23(b) *Eucalyptus* plantation exhibit allelopathic effects which reduce undergrowth.

Figure 4. 23 Impacts of introduced alien plant species on the target species.

In the figure, (a) shows a single-species introduction (shown by blue circle) in a natural vegetation, (b) reduced understory due to allelopathic effects of *Eucalyptus* species, (c) few surviving individuals of *T. napperae* in *Eucalyptus* plantation within Ngutwa-Nzaui area.

Various alien invasive plant species such as *Lantana camara* L, *Dodonaea viscosa* var. *angustifolia* (L. f.) Benth, *Euclea divinorum* Hiern, and *Cuscuta reflexa*, among others, were observed within the study area. Interestingly, *Lantana camara*, which previously established itself in low elevations, was found at higher altitudes during the mapping exercise, indicating their continuing spread presumably due to animal dispersal. In most of the mapped subpopulations, *Lantana camara* was found in close association (see figure 4.24a, b & c).

Figure 4. 24 Prevalence of *Lantana camara* within the study area.

In the figure, (a & c) shows *E. friesiorum* growing in close association with *Lantana camara*, (b) *M. vatkei* growing together with *Lantana camara*.

Another invasive species showing a rapid increase within the study area and identified during the field assessment is *Cuscuta reflexa*. It previously attacked trees but currently has invaded farmlands where it is causing havoc in fruit orchards within the study locality (refer figure 4.25 d & e). *Cuscuta reflexa* is holoparasitic and thus requires a host plant for survival. It kills its host by obtaining water and nutrients from it. During the field investigation, the project team encountered several individuals of *P. teitana*, and *E. friesiorum* densely surrounded by this killer weed (see Figure 4.25 a, b). In other species, effects of the parasitic relationship were evident from the drying branches (refer to Figure 4.25 f). Besides, few individuals of *T. napperae* were found in close association with *Dodonaea viscosa* (see figure 4.25c).

Figure 4. 25 Threats of *Cuscuta reflexa* and *Dodonaea viscosa* on the target species and crops.

In the figure, (a) is a *P. teitana* in proximity with the *Cuscuta reflexa*, (b), *E. friesiorum* surrounded by *Cuscuta reflexa*, (c) *Dodonaea viscosa* within a *T. napperae* population, (d) Avocado plant attacked by *Cuscuta reflexa* (e) invasion of farmlands by the killer weed, (d)-dying effect of *Cuscuta reflexa* on a live fence.

3. **Prolonged drought**

The study site lies within an arid and semi-arid region and therefore, shortage of rainfall and high temperatures was found to be a great challenge to the target species. Limited water leads to drying and loss of vegetation (target species included). For example, of the four-target species, T. napperae was found to be the most affected by extended drought. In such times of water scarcity *T. napperae* usually dieback and re-sprout during rains. Incidences of drought increase the demand for forest resources thereby leading to rapid loss of vegetation cover and land degradation. Additionally, prolonged drought lead to mass drying of vegetation which make it more flammable and hence higher chances of largescale fires. Droughts encourage soil erosion (figure 4.26-a) and drying of plants (see 4.26 b &c).

Figure 4. 26 Effects of drought on target plant species and soil within Ngutwa-Nzaui.

In the figure, (a) shows effects of drought on soil, (b) drying *M. vatkei* and (c) *E. friesiorum* within the study area drying because of drought.

Table 4. 9 **Threat rating summary**

Threat/Target	*Thunbergia napperae*	*Pavetta teitana*	*Millettia vatkei*	*Euphorbia friesiorum*	Summary Threat Rating
Soil erosion	High	Low	High	High	High
Road & Track Development	High	Low	Medium	High	High
Over-exploitation (over-extraction)	Negligible	High	Very High	Very High	Very High
Invasive/alien plant species	High	High	Medium	High	High
Human settlement	High	Medium	Low	High	High
Herbivory	Very High	Low	Very High	Negligible	Very High
Fire	Low	Low	High	High	High
Crop farming	Very High	High	Very High	Very High	Very High
Climate change & severe weather	High	High	Medium	Low	High
Threat Summary for Targets	Very High	High	Very High	Very High	VERY HIGH
Overall Project Rating					

4.2 Mass Propagation and Restoration of *Millettia vatkei* within Ngutwa-Nzaui

Using locally available materials, the study built upon what the locals were already practicing in coming up with an appropriate propagation system that best suits the local community's needs. A good propagation requires an environment with minimal physiological stress. For example, mist propagators have been used to prevent excessive water loss through transpiration. However, such a system has been found inappropriate in areas without reliable water supply and electricity, such as the Ngutwa-Nzaui area.

4.2.1 Establishment of a Propagation System

Figure 4. 27 Engaging the locals in establishing a propagation system.

In the figure, (a) shows the locals of Ngutwa-Nzaui being engaged in constructing a non-mist propagation system, (b) end-view and (c) side-view of the established non-mist propagator.

As an alternative to the mist propagation, the study engaged the locals in constructing a non-mist propagation system using poly-tunnels. These tunnels were used to create a high humid microclimate conducive to germinating the *M. vatkei* seeds. Unlike mist propagators, the use of poly-tunnels has been found effective in areas without reliable electricity and water supply (Murray and Thompson, 1987).

Figure 4. 28 An established non-mist propagator using poly-tunnels.

In the figure, (a) shows two tunnels used in sowing *M. vatkei* seeds, (b) a constructed tunnel inside a wooden frame.

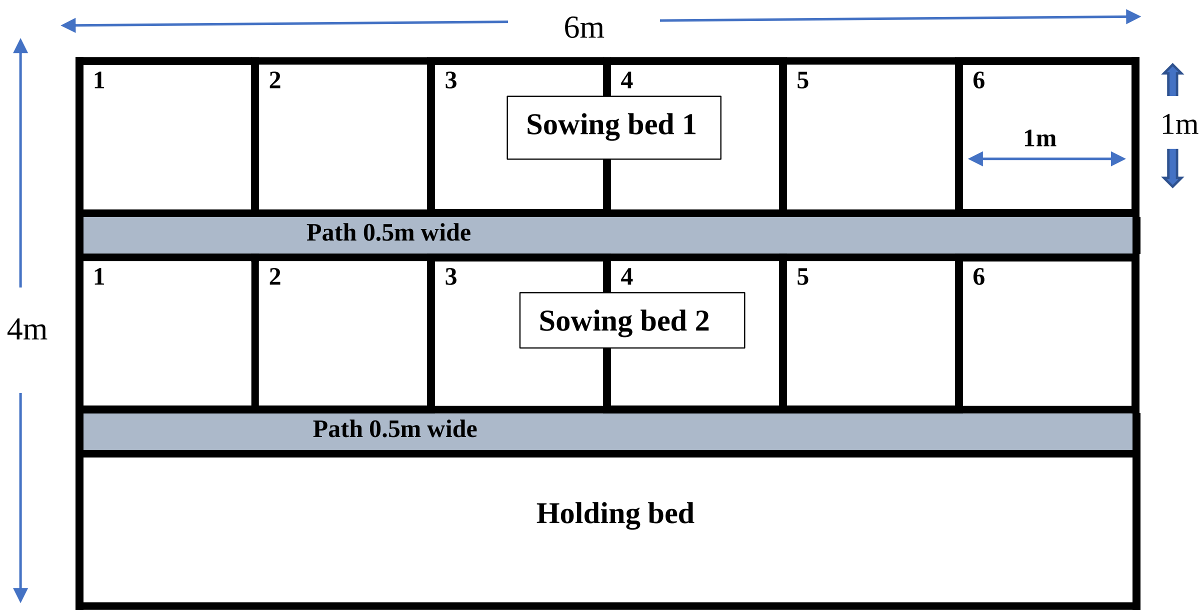


Figure 4. 29 A floor layout of the constructed poly-tunnel.

This layout consists of two sowing beds and one holding bed for immediately transplanted seedlings into sleeves. Within the sowing beds, each is divided into 6 equal blocks.

4.2.2 Collection of Seeds and Mass Propagation of *Millettia vatkei*

According to IUCN (2001; 2012b), locations are geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. Within a location, there may be several subpopulations. For the case of the present study, the most serious plausible threat is habitat loss which occurs gradually and cumulatively through many small-scale events, such as clearance of small areas for crop farming or settlement. Therefore, according to IUCN Standards and Petitions Committee (2019), location is an area over which the target population will be eliminated or severely reduced within a generation. Three locations (Ngutwa, Kathuma and Nzaui) were identified based on altitude (which affect temperature and rainfall regime within the study area) and level of vegetation protection (Nzaui forested area legally protected, both Ngutwa and Kathuma no legal protection). Under climate change, these three locations are defined as suitable habitats for the target species and are reduced because of changes in rainfall and temperature.

