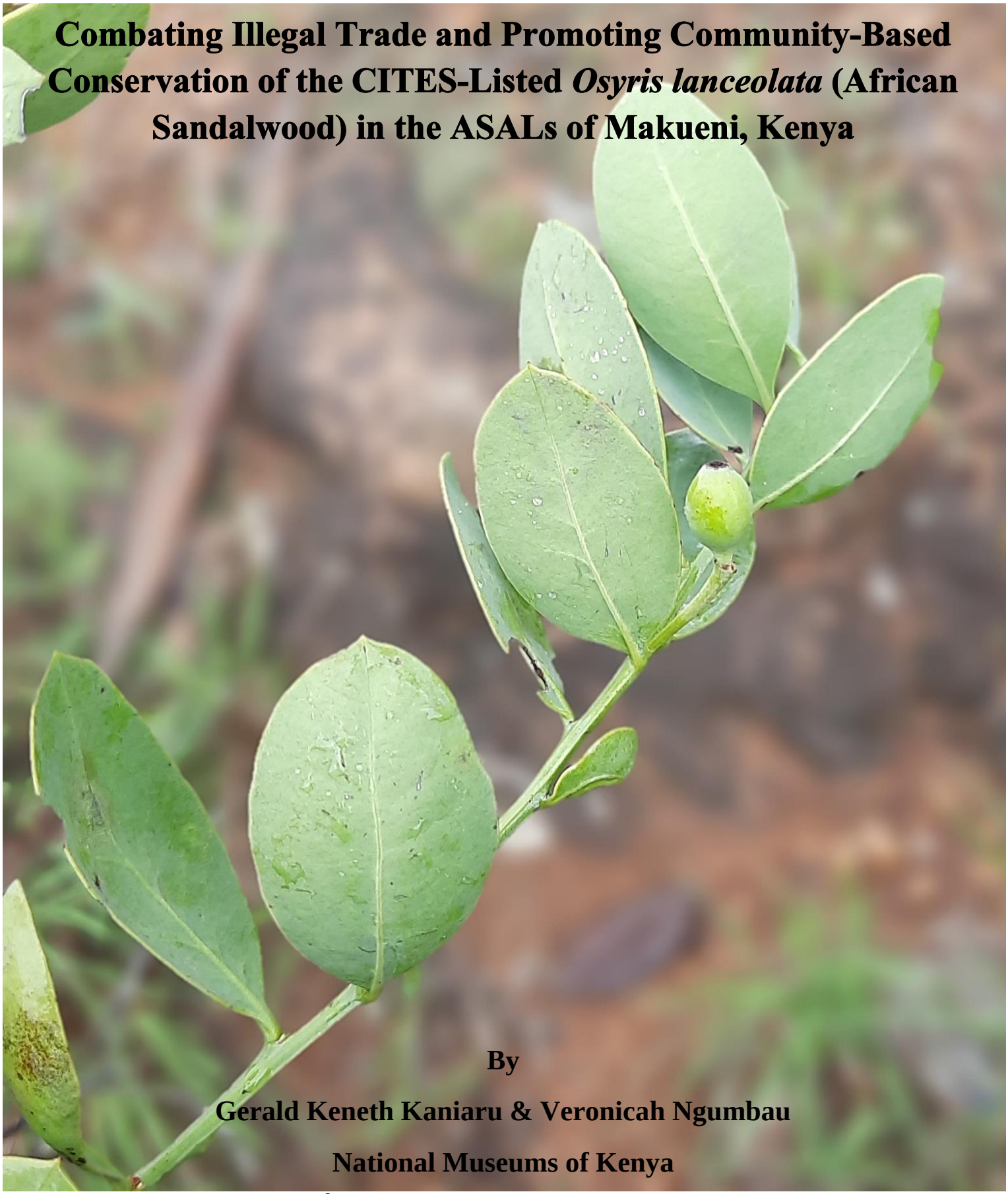
Combating Illegal Trade and Promoting Community-Based Conservation of the CITES-Listed *Osyris lanceolata* (African Sandalwood) in the ASALs of Makueni, Kenya



By

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National Museums of Kenya

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Cover photo: A photo of an *Osyris lanceolata* branch.