Fifteen (15) *M. vatkei* subpopulations were mapped within the Ngutwa-Nzaui area; however, during reconnaissance, ten (10) of them (Ngutwa-6, Kathuma-3, and Nzaui-1) were found to have mature seeds and therefore were demarcated for collection. Thus, using the above subpopulation sizes for each stratum or locations (Ngutwa, Kathuma, and Nzaui), and a proportionate stratified random sampling formula, a stratified sample for each region were as follows; -

Table 4. 10 Populations used in seed collection from each site within Ngutwa-Nzaui area.

Stratum	Subpopulation size	Stratified sample
1. Ngutwa location	6	4
2. Kathuma location	3	2
3. Nzaui location	1	1
Size of entire sample	10	

Therefore, in the Ngutwa area, four (4), Kathuma two (2), and Nzaui one (1) population were used for seed collection (Table 4.10).

Seed collection is the first step towards a successful conservation of threatened plant species. To collect quality seeds, several factors were considered. According to Muthoka *et al.* (2003), a good indicator of high-quality seeds in *M. vatkei* is the color change of the pods from green to brown and when natural dehiscence is ongoing. Seeds from good phenotypes or trees of good form exhibiting luxuriant growth are highly preferred. For this reason, the study avoided collecting seeds from wolf trees, and limby stands with incidences of disease infestation. Cognizant of the rarity of the target species, the collection teams were forced to compromise some phenotypic attributes with seed quantity. For instance, the teams encountered stands of *M. vatkei* with poor form but a lot of fruits/pods. Others were of extremely good form but, unfortunately, with very few fruits/pods to permit an ethical collection. In most of these instances, the teams avoided collecting from very small subpopulations because they have been found to be less attractive to pollinators than large populations (Kunin, 1997; Agren, 1996).

It is believed that reduced cross-pollination encourages mating within related individuals (self-fertilization). Where this was unavoidable, caution was exercised not to over-collect from small populations of the target species. As recommended by Farnsworth (2005), collections were made from less than10% of the individuals in those populations. Still, this was not appropriate in extremely small populations with a limited number of pods and a small proportion of reproducing individuals. Brown and Briggs (1991) recommend that at least ten individuals from each of five populations should serve as seed sources. In our case, the teams collected seeds from less than 5% of the individuals. Since some populations flowered at different times compared to those of the same kind, the collection was carried out twice per year, each coinciding with two rain seasons encountered within the study area. Unfortunately, the unpredictability of the rain season, as commonly experienced in the area, greatly influenced the timings for seed collection and some planned project activities. This was addressed by engaging locals in collecting seeds.

Though direct sowing is relatively inexpensive to restore threatened plant species, the use of seedlings, especially in stressful areas, has recorded a higher survival rate (Godefroid *et al.*, 2011). Seeds are cheaper to establish than seedlings, but they present a low survival rate (Kaye 2009). Therefore, the study preferred seedlings raised in a propagator to direct sowing to increase the survival rate. To supplement these seedlings, the teams collected *M. vatkei* saplings, which had sprouted from seeds banked in the soil and out-planted them to the field.

A total of 3011 *M. vatkei* seeds were realized after cleaning and were subjected to water floatation technique before the final pre-treatment. After 108 seeds floated and were discarded, A total of 2903 seedlings were retained as viable seeds for sowing. While a total of 2903 seeds were sown, only 2528 germinated. There was 87% germination after 375 seeds (13%) failed to sprout. The first emergence was realized during the third week after sowing the seeds. Maximum germination was achieved on the fifth week, and all the viable seeds had grown by the tenth week after sowing.

Figure 4. 30 *M. vatkei* seedlings grown in the established tunnel.

One advantage realized using a tunnel in the propagation of *M. vatkei* was minimal water loss and fast emergence of seeds.

Figure 4. 31 Potted *M. vatkei* being hardened-off before transplantation.

In the figure, (a) shows a 2-month young *M. vatkei* seedlings, (b) 5-Month *M. vatkei* seedlings (c) *M. vatkei* seedlings being hardened before being transplanted into the field.

The study also used bare-root *M. vatkei* seedlings from natural regeneration (see figure 4.32) for transplanting. 200 of this were used in the recovery efforts in the identified areas within the Ngutwa-Nzaui area.

Figure 4. 32 A photo of *M. vatkei* seedlings established through natural regeneration.

Figure 4. 33 Snails posing a challenge to the growing *M. vatkei* seedlings.

In the figure, (a) is an image of snails attacking potted seedlings, (b) affected seedlings (c) snails attached on a potted *M. vatkei* seedling.

4.2.3 Integrated recovery strategy for *Millettia vatkei*

There is no substitute for *in-situ* protection of rare and threatened plant species. However, since most of the existing subpopulations of *M. vatkei* in the Ngutwa-Nzaui area are in privately owned lands where legal protection is not possible, augmentation, re-introduction, and translocation were considered. The study adopted the three-step process in planning for the restoration of the declining subpopulations of *M. vatkei*. This species is represented by few and highly fragmented subpopulations within Ngutwa-Nzaui, and therefore reinforcement (IUCN 1998), similarly referred to as enhancement (Allen, 1994), was the first approach applied. The remaining subpopulations of this species within the study area indicated that survival for the enhancing *M. vatkei* seedlings was possible. Initiatives of this nature work best in non-degraded and protected sites; unfortunately, only Nzaui forest has been offered legal protection, with most of the remaining subpopulations occurring in private lands which are relatively degraded. Though the recipient sites identified were degraded, they were still functioning and, therefore, able to sustain viable subpopulations of *M. vatkei*.

In preventing the loss of this species, it was important to conserve the mature stands to attract pollinators and establish young plantlets to rejuvenate the degraded subpopulations. Securing safe havens for rare and threatened plant species is challenging. Realistically, locating intact habitats for them, especially in the study area, is virtually impossible, and therefore using altered sites with a certain degree of protection was found to be a feasible option. In this regard, the study adopted an integrated approach defined as conservation-oriented restoration (Volis, 2016). Though paradoxical, this approach attempts to conserve threatened plant species by restoring their habitats and, at the same time restoring their habitats using threatened plant species. This approach is hinged on a partially degraded area that is still functioning. Within Ngutwa-Nzaui, it was found out that a relatively large proportion of *M. vatkei* subpopulations were flanked by farmlands existing as 'islands' in croplands. One similarity in these subpopulations was that they occurred in gullied landscapes that could not be cultivated or easily accessible by both people and livestock. Therefore, the study used these microsites as suitable sites to reinforce them. This restored the eroded areas and increased the survival of *M. vatkei* and the other conservation targets for the study.

The second strategy used in the recovery of *M. vatkei* was re-introduction. Usually, conservation of rare and threatened plant species emphasizes protecting the existing subpopulations, but through this strategy, the study aimed at reintroducing *M. vatkei* in areas known to have lost them. The classic vision of this effort was to replace the lost population within the study area and bolster their declining numbers. By supplementing the existing *M. vatkei* individuals in the area, it was believed that this would enhance their population viability by increasing their population sizes and reducing the chances of permanent loss. In such initiatives, the genetic origin of the seedling plays an important role. According to Keller *et al.* (2000) and Hufford and Mazer (2003), reintroducing seedlings adapted to different areas results in outbreeding depression. Aware of this setback, all the seeds were collected in subpopulations close together but genetically diverse. Since *M. vatkei* in the area had already experienced a sharp decrease in numbers and genetic variation, the propagation and re-introduction of seedlings from the same subpopulations were likely not going to improve their genetic make-up. Therefore, the study propagated seeds of local origin and those from the geographically closest population(s) within the Ngutwa-Nzaui landscape. For example, seeds from Ngutwa, Kathuma, and Nzaui were collected and propagated separately; however, during re-introduction, those from neighboring areas were combined as a way of diversifying their gene pool. For example, in the re-introduction of *M. vatkei* subpopulations in the Ngutwa area, seedlings from Ngutwa were combined with those of Kathuma (nearest neighbor to Ngutwa).

The last strategy employed by the study was translocation. It was considered as the last alternative option after having reinforced and reintroduced *M. vatkei* within the study area. The express motivation was to prevent further loss of some *M. vatkei* subpopulations because of the ongoing conversion of forested land into farmlands. In one case, the investigating team found some *M. vatkei* subpopulations cleared to pave the way for agriculture and plantation farming (*Eucalyptus* sp.). Luckily, the team encountered some saplings which were translocated to other safe areas such as the Nzaui forest. Translocation in the conservation of threatened plant species is oft-debated, and in most cases, it is sparingly used. As the road to hell is paved with good intention, translocations have their share of adverse impacts on the receptor sites. A well-intentioned transplantation effort could present negative economic and ecological consequences (*see* Ricciardi & Simberloff, 2009). Fahselt (1988) outlines challenges of transplantations and such reservations seconded by others (e.g., Hubbard *et al.,* 2001; Bullock, 1998). Therefore, as a prelude to the translocation exercise, the team first identified suitable receptor microsites for the *M. vatkei* in the Ngutwa-Nzaui area.

Within the study area, *M. vatkei* occurs on small remnant vegetation surrounded by arable land, making it an attractive refuge for wild animals (Hyraces & Ochre Bush Squirrel) and fodder for domestic flock (usually during the dry season). Indicators of herbivore damage were evident from the bark-stripped stems and nipped-off shoots for the existing *M. vatkei*. Usually, the area receives unreliable rainfall that influences pasture availability. Because of the evergreen nature of *M. vatkei*, it is mostly targeted, especially during dry seasons when palatable pasture is scarce. The locals have devised a vertical grazing strategy whereby grazing is concentrated on hilltops during dry seasons. Similarly, during the wet season, the locals of the Ngutwa-Nzaui area tend to graze on low-lying areas close to their homes. On these hills, most *M. vatkei* subpopulations occur on rock outcrops and deep gullies inaccessible by livestock, and thus, grazing pressure was found to be minimal. A similar observation was made of the low-lying areas where *M. vatkei* subpopulations in gullied landscapes were less disturbed. Contrary to this keen observation, some level of herbivory was witnessed on *M. vatkei* subpopulations situated on rock outcrops. According to local knowledge, the browsing was from rock hyraces living in rock crevices and preferred *M. vatkei* to other vegetation types.

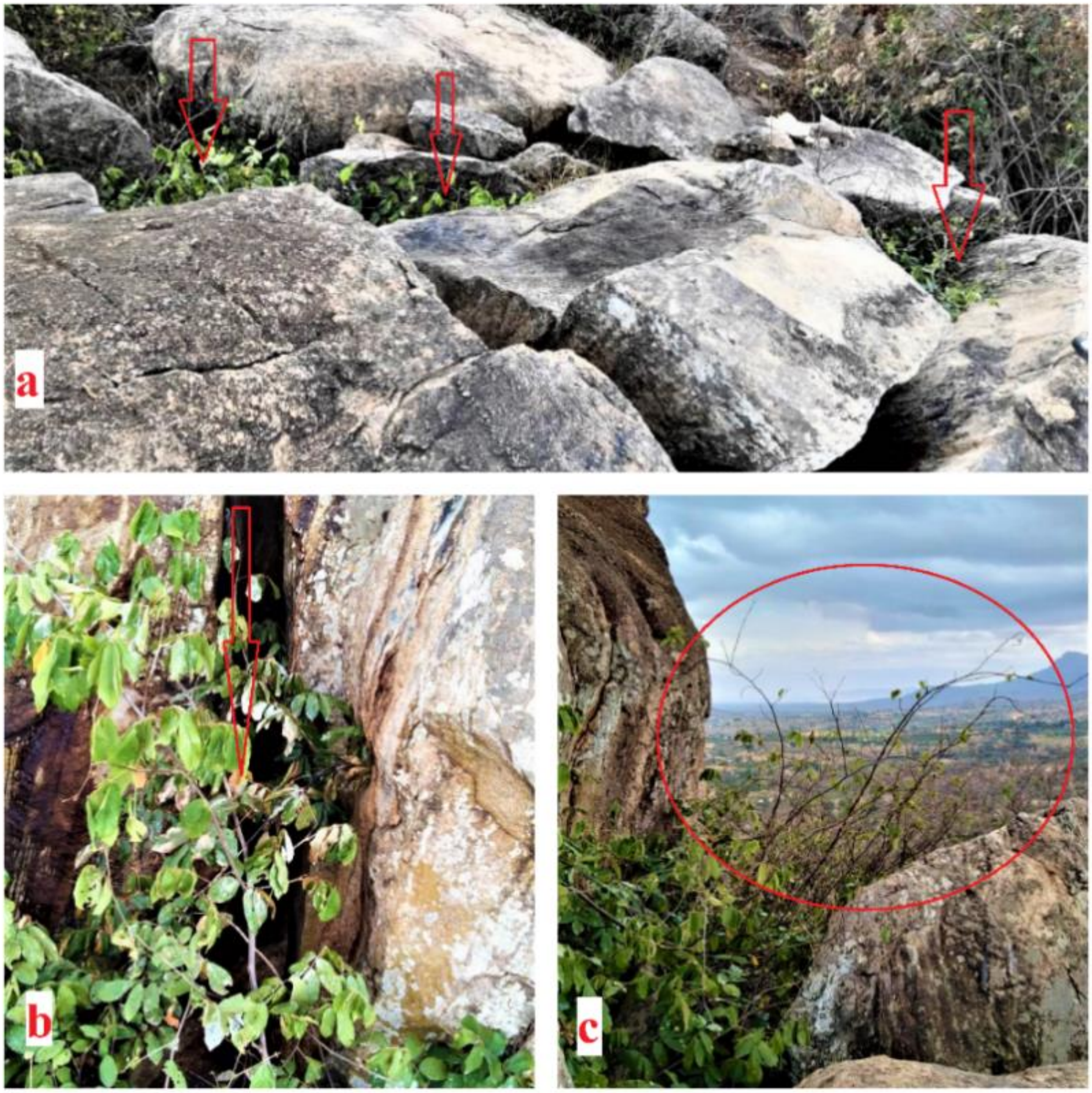


Figure 4. 34 A photo of *M. vatkei* occurring in rock outcrops.

In the above figure, (a) shows an inaccessible *M. vatkei* (shown in red arrows) because of the rock boulders, (b) *M. vatkei* in rock crevice inaccessible by livestock but accessible to rock hyraces and (c) defoliation of *M. vatkei* individuals by rock hyraces.

Sporadic rock outcrops are prevalent within the Ngutwa-Nzaui area and therefore were chosen, based on several reasons, as potential receptor sites for the translocation of the seedlings. Firstly, the similarity of the donor and recipient microsites in terms of ecological characteristics, distribution range and habitat security informed the selection process. Most of the donor *M. vatkei* subpopulations were established on rocky areas and thus was prudent to translocate to similar habitats. Secondly, to a certain degree, these sites were protected from livestock herbivory by the presence of rock boulders. Other sites selected for the translocation exercise were gullied lands where the occurrence of *M. vatkei* had not previously been documented. Such assessment of whether *M. vatkei* stands existed in a site solely relied on local knowledge.

Three types of translocation recipient sites were considered and described based on the above criteria. The first recipient microsite selected was open, exposed, and rocky. While these sites are open and exposed, and thus one may express disfavor due to increased exposure to water stress, the study chose open areas to maximize sunlight and slightly close to slanting rocks to optimize the collection of water even at lightest showers. Similarly, only the bottom part of the sleeves was removed during planting, leaving a hollow tube filled with soil and the seedling roots. This strategy aims to bring water close to the seedling roots by preventing its lateral movement to the surrounding soil. Since the seedlings were exposed to threats of herbivory, they were protected with stock-proof caging using dry thorny branches. The second type included partly-sheltered and rocky microsites. While selecting sheltered sites sought to prevent excess water loss through transpiration, the presence of boulders was to minimize access by livestock and possibly other animals. The third receptor microsites considered had no rock outcrops but were situated in dense inaccessible vegetation cover. Sites of this nature were mostly in deep gullies in relatively low-lying areas sometimes dominated by thorny vegetation such as *Maytenus senegalensis, Acacia brevispica* et cetera.

Figure 4. 35 Restoration of the target threatened plant species within the study area.

From the figure, (a) shows engagement of the locals in planting *M. vatkei* within the study area, (b) supplemental watering of the planted seedlings, (c & d) Engaging pupils in planting some *E. friesiorum*, and *T. napperae* individuals within the school compound, (e) Individuals of *T. napperae* established to serve as seed sources for propagation and restoration.