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Executive Summary

Osyris lanceolata (African sandalwood) is an evergreen, slow-growing, hemiparasitic, and drought-tolerant tree listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. It is threatened by illegal logging and trade for the production of perfumery and medicinal products. This is owing to the rising demand for the species' essential oils from Africa, Europe, the Middle East, and East Asian countries. From the previous second Rufford Grant, it was observed that most of the local community members are unaware of the species' ecosystem and economic value and are lured by sandalwood traffickers to over-harvest and sell its logs to them at US$100 for a full 4-wheel double cabin. Additionally, community members unsustainably exploit the species and its host plants as fuel, resulting in a rapid decline in their population sizes and survival rates. Furthermore, inadequate data on the current status of African sandalwood populations threatens the species' survival in the wild. This project aimed to: reduce illegal African sandalwood logging and trade of African sandalwood, raising community awareness of the species' ecosystem and economic value and building their capacity to protect, conserve, and restore the species, its host plants, and its habitats, determine the current African sandalwood population status, increase the population size of African sandalwood and its host plants and reduce the local community's unsustainable use of African sandalwood and its host plants as fuel.

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Chapter One: Introduction

1.1. *Osyris lanceolata* Hochst. & Steud. (African Sandalwood)

This species of focus is commonly known as African Sandalwood and belongs to the Santalaceae family. It is a shrub or tree with 1-6 meters in height. This evergreen species exhibits smaller branches that droop (Figure 1). Its leaves are bluish-green or yellow-green in color, slightly fleshy, narrowly elliptic to broadly ovate in shape, with a cuneate base and a spiny-acute apex. The leaves' margin is somewhat thickened, and measure 1-7 by 0.4-3 centimeters, appearing glabrous. Its flowers are tiny and yellow-green, arranged in few-flowered axillary cymes. The species' fruits are orange or red in color, round-shaped, and measure between 5-8 mm in length.

Figure 1: Morphological characteristics of *O. lanceolata*

1.2. Global Distribution of *O. lanceolata*

This species exhibits a wide but fragmented global distribution, primarily across Africa, the Middle East, and parts of Asia (Figure 2). In Africa, it is found in various countries including Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Democratic Republic of Congo, Sudan, and South Africa, with its range extending from East to Southern Africa. In the Middle East, it occurs in countries such as Saudi Arabia, Yemen, and Oman, while in Asia, it can be found in regions of Pakistan and India. However, its distribution within these countries is often localized, with populations occurring in specific habitats such as rocky outcrops, dry forests, and savannas.

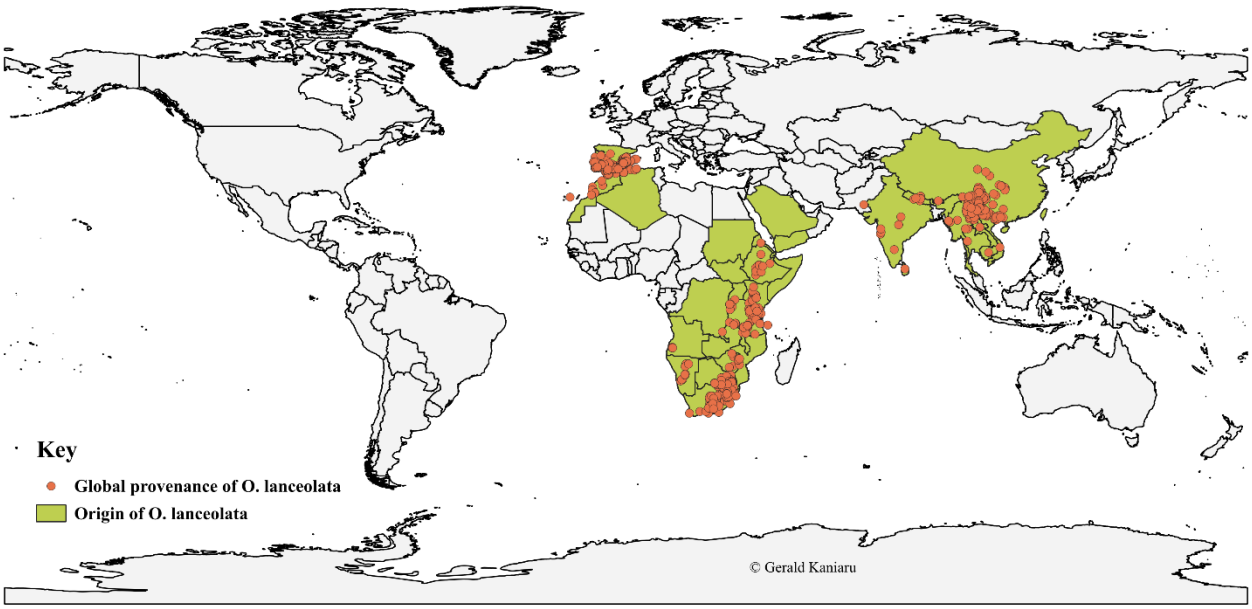

Figure 2: Global provenance and origin of *O. lanceolata*. Occurrence data points were extracted from GBIF.org (2024) and POWO (2024)

1.3. Ecology of *O. lanceolata*

The species grows in bushland ecosystem with grassland and bare ground and is susceptible to erosion. It is characterized by a mix of grassy areas, scattered trees or shrubs, and exposed soil patches (Figure 3.a). This type of landscape is typically found in semi-arid and arid regions where rainfall is limited and irregular. In this ecosystem, the grassland areas are dominated by hardy grass species adapted to survive in harsh environmental conditions, including periods of drought and intense sunlight.

The species is also known for its unique ability to grow on rocky substrates (Figure 3.b). This characteristic sets it apart from many other plant species, as it demonstrates remarkable adaptability to harsh and challenging environments. Despite its resilience, the species faces significant threats when growing on rocks. These threats include limited access to water and nutrients due to the rocky nature of the substrate, which can hinder growth and development. Additionally, competition for resources from other plant species and the risk of soil erosion further exacerbate the challenges faced by this species in rocky habitats.

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Human activities such as illegal logging, habitat destruction, and land conversion for agriculture pose additional threats to the survival of this species in rocky environments. Thus, while this species has the ability to thrive on rocks (Figure 3), it is also vulnerable to a range of threats that necessitate careful conservation efforts to ensure its continued existence.

Figure 3: (a) A bushland ecosystem with grassland and patches of bare ground where *O. lanceolata* is localized. (b) Young sandalwood seedling thriving on rocky substrates.

1.4.Uses of *O. lanceolata*

1) ***Aromatic purposes:*** The primary application of this species is in perfumery. Sandalwood oil, historically derived from various species of the *Santalum* genus, is extracted from its wood. It carries a rich, woody fragrance reminiscent of true sandalwood and is commonly employed as a base or fixative in perfumes.
2) ***Medicinal applications:*** The species is valued for its medicinal properties. Extracts from various parts of the plant, including the bark, leaves, and roots, are used to treat a range of ailments. These may include digestive disorders, respiratory issues, skin conditions, and even as an analgesic or antipyretic agent.
3) ***Religious and spiritual practices:*** The aromatic smoke produced by burning its wood or incense made from its resin is believed to purify the environment and enhance spiritual experiences. It is often used in rituals, prayers, and meditation practices across cultures.
4) ***Woodcraft and art:*** Although not as commonly utilized for woodcraft as true sandalwood, the species' wood is still valued for its hardness and durability. It is occasionally used in carving small decorative items, beads, or ornaments. The distinctive grain and color of the wood make it aesthetically pleasing for artistic endeavors.
5) ***Economic Trade:*** This species has gained attention in international trade as a substitute for true sandalwood, particularly due to the increasing scarcity and regulations surrounding genuine sandalwood species. This has led to its exploitation for commercial purposes, with its wood and essential oil being traded in global markets.

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1.5. Objective of the Study

This study aims to:

1) Reduce illegal African sandalwood logging and trade of African sandalwood by developing and implementing an illegal African sandalwood trade prevention strategy; raising community awareness of the species' ecosystem and economic value and building their capacity to protect, conserve, and restore the species, its host plants, and its habitats; and fencing its habitats to prevent further encroachment and degradation.
2) Determine the current African sandalwood population status by assessing, mapping, and documenting its population size, distribution, and regeneration patterns.
3) Increase the population size of African sandalwood and its host plants through mass propagation and planting in suitable threat-free sites and on-farm as alley-crops and woodlots.
4) Reduce the local community's unsustainable use of African sandalwood and its host plants as fuel by promoting paper log briquette use as an alternative, long-term fuel source.