The timing of enrichment, re-introduction, and translocation of *M. vatkei* seedlings was found to play a crucial role in the success of the conservation efforts. Due to uncertainty of how the seedlings might respond in the recipient sites, transplantation was done in phases to minimize losses. The first phase involved planting 200 *M. vatkei* seedlings (obtained from natural regeneration) during the short rains (November-December 2020) in the study area. Survival to the first dry season (February and March (2021)) was the key factor for measuring the success of the first planting effort. Out of the 200 only 178 seedlings survived to the long rain season (March to May 2021), translating to 89% success. The second phase of planting seedlings was during the long rain season (March to May (2021) whereby the team introduced 926 seedlings to the receptor sites. The third planting was carried out before the onset of short rains (November-December, 2021), whereby 952 seedlings were planted. Also, 650 *M. vatkei* seedlings were donated to the locals to plant in their pieces of land, most preferably along gullied landscapes, as a way of rehabilitating such areas. The study hastens to note that no translocation was carried out at the first planting season because of inadequate information about the receptor sites. Similarly, the team chose not to translocate them in short rains but rather during long rains since it was believed that the extended rainfall would lead to seedlings' stability before the onset of the dry season (August to October).

Restoration initiatives usually fail because of limited monitoring, management, and inadequate seedlings to prevent stochastic demographic and environmental fluctuations. As part of post-planting monitoring, anti-stock caging using dry-thorny branches and supplemental watering was used to prevent herbivory and increase the survival of the seedlings during the dry spell respectively. Similarly, as compensation for the ignorance of species requirement, recovery adopted a three-step strategy and was done in phases. The recovery of *M. vatkei* was an example of a low-cost initiative that the engaged the locals in mapping, seed collection, propagation, and re-introduction. Therefore, it is believed that restoration of *M. vatkei* would further guide the conservation of the remaining target species (*P. teitana*, *T. napperae*, and *E. friesiorum*). Besides, the long-term monitoring of the recovered *M. vatkei* seedling is imperative to examine the viability of the restoration approaches adopted by the study. The team believes that the conservation of *M. vatkei* will serve as a model for the conservation of the other threatened species within the Ngutwa-Nzaui landscape and, more widely, of the arid and semi-arid lands (ASALs) of southeastern Kenya.

4.3 Creation of Awareness

Awareness was created throughout the project cycle; however, the main awareness meeting was carried during the project inception, training sessions, and dissemination of project results.

Figure 4. 36 Public awareness with the locals of Ngutwa-Nzaui area.

In the figure, (a) shows project inception meeting involving the stakeholders, (b) Locals taking notes during a training session, (c) dissemination of the project findings (d) Due to challenges posed by COVID-19 Pandemic some under-tree meetings were carried out to ensure as many locals as possible became aware of the need to conserve the target species within Ngutwa-Nzaui area.

Generally, it was found out that most of the young generation was unaware of the target species, leave alone their local names. Most of the elder generation knew the target species within the locality and their uses. Knowing what to be conserved as well as the roles served, is the first step towards a sustainable conservation. Therefore, the study carried out several training sessions with the locals to make them aware of the target species and their importance within the Ngutwa-Nzaui area. Additionally, the need to conserve general biodiversity was emphasized as through doing so, the target threatened plant species would also be conserved.

Figure 4. 37 Use of live plant specimen in awareness creation meetings within Ngutwa-Nzaui.

In the figure, (a) shows the principal investigator demonstrating living plant specimen for the target species to locals of Nzaui area, (b) project team members showing the locals of Ngutwa area a live *T. napperae* individual, (C) Pupils posing for a photo with some donated *M. vatkei* seedlings.

Most of the school-going pupils were unaware of the project's four target plant species. Therefore, to make them aware, the project donated and engaged them and their teachers in growing *T. napperae*, *P. teitana*, and *E. friesiorum* within their school compound to serve as a source of seeds for the next phase. However, because of the nature of *M. vatkei*, it could not be planted within the school, but the study established what was dubbed as '*M. vatkei* Challenge.' The pupils were given a seedling to plant at home with the help of their parents. They were taught on the suitable areas to grow them as a way of increasing their survivability. Pupils whose their planted seedlings would survive to the next six months were promised a token as a way of appreciating their efforts towards the conservation of threatened plant species within the area.

Because of the challenges posed by the COVID-19 pandemic, much of the training sessions/ awareness-creation meetings involved the locals. The feedback from the trainees was analyzed using the Microsoft Excel application. Based on the contents of the subjective statements, analysis was divided into two sections; demographic characteristics and relative index analysis for ranking the statements based on their importance to the trainees.

1. **Demographic Characteristics of the Trainees**

(a) Gender

Table 4. 11 Gender of the respondents during awareness-creation meeting.

	Male	Female	Total
Number	57	49	106
Percentage (%)	53.8	46.2	100.0

According to gender distribution, 57 (53.8%) were males while 49 (46.2%) were females. With the majority being male, this attendance disparity echoes role orientation among most African societies where gender roles and responsibilities were rigidly structured. As such, women were viewed as mothers and caretakers while their male counterparts assumed the roles of productive activities. However, from the statistics above, women are actively participating in biodiversity conservation. Similarly, this change in basic assumptions is further evidenced by local women's commitment to the management and conservation of Kakamega Forest (Andole et al., 2020).

Additionally, women's engagement in agroforestry technologies has promoted climate change adoption in Makueni (Kalovoto, 2021). According to Zelezny and colleagues (2000), women are associated with extraordinary character of care, including care for nature. Therefore, women should be equally and actively involved in biodiversity conservation. In many countries, women are increasingly managing their small-scale farms; unfortunately, they are under-represented in environmental and economical decision-making processes. Therefore, increasing women's representation in environmental decision-making roles is the way to sustainable biodiversity conservation.

(b) Age distribution of respondents

Table 4. 12 Age distribution of the respondents during awareness creation.

Age group	Number	Percentage (%)
≥12	0	0
13-18	15	14.2
19-30	36	33.9
31-50	43	40.6
51 and above	12	11.3
Total	**106**	**100.0**

From table 4.12, most of those who took part in the conservation of threatened plant species training were young adults of the working category (ages 31-50), followed closely by the youth (19-30). A probable explanation for this is their availability and autonomy compared to the aged. Few individuals below the 18-age bracket attended the training, possibly because the majority could not participate because they were in school at the time of the exercise. Similarly, lesser individuals (above 51 years) attended the training because of restrictions by the Ministry of Health guidelines on containment of COVID-19.

(c) Level of education

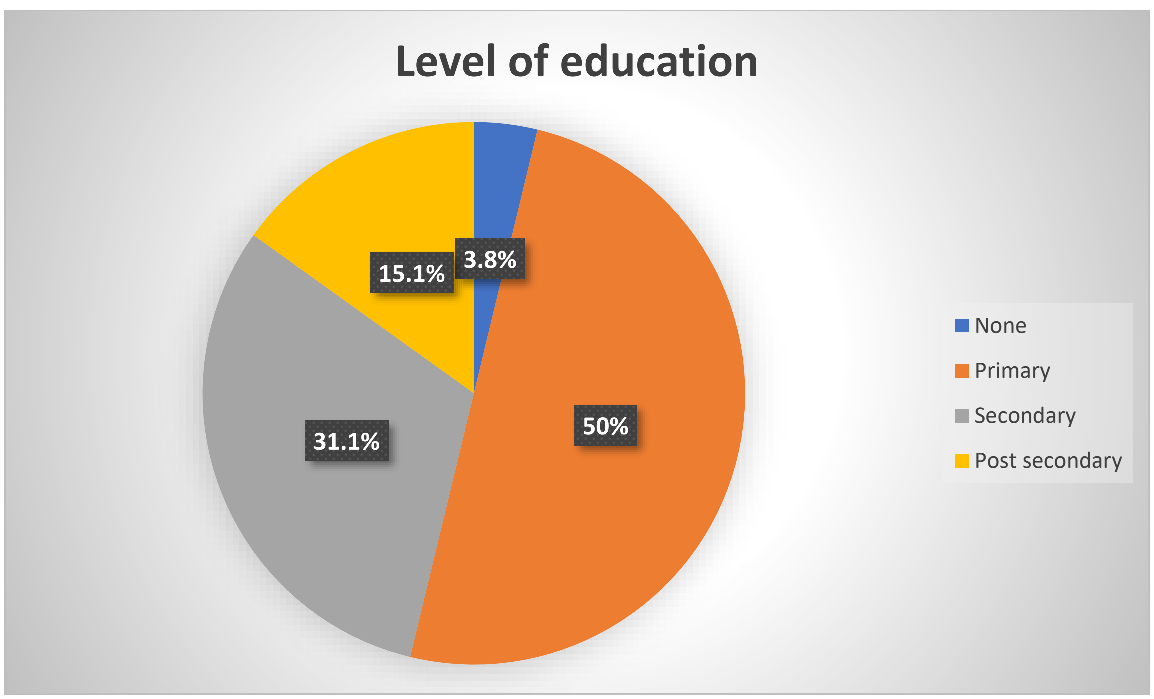


Figure 4. 38 A pie-chart showing education level among the trainees.

The level of education is a major factor in determining the success of species conservation. Liordos *et al.* (2017) noted that urban residents of higher education have more chances to support species conservation. Most of the trainees had attained primary education (50%), which is the basic level for reading and writing. The secondary level also claims the second-biggest share (31.1%). Both levels of education serve as a catalyst for facilitating the ease of training, effective communication, and the ability to use appropriate conservation technologies.

(b) Occupation

Table 4. 13 Occupation of the respondents.

Occupation	Number	Percentage (%)
Farmer	76	71.7
Business	24	22.6
Others	6	5.7
Total	106	100.0

About 72% of the trainees were farmers, and thus important to educate them on their roles in biodiversity conservation. Agriculture has threatened the existence of the target species within the area and therefore peaceful coexistence of natural vegetation and crops is important.

2. Relative Index Analysis

To assess the effectiveness of the training seminar to the trainees, a relative importance index was calculated, which helped rank the statements based on their relevancy to the attendees.

Table 4. 14 Assessment of the effectiveness of the training sessions.

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total	Total No (N)	A*N	RII	Rank
1. Content easy to follow	415	80	6	2	0	503	106	530	0.9491	7
2. Group size appropriate	420	72	9	0	1	502	106	530	0.9472	8
3. Interaction encouraged	455	48	9	0	0	512	106	530	0.9660	3
4. Expectation met	430	52	15	2	1	500	106	530	0.9434	9
5. Demo. material helpful	425	80	3	0	0	508	106	530	0.9585	5
6.Trainers knowledgeable	420	76	6	2	0	504	106	530	0.9509	6
7. Learnt new things	445	64	3	0	0	512	106	530	0.9660	3
8. Training time sufficient	375	100	12	2	1	490	106	530	0.9245	10
9. Training well organized	455	52	6	0	0	513	106	530	0.9679	2
10.Recommend to friends	480	32	3	0	1	516	106	530	0.9736	1

Based on the ranking of the Relative Importance Indices (RII), it was observed that all the cues were of high importance level. Akadiri (2011) notes that values from 0.8-1 denote a high importance level, 0-4-0.6 medium importance level, while values 0-0.2 denote a low importance level. However, the perception that most people were likely to recommend/extend the training to other people ranked highest (RII =0.9736). This is positive feedback given the role of community outreach programs in the sustainable long-term conservation of nature. According to the respondents, the training was well organized. Despite the challenges posed by the COVID-19, the training sessions were organized in such a way as to minimize exposure to the disease. This involved organizing under-tree meetings with small groups throughout the study area.

From the feedback, the general feeling among the respondents was that the training time was not enough. This was also echoed by the majority who hinted addition of training time after the training sessions. Time is important during knowledge sharing; however, in this case, it was limited due to the strict adherence to government directives to contain COVID-19. Also, the training positively impacted the locals as the majority learned new things (see table 4.14). After the training session, one of the locals had this to say, '*I have learned many things that I never knew before the training, especially on propagation; I will use the knowledge I got from this training to raise by lemon seedlings.*' Another one was captured as '*I usually see M. vatkei along gullied and rocky areas, and I have never imagined their importance. With the training, I now know the role of the plant species.*' The participant recalled seeing *M. vatkei* timber and fibers commonly used to construct traditional grain storage silos. Still, with no more construction of traditional silos, they appear to him that they are of no importance.

From the feedback, a sizable number of the locals expected something different from what was trained. It was found out that they expected training on commercialized forestry ventures such as growing fruit trees and timber trees such as *Eucalyptus*, *Mellia volkensii*, among others. To get a deeper understanding of why the majority were unwilling to plant indigenous plants such as the target species, blank sheets of paper were issued upon which they wrote their responses. Most of the reactions included less monetary value, water scarcity, and inadequate land. These responses appeared consistent with their perceptions on the importance of the ecosystem to them (section of this project report), where the charcoal burning, provision of water, fodder and fuel was highly ranked as the most important. It also highlights the need for nature-based ventures that integrate conservation of the environment and the improvement of the local's livelihoods. Land appears to be limiting the establishment of indigenous plants, and therefore, the attendees were taught on the agroforestry practices as a way of maximizing this scarce resource.

Figure 4. 39 Collecting views on the locals' unwillingness to grow indigenous plants.

Most participants expressed the need for more seminars to enhance their knowledge on the conservation of not only the target species but also on biodiversity generally. Other concerns to the locals included value addition and marketing of some of the local natural products, methods of propagation, and pest control.

Figure 4. 40 Group photos of the locals after the training sessions.

From the figure, (a) shows the locals of both Ngutwa and Nzaui area posing for a photo after a training session, (b) project team member distributing *M. vatkei* seedlings to the locals of Nzaui area, (c) residents of Ngutwa area pose for a photo with donated seedlings of *M. vatkei* after a training session.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

Ngutwa-Nzaui area is an important ecosystem for plants and animals, including rare, endemic, and threatened plant species. It also provides the residents with water, food, pasture, and raw materials. However, the conservation of threatened plant species in Makueni through community mobilization has established that land use/cover for the area has substantially changed. The main land use/cover within the Ngutwa-Nzaui area includes scrubland, cropland, bare land, forest, built-up area, and water bodies. Over the past three decades, the area has witnessed a rapid increase in human settlement and crop farming, leading to a decrease in forest and scrubland, which serve as habitat for the target threatened plant species. The locals also perceive the ecosystem as a habitat for biodiversity as less important to them and thus their continued destruction. Similarly, erosion of cultural values has seen increased destruction of sacred groves, which serve as crucial repositories for biodiversity by providing refuge for imperiled flora. The study mapped seven subpopulations for *T. napperae*, fifteen *E. friesiorum*, fifteen *M. vatkei*, and nineteen *P. teitana* within the Ngutwa-Nzaui area. Agriculture, herbivory, soil erosion, overexploitation, infrastructure development, alien invasive plant species, and climate change are some of the main threats facing the target species within the area. Non-mist propagation system using poly-tunnels proved an appropriate technology in the propagation of *M. vatkei*. Awareness among the locals on the target species is low, especially among the young generation, and perhaps the reason for their declining numbers.

Further, to aid in the conservation of threatened plant species within Ngutwa-Nzaui area, the following recommendations are hereby proposed; -

- Initiate a post-planting monitoring for the *M. vatkei* to determine the survival success of the study's conservation strategies. Supplemental watering, especially during the dry season, is a good way of increasing their survival success.
- Undertake mass propagation and restoration of the three remaining threatened plant species, which include *E. friesiorum, P. teitana*, and *T. napperae*, to increase their population numbers. The use of the Miyawaki method would be an appropriate way to restore the declining subpopulations for these species.
- Identification and mapping of rare, endemic, threatened plants and animals' species and sacred groves as a way of conserving biodiversity and cultural heritage of the area. This should also be strengthened through educating the locals on the importance of preserving sacred groves (some serve as a source of water, e.g., Kithoni, etc.)
- Establishment of ecotourism ventures within Ngutwa-Nzaui such as bird-watching, rock climbing, especially for Nzaui rock cliff, and indigenous tree planting. The study area, especially Nzaui hill, plays an important part in the Akamba culture, as evidenced by several sacred groves used for appeasing the gods, offering sacrifices, initiation ceremonies, and blessings and protection of the Kamba community. It is believed that the first Kamba people originated from Nzaui hill, as evidenced by rocks engraved with footprints believed to be for ancient people and animals. Regrettably, these sites' potential

for ecotourism is unexploited, and some rock art is quickly disappearing through water attrition.