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Chapter Two: Materials and Methods

2.1. Study Area

2.1.1. Location, Topography and Climate

This study was carried out in Kenya's southeastern region in Wote sub-county (1.8199°S; 37.5734°E), Makueni county (1.5833°-2.98333°S; 37.1667°-38.5°E). It is one of the arid and semi-arid regions of Kenya, with an area of 8170km^2, a population of 987,653 and a population density of 120.9 per km^2 as per Kenya's 2019 census.

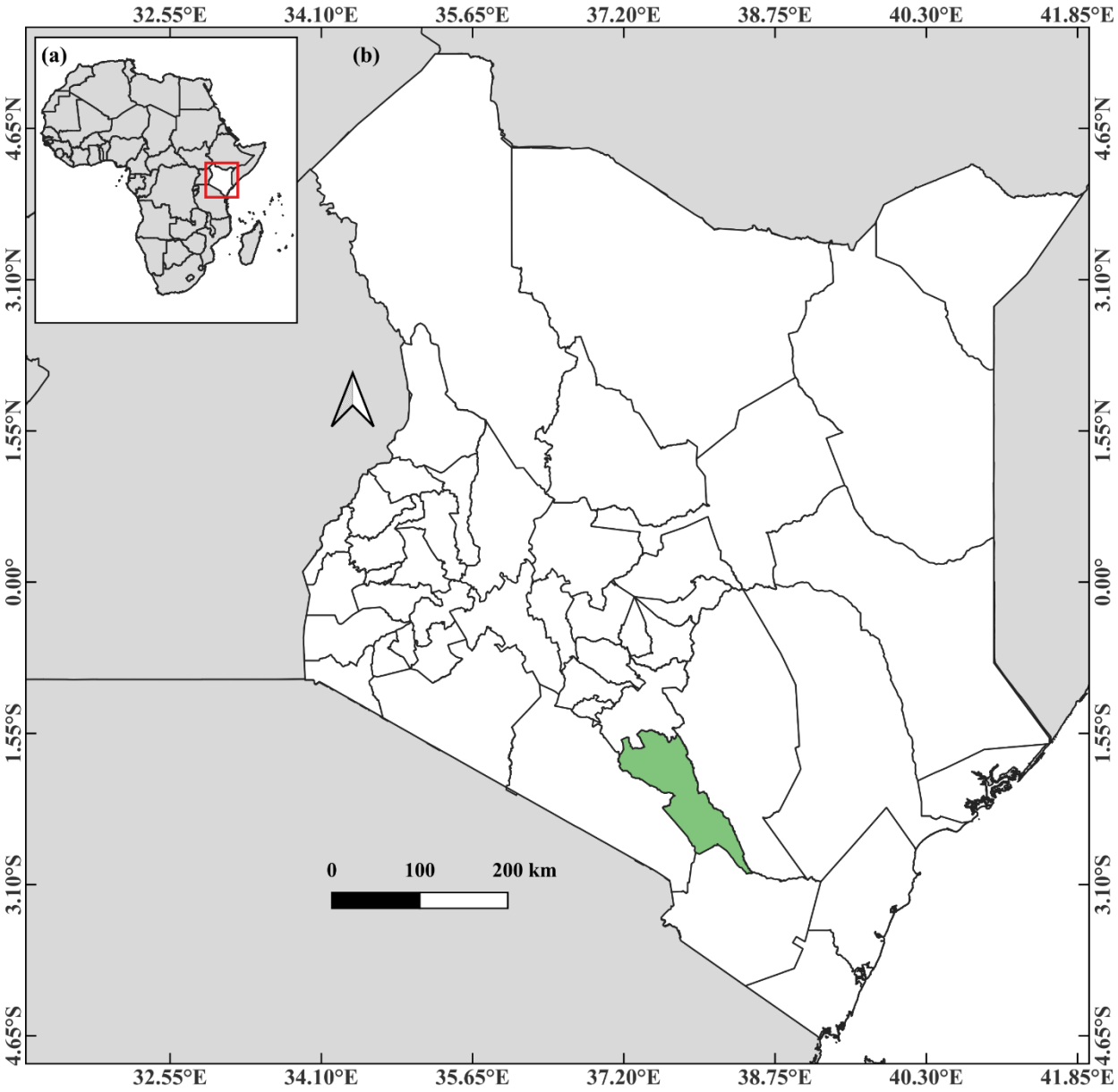

Figure 4: (a) A map of Africa highlighting Kenya. (b) A map of Kenya with Makueni County (study area) highlighted in green