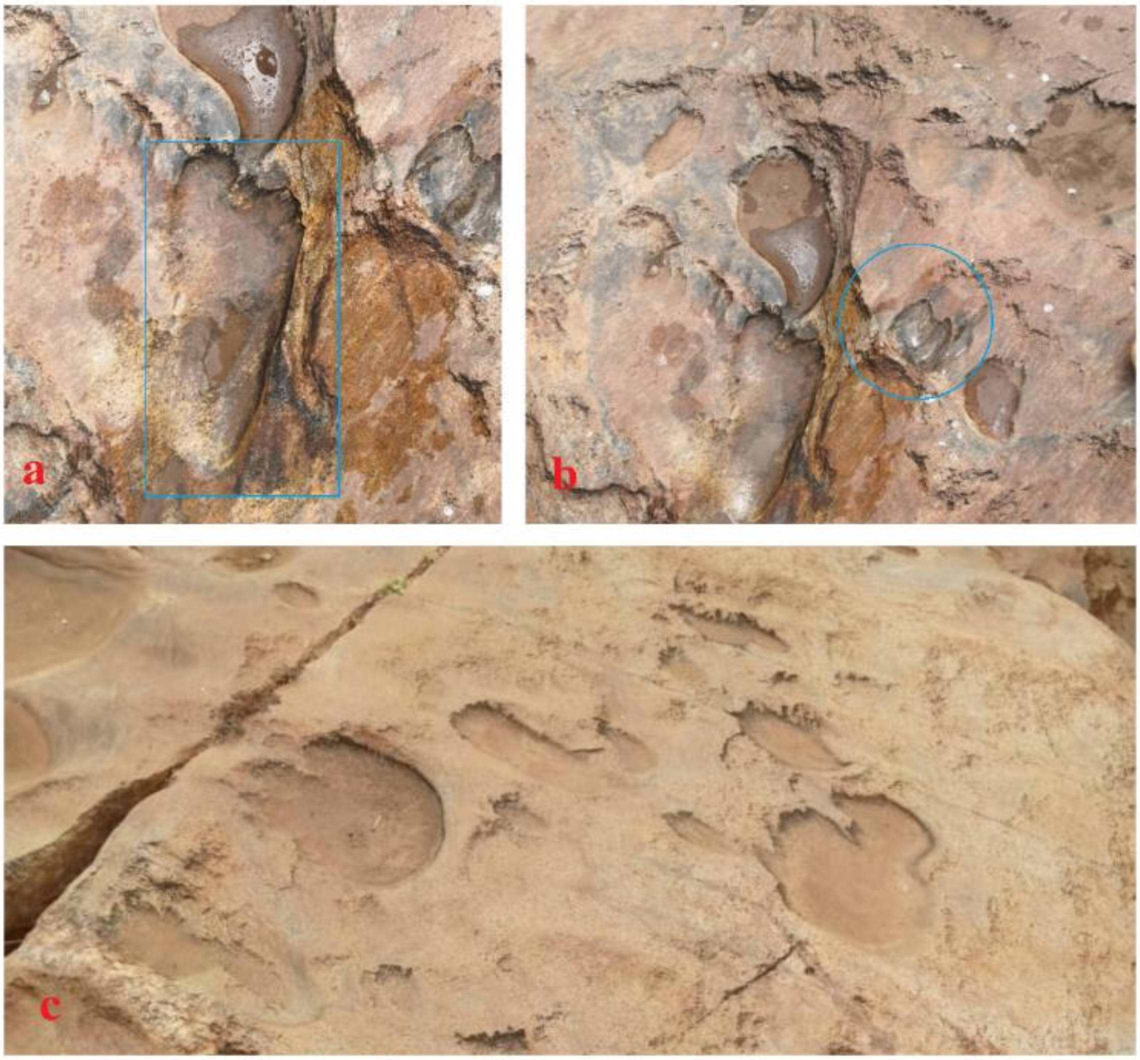


Figure 5. 41 Rock art within Ngutwa-Nzaui which is a potential tourist attraction within the study area.

From the figure, (a) shows a footprint (circled) believed to be for the ancient people, (b) animal hoof (circled) engraved in a rock within Ngutwa-Nzaui area. (c) attrition effect to the rock art.

- Ngutwa-Nzaui area, though a semi-arid region, has a conducive climate for the establishment of agriculture. The range of hills provides optimal conditions for crop farming, such as orange and mango farming. The past decade has witnessed an increased conversion of natural vegetation to fruit orchards. However, such farming practices are not sustainable, as demonstrated by fallowed land within some areas of Ngutwa-Nzaui. Fortunately, some farmers are engaging in regenerative agriculture though weakly embraced. Therefore, this study recommends educating the locals on climate-smart agriculture to strengthen sustainable conservation agriculture in the area.

Figure 5. 2 Fruit farming within Ngutwa-Nzaui area.

From the figure, (a) shows weeding as proper agronomic practice of reducing competition for nutrients, (b) a pixie tree with a good load of healthy fruits, (c) enlarged pit for harvesting water especially from cut-off drainage within Ngutwa-Nzaui area.

- Ngutwa-Nzaui has a favorable climatic condition that can support a modern beekeeping economy. For example, *Acacias* and *Combretum* are predominant in the area and thus can be used to produce the most-sought *Acacia-Combretum* honey. There is the existence of traditional beekeeping within the region and thus can be strengthened by establishing modern beekeeping technologies. Traditional beekeeping excludes both the youth and women from such economic activity. Therefore, modern beekeeping will act as an alternative source of livelihood for some locals who engage in forest destructive activities and this will conserve biodiversity. The predominance of log-hives within the study area is unsuitable in the warming temperatures. Therefore, establishing climate-smart beekeeping technologies will meet domestic and export demands.

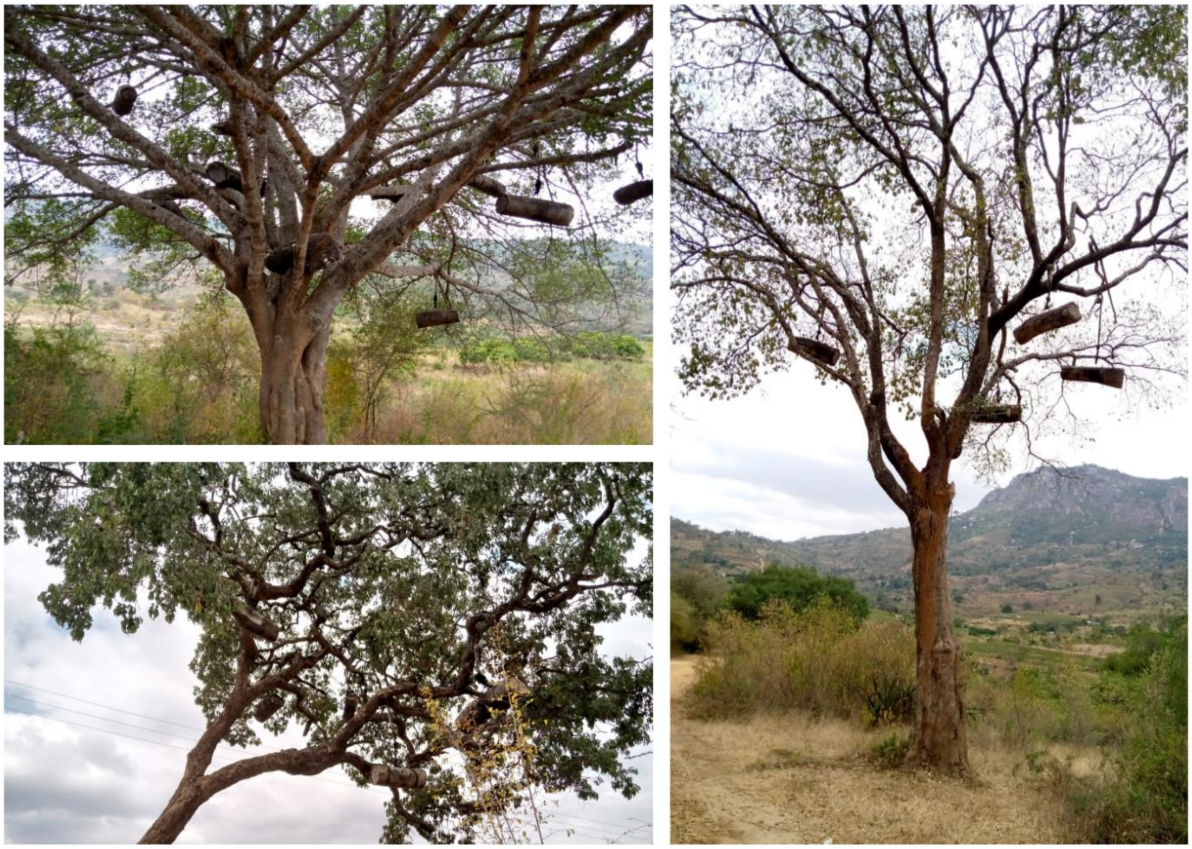


Figure 5. 42 Predominance of log-hive within Ngutwa-Nzaui area.

- Value addition on indigenous wild fruits (IWFs) within Ngutwa-Nzaui area is another aspect in need of attention. During the mapping exercise, various nutritional wild fruits were encountered, such as *Tamarindus indica* (Ngwasu, Nzumula-Kamba), *Adansonia digitata* (Namba), *Ximenia americana* (Ndula-Kamba), *Balanites aegyptiaca* (Ndului-Kamba), *Carissa spinarum* (Ngaawa-Kamba) *Vangueria madascariensis* (Ngomoa-Kamba), *Vitex payos* (Muu-Kamba), *Strychnos spinosa* (Kimee-Kamba), *Mystroxylon aethiopicum* (Ngongoo-Kamba). These wild fruits have attracted less scientific research, and therefore nutritional analysis needs to be done to provide more information to the public. Also, there is a need for more awareness and education among the locals to change their attitudes towards them and raise their value. Importantly, cultural crops and wild crop relatives and cultural practices would be a target to increase knowledge on climate change adaptation. The area hosts many common but threatned diversity with potential as pesticidals (e.g. *Zanha africana* (kikolekyia-Kamba), *Securidaca longepedunculata* (Muuka-Kamba) etc), wild food relatives only occurring in that zone (endemic) such as *Pachystigma* *schumannianum* ssp. *mucronulatum* (ndootoo-Kamba), and *Uvaria scheffleri* (ngukuma-Kamba) (Figure 5.4).

Figure 5. 43 Photos of some nutritious indigenous wild fruits within the study area.

From the figure, (a) *Uvaria scheffleri,* (b) *Tamarindus indica* (c) *Mystroxylon aethiopicum.*

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Appendices

Part 1: Data Collection Form

Conservation of Threatened Plant Species (CTPS) Project

Towards Community-based Conservation

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Voucher no:		Collection Date			
Family		Genus		Species	
Locality		Latitude	Longitude	Altitude/Elevation	

Habit type	**Sample type**	**Genetic status**	**Source of Collection**
1. Tree 2. Shrub 3. Liana 4. Herb	1. Single plant 2. Pure line/clone 3. Population/mixture 4. Others (specify)	1. Wild 2. Weed 3. Landrace 4. Breeders line 5. Advanced Cultivar	1. Farmland 2. Natural vegetation 3. Backyard 4. Farm store 5. Threshing place 6. Others
Plant description			

Habitat Type	**Habitat description (include associated species)**
1. Wetland 2. Grassland 3. Bushland 4. Woodland 5. Forest 6. Farmland 7. Desert 8. Semi-desert	

Local Frequency	**Flower Phenology**	**Fruit Phenology**
1. Rare 2. Occasional 3. Common	1. None 2. Buds 3. Buds/open	1. None 2. Unripe 3. Unripe/ripe 4. Ripe

Site Description	
Soil Texture	Sand, Sandy loam, Loam, Organic, Clay loam, Clay, Silt
Soil Color	Black, Brown, Red, Orange, Yellow
Stoniness	None, Low, Medium, Rocky
Drainage	Poor, Moderate, well-drained, Excessive
Topography	Flat, Undulating, Hilly, Mountainous or describe…………………………………….

Local Use:	
Threats:	
Contributing Factor:	
Other Remarks:	

Part 2: Attendance List

Conservation of Threatened Plant Species in Nzaui through Community Mobilization

The Rufford Foundation
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Attendance List

NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON

S/no	Name	Phone Number	Signature
1.			
2.			
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Part 3: Training Evaluation Form

TRAINING EVALUATION FORM

for *Participants* in Conservation of Threatened Plant Species (CTPS) Project

Date…………………………………………………………………………………….

Location of Training…………………………………………………………………….

Trainer (s)……………………………………………………………………………….

PART A: Demographic Data

Name: ……………………………………….. Gender: Male ( ) Female: ( )

Age (please tick): Below ≤ 12 ( ); 13-18 ( ) 19-30 ( ); 31-50 ( ); 51 and above ( )

Level of education: None ( ); Primary ( ); Secondary ( ); Post-secondary ( )

Occupation: Farmer ( ); Business ( ); Other specify…………………………

PART B: Please indicate your level of agreement in the statements listed below in #1-10

Statement	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1.The training course met my expectations.					
2. The size of the training group was appropriate.					
3. Participation and interaction were encouraged.					
4. The content was easy to follow.					
5. The demonstration materials were helpful.					
6. The trainer(s) were knowledgeable and well-prepared on the training topics.					
7. I learnt new things.					
8. The time allotted for the training was sufficient.					
9. The training was well-organized.					
10. I would recommend the training to friends.					

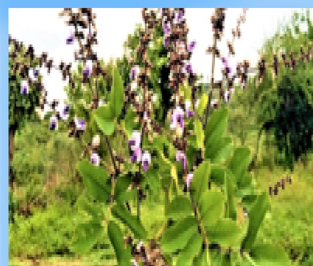
11. Do you have any suggestions or comments to improve this initiative?

………………………………………………………………………………………………
………………………………………………………………………………………………

Thank you for your Feedback!

Part 4: Leaflet on conservation of *Millettia vatkei*

Conservation of Endangered *Millettia vatkei* P.K. Lôc



Taxonomy and nomenclature

Millettia vatkei P.K. Lôc

This species was previously known as *Millettia leucantha* Vatkei –

but was found to be a homonym and hence it was

renamed to *Millettia vatkei* P.K. Lôc.

Family: **Fabaceae**; Genus: Millettia

Common name/ vernacular: Utw'aa/kitw'aa (Kamba).

Botanical description

It usually occurs as lianas, shrubs, trees, and (though rarely) as semi-herbaceous plant with a woody rootstock.

Usually evergreen; young twigs pale brown velvety, older twigs dark grey with white lenticels. Pods velvety with the tip straight (Verdcourt, 1968).

Distribution and habitat

It is a rare species occurring in few clustered clumps within its distributional range.

This species is endemic to central and lower Eastern Kenya (K4 and K6). Its estimated Extent of occupancy (EOO) is 15735 km² and estimated area of occupancy (AOO) is between 24-60 km² and thus assessed as Endangered (IUCN, 2019).

It does well in elevational range of 1050m to 1700m (IUCN, 2019)

It is found in semi-evergreen forest remnant on rocky hills and has also been found to survive in secondary vegetation after clearance (Beentje,1994).

Community-based Conservation

Ethnobotanical uses

The plant is used as source of dry season fodder, fuel wood and source of mulch. This species is also used in the production of fiber and timber for construction. Its flowers also attract bees.

Conservation status

The species is declared vulnerable and thus highlighted as potential taxa for conservation concern (Beentje,1988,1994).

Propagation

The species can be regenerated from seeds. The seeds are soaked in hot water to enhance and improve germination. It can also be propagated vegetatively.

Storage and viability

Seed storage behaviour is orthodox; long-term storage (Muthoka et al., 2003).

Threat Information

Clearance to pave way for agriculture, cutting for fire wood and timber as well as herbivory by livestock and wild animals (Rock hyraces).

References

Beentje, H. J. (1988). Atlas of the rare trees of Kenya.

Beentje, H., Adamson, J., & Bhanderi, D. (1994). Kenya trees, shrubs, and lianas. National Museums of Kenya.

IUCN SSC East African Plants Red List Authority. 2019. *Millettia vatkei*. The IUCN Red List of Threatened Species 2019: e.T179809A1590894. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T179809A1590894.en. Downloaded on 01 March 2021.

MUTHOKA, P. N. & al. (2003). Seed quality studies in the Kenyan shrub *Millettia leucantha*. In: SMITH, R. D. & al., Eds., Seed conservation: turning science into practice: 135-149. The Royal Botanic Gardens, Kew.

Verdcourt, B. (1968). Flora of tropical east Africa. Taylor & Francis.

Part 5: Training Module

The overall objective of this training module is to create awareness on the importance of conserving biodiversity within Ngutwa- Nzaui area. The main immediate objectives are:

- To achieve a greater awareness, and understanding on the importance of conserving biodiversity specifically *M. vatkei*, *T. napperae*, *P. teitana* and *E. friesiorum* and their habitat.
- To strengthen the technical capacity and the knowledge of the locals on propagation, handling, and sustainable harvesting target species and general biodiversity.