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The study area has an annual average rainfall ranging from 1200 mm in the hilly north to 500 mm in the low lying areas. The rainfall is bimodal with long rains occurring between March and May and the short rains between October and December. January to about March is characterized by a short dry season while June to around October is characterized by a long dry season. The short rains are generally more pronounced and reliable than the so-called long rains. Most of the district experiences high temperatures during the day and low temperatures at night. During the rainy season, the temperatures range between 24 °C-33 °C, while in the dry/cool season it ranges between 18 °C-24 °C. Most of the vegetation is adapted to arid and semi-arid conditions.

2.1.2. Vegetation and Biodiversity

The area has three types of vegetation: arid, semi-arid, and forest, although aridity and semi-aridity are the most dominant. The vast dryland ecosystem of Makueni is often interrupted by numerous rocky hills (inselbergs), ranging from 700 to 1750 meters above sea level, rarely reaching 2000 meters. It is characterized by wooded Combretum grassland and a semi-moist montane vegetation type. This vegetation type is an important biodiversity refugium, comprising nearly 68 percent of the nation's vascular plant diversity (Malombe *et al*., 2015). At least 847 species of plants and fungi have been recorded, with 69 of them being endemic to the eastern African region, while a number of them are affiliated with the Eastern Arc Mountains and Coastal forests. Additionally, four new species, including Aloe ngutwaensis, were described (Malombe *et al*., 2015).

Figure 5: The dry hilltops of Makueni where *O. lanceolata* occurs

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Since the hilltops contain crucial biodiversity genetic resources, which are important for the reconstruction and restoration of the degraded larger ecosystem, there is a need to increase efforts to rescue such vulnerable habitats. The need for restoration and conservation of this species is one of the key obligations of national governments, as stipulated in the Convention on Biological Diversity (CBD) and the National Strategy for Species Conservation policy. Community participation is, however, critical for the success of conservation programs and to support the socio-economic pillars envisaged in Vision 2030 and the Millennium Development Goals. Continued protection will not only help sustain biodiversity conservation but also ensure improved livelihoods and increased prosperity for the community.

2.1.3. Land Tenure, Population and Human Activities

There are various categories of land ownership in Makueni County. There is trust land (under the County Council), gazetted land (owned by the government), and free hold (registered and owned by farmers or other individuals). Gazetted forest land occupies only about 2% of the total area of the county. Trust lands account for approximately 10% of the total land area, with the remainder being freehold. The northern areas with higher rainfall are densely populated, with Mbooni and Kilungu sub-counties having up to 400 people per square km and a lower poverty index. The low-lying, semi-arid areas that occupy most of the district are sparsely populated and have a high poverty index. Human activities in the area have a major influence on the vegetation due to their high dependence on natural resources for livelihood support. Subsistence agriculture, where farmers till the land to grow crops whenever there are good rains, and animal husbandry, with cattle and goat rearing, are important activities that have altered the natural vegetation. Income-generating activities, especially charcoal burning, mining for building stones, and sand harvesting from rivers, have negatively impacted the natural vegetation and landscape of the affected areas.

2.2. Baseline and Field Surveys

2.2.1. Literature Review

To conduct a detailed survey of *O. lanceolata* and its host plants, we employed a multifaceted approach that combined literature review and field survey methodologies. We conducted a comprehensive review of existing literature on the species to gather information on its distribution, habitat preferences, and ecological requirements. This involved studying scientific publications, reports, and relevant conservation documents. Additionally, we analyzed data from previous surveys in similar ecological regions to identify areas where the species' populations have been historically documented.

2.2.2. Field Surveys: Species' Mapping and Threat Assessment

The surveys were conducted on the targeted hilltops known to harbor the populations of the species and its host plants. The project team, along with trained local community members, systematically traversed the study site, employing various survey techniques such as transect walks, quadrat sampling, and GPS mapping to locate and document individuals of *O. lanceolata*.

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During the surveys, we collected data including precise geographical coordinates of observed populations, population size, density, and health status of individuals. At the same time, we assessed the environmental status of the hilltops, focusing on factors such as habitat quality, vegetation composition, and the presence of threats. We conducted species mapping to create detailed maps depicting the distribution and density of *O. lanceolata* populations across the surveyed hilltop environments. We employed GIS software to integrate field-collected data with satellite imagery and topographic maps, facilitating the visualization of population clusters and habitat characteristics. Our mapping efforts aimed to provide spatially explicit information to aid in conservation planning and management decisions.

In addition, the project team conducted threat assessments through field observations and consultation with local communities, identifying key threats to the hilltop environments. Threats were assessed in terms of their level, severity, and potential impact on *O. lanceolata* populations. By employing this integrated approach, the project achieved a comprehensive understanding of the species' populations, their habitat requirements, and the threats they face in hilltop environments, providing valuable insights for conservation planning and management strategies.

Figure 6: Mapping of *O. lanceolata* individuals and populations during field surveys

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2.3. Community Engagement and Collaboration

2.3.1. Assessment of Existing Community Groups

This was a crucial step in implementing this study, ensuring effective engagement and collaboration with local stakeholders. An inventory of new and existing community groups involved in conservation-related activities within the target area was conducted. This fostered meaningful engagement, built trust, and cultivated strong partnerships with local stakeholders, ultimately enhancing the effectiveness and sustainability of conservation efforts.

2.3.2. Community Mapping and Needs Assessment

The project team conducted community mapping exercises to identify geographical areas where community groups are located and assess their conservation needs and priorities. By conducting a thorough community mapping and needs assessment, the project team gained valuable insights into the strengths, challenges, and opportunities within the community, enabling the team to develop targeted interventions that address the community's most pressing needs effectively.

2.3.3. Identification of Additional Community Groups

The project team utilized participatory approaches, such as focus group discussions and surveys, to identify other community groups that may not be actively engaged in conservation but have the potential to contribute to conservation efforts. The project team collaborated with county conservation agencies and local leaders to identify and reach out to marginalized or underrepresented groups, ensuring inclusivity and diversity in community engagement efforts. By systematically consolidating existing community groups and identifying additional ones in collaboration with county conservation agencies, we built a strong network of stakeholders actively engaged in conservation efforts, thereby enhancing the effectiveness and sustainability of conservation initiatives at the local level.

2.3.4. Stakeholder Consultations

A stakeholder meeting was organized, involving representatives from existing community groups, county conservation agencies, and local government authorities. The project team facilitated discussions to identify shared conservation goals, challenges, and opportunities for collaboration. Inputs from community members were sorted by the project team in order to understand their needs, priorities, and aspirations regarding conservation initiatives. Additionally, the project team analyzed the perceptions of the local people (indigenous knowledge in resource conservation) and administrative structures on the viability of the proposed project.

2.4. Effective Conservation and Restoration Programme for *O. lanceolata*

2.4.1. Seed Collection and Propagation of O. lanceolata and its Host Plants

The seeds of African sandalwood and selected host plants were collected (Figure 8), processed, and then mass-propagated and transplanted in non-mist propagators and tree nurseries following the guidelines outlined by Kamondo *et al*. (2012) in collaboration with trained stakeholders.

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Additionally, seedlings of the species and its host plants were sourced from ecogeographically similar areas and mixed with the local seed collection (composite provenance). All seedlings were transplanted at a spacing of 3m x 3m (FAO, 1989) and cared for by trained members in suitable, threat-free sites and on-farm as alley crops and woodlots.

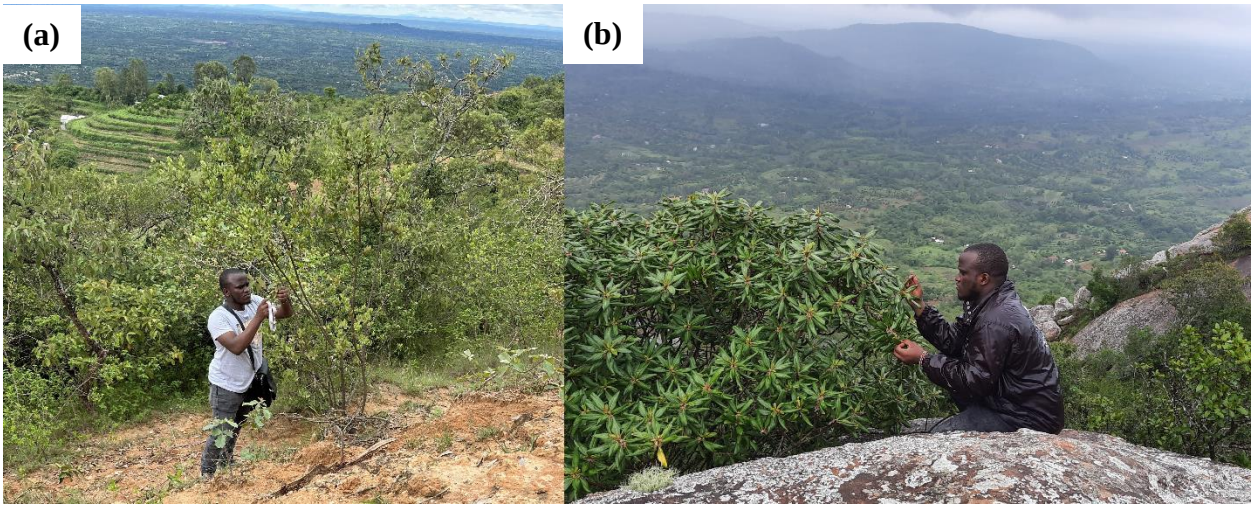

Figure 7: Seed collection of (a) *O. lanceolata* and (b) *Myrsine melanophloeos* (a host plant)

2.4.2. Translocation of O. lanceolata Saplings

This involved carefully uprooting *O. lanceolata* saplings from their current location in threat-prone pathways using a shovel and transplanting them in media-potted tubes in community-tree nurseries. Care was taken to minimize root damage during the extraction process. Once relocated to the nurseries, the seedlings and saplings were nurtured and monitored to promote their growth and development until they were ready for planting to safer and more suitable habitats.

Figure 8: An *O. lanceolata* wildling growing on pathways

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2.4.3. Develop a Collaborative Illegal Trade Prevention Strategy for O. lanceolata

The Situational Crime Prevention (SCP) strategy, as outlined in the Fauna & Flora International (2021) toolkit, will be used in collaboration with the local community, county authorities, and conservation agencies to combat illegal logging and trade of African sandalwood. The approach includes:

1) Defining the target illegal activity
2) Describing the current situation
3) Improving understanding of the situation
4) Developing and refining interventions

This proactive method aims to prevent illegal activity by analyzing the problem thoroughly and devising targeted interventions to deter the activity before it occurs.

2.4.4. Adoption of Paper log Briquettes as an Alternative Fuel Source

The use of *O. lanceolata* as fuel has been a common practice in the study area due to its combustible properties. However, this practice has had detrimental effects on the species and its surrounding ecosystem. Overharvesting of the species for fuel has led to habitat degradation, loss of biodiversity, and disruption of ecological processes. As a result, the production and use of paper log briquettes were promoted through this study as an alternative fuel source and sustainable energy practice to reduce reliance on *O. lanceolata* and other wood-based fuels. Four selected community groups underwent comprehensive training conducted by the project team to learn the techniques and procedures for the mass production and commercialization of paper log briquettes.

The adoption of paper log briquettes as an alternative fuel source involved utilizing compacted paper waste to create a cheap, eco-friendly, and sustainable fuel option. Waste paper materials, such as newspapers, cardboard, and office paper, were collected from Ngutwa Primary School, a school within the study area. The paper waste was then shredded into small pieces and mixed with water and other combustible materials, such as sawdust or agricultural residues, to form a pulp-like mixture. The wet pulp was then compressed and molded into briquettes using a briquetting machine. These briquettes were then left to dry thoroughly, usually in the sun or in a well-ventilated area, until they achieved a solid and compact form. Once dried, the paper log briquettes can be used as an alternative fuel source for cooking, heating, or other purposes typically served by traditional firewood or charcoal. In earnest, transitioning to more sustainable and eco-friendly fuel alternatives is essential for the conservation of *O. lanceolata* and the preservation of its natural habitat.

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Chapter Three: Results and Discussion

3.1. Sampled Populations of *O. lanceolata*

Populations of this species were identified in various localities across Makueni County, including Matooi, Nzaui, Makuli, Malibani, Mutula, and Nthangu (Figure 9). These areas shared similar