Session	Training Objectives	Teaching Aid	Resource person/ Facilitator
1.Opening and introduction	1.1 Registration 1.2 Introduction of participants, facilitators and the Rufford foundation 1.3 Aims of the study 1.4 Comments and queries		
2.Introduction of conservation targets	2.1 *M. vatkei* 2.2 *T. napperae* 2.3 *P. teitana* 2.4 *E. friesiorum*	Live specimen	
	2.5Uses of target species		
	2.6Threat profile to the targets		
3.Conservation of the target threatened plant species	3.1 *In-situ* and *ex-situ* conservation 3.2 Types of seeds 3.3 Seed collection schemes		
4.Propagation and restoration of conservation targets	4.1 Non-mist propagation system (Poly-tunnels) 4.2 Propagation 4.3 Restoration strategy (Augmentation, reintroduction & translocation) 4.4 Post-planting monitoring	On-site demonstration Manual booklet	
5.Evaluation	5.1 Evaluating the effectiveness of training	Questionnaires and interviews	

Part 6: Modified IUCN - CMP Unified Classification of Direct Threats (version 3.2) (adapted from Salafsky et al. 2008).

VERSION 3.2	**Direct threats** are the proximate human activities or processes that have impacted, are impacting, or may impact the status of the taxon being assessed (e.g., unsustainable fishing or logging). Threats can be past, ongoing, and/or likely to occur in the future.	
Level 1 Threat	**Level 2 Threat**	**Level 3 Threat**
1.Residential & Commercial Development: Threats from human settlements or other non-agricultural land uses with a substantial footprint		
	1.1 Housing & Urban Areas	Human cities, towns, and settlements including non-housing development typically integrated with housing
	1.2 Commercial & Industrial Areas	Factories and other commercial centers
	1.3 Tourism & Recreation Areas	Tourism and recreation sites with a substantial footprint
2. Agriculture & Aquaculture: Threats from farming and ranching as a result of agricultural expansion and intensification, including silviculture, mariculture, and aquaculture		
	2.1 Annual & Perennial Non-Timber Crops	Crops planted for food, fodder, fiber, fuel, or other uses
	2.2 Wood & Pulp Plantations	Stands of trees planted for timber or fiber outside of natural forests, often with non-native species
	2.3 Livestock Farming & Ranching	Domestic terrestrial animals raised in one location on farmed or non-local resources (farming); also domestic or semi-domesticated animals allowed to roam in the wild and supported by natural habitats (ranching)
	2.4 Marine & Freshwater Aquaculture	Aquatic animals raised in one location on farmed or non-local resources; also hatchery fish allowed to roam in the wild
3. Energy Production & Mining: Threats from production of non-biological resources		
	3.1 Oil & Gas Drilling	Exploring for, developing, and producing petroleum and other liquid hydrocarbons
	3.2 Mining & Quarrying	Exploring for, developing, and producing minerals and rocks
	3.3 Renewable Energy	Exploring, developing, and producing renewable energy
4. Transportation & Service Corridors: Threats from long, narrow transport corridors and the vehicles that use them including associated wildlife mortality		
	4.1 Roads & Railroads	Surface transport on roadways and dedicated tracks
	4.2 Utility & Service Lines	Transport of energy & resources
	4.3 Shipping Lanes	Transport on and in freshwater and ocean waterways
	4.4 Flight Paths	Air and space transport
5. Biological Resource Use: Threats from consumptive use of "wild" biological resources including both deliberate and unintentional harvesting effects; also persecution or control of specific species		
	5.1 Hunting & Collecting Terrestrial Animals	Killing or trapping terrestrial wild animals or animal products for commercial, recreation, subsistence, research, or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch
	5.2 Gathering Terrestrial Plants	Harvesting plants, fungi, and other non-timber/non-animal products for commercial, recreation, subsistence, research, or cultural purposes, or for control reasons
	5.3 Logging & Wood Harvesting	Harvesting trees and other woody vegetation for timber, fiber, or fuel
	5.4 Fishing & Harvesting Aquatic Resources	Harvesting aquatic wild animals or plants for commercial, recreation, subsistence, research, or cultural purposes, or for control/persecution reasons; includes accidental mortality/bycatch
6. Human Intrusions & Disturbance: Threats from human activities that alter, destroy, and disturb habitats and species associated with non-consumptive uses of biological resources		
	6.1 Recreational Activities	People spending time in nature or traveling in vehicles outside of established transport corridors, usually for recreational reasons
	6.2 War, Civil Unrest & Military Exercises	Actions by formal or paramilitary forces without a permanent footprint
	6.3 Work & Other Activities	People spending time in or traveling in natural environments for reasons other than recreation or military activities
7. Natural System Modifications: Threats from actions that convert or degrade habitat in service of "managing" natural or semi-natural systems, often to improve human welfare		

	7.1 Fire & Fire Suppression	Suppression or increase in fire frequency and/or intensity outside of its natural range of variation
	7.2 Dams & Water Management/Use	Changing water flow patterns from their natural range of variation either deliberately or as a result of other activities
	7.3 Other Ecosystem Modifications	Other actions that convert or degrade habitat in service of "managing" natural systems to improve human welfare
8. Invasive & Other Problematic Species, Genes & Diseases: Threats from non-native and native plants, animals, pathogens/microbes, or genetic materials that have or are predicted to have harmful effects on biodiversity following their introduction, spread and/or increase in abundance		
	8.1 Invasive Non-Native/Alien Species/Diseases	Harmful plants, animals, pathogens, and other microbes not originally found within the ecosystem(s) in question and directly or indirectly introduced and spread into it by human activities
	8.2 Problematic Native Species/Diseases	Harmful plants, animals, or pathogens and other microbes that are originally found within the ecosystem(s) in question, but have become "out-of-balance" or "released" directly or indirectly due to human activities
	8.3 Introduced Genetic Material	Human altered or transported organisms or genes
	8.4 Problematic Species/Diseases of Unknown Origin	Harmful plants, animals, or pathogens and other microbes of unknown origin. It is not known if they were deliberately or accidentally introduced or if they were originally found within the ecosystem(s) in question.
	8.5 Viral/Prion-induced Diseases	Viruses are small infectious agents that replicate only inside the living cells of an organism. Although viruses occur universally, each cellular species has its own specific range that often infect only that species. Most viruses co-exist harmlessly in their host and cause no signs or symptoms of disease. However, a number are important pathogens which can result in diseases which significantly reduce reproduction or increase mortality. Prions are infectious agents composed of protein in a misfolded form. They do not contain nucleic acids. All known prion diseases affect the structure of the brain and other neural tissue, they are mainly found in mammals, are currently untreatable and are universally fatal.
	8.6 Diseases of Unknown Cause	Occasionally plants and animals are impacted by diseases of unknown origin and often it may take many years to identify the pathogen responsible
9. Pollution: Threats from introduction of exotic and/or excess materials or energy from point and nonpoint sources		
	9.1 Domestic & Urban Waste Water	Water-borne sewage and non-point runoff from housing and urban areas that include nutrients, toxic chemicals, and/or sediments
	9.2 Industrial & Military Effluents	Water-borne pollutants from industrial and military sources including mining, energy production, and other resource extraction industries that include nutrients, toxic chemicals, and/or sediments.
	9.3 Agricultural & Forestry Effluents	Water-borne pollutants from agricultural, silvicultural, and aquaculture systems that include nutrients, toxic chemicals, and/or sediments including the effects of these pollutants on the site where they are applied
	9.4 Garbage & Solid Waste	Rubbish and other solid materials including those that entangle wildlife
	9.5 Air-Borne Pollutants	Atmospheric pollutants from point and nonpoint sources
	9.6 Excess Energy	Inputs of heat, sound, or light that disturb wildlife or ecosystems
10. Geological Events: Threats from catastrophic geological events		
	10.1 Volcanoes	Volcanic events
	10.2 Earthquakes/Tsunamis	Earthquakes and associated events
	10.3 Avalanches/Landslides	Avalanches or landslides
11. Climate Change & Severe Weather: Threats from long-term climatic changes that may be linked to global warming and other severe climatic/weather events that are outside of the natural range of variation, or potentially can wipe out a vulnerable species or habitat		
	11.1 Habitat Shifting & Alteration	Major changes in habitat composition and location
	11.2 Droughts	Periods in which rainfall is below the normal range of variation
	11.3 Temperature Extremes	Periods in which temperatures exceed or go below the normal range of variation
	11.4 Storms & Flooding	Extreme precipitation and/or wind events
	11.5 Other Impacts	Other impacts of climate change or severe weather events not covered above (list the specific type of impacts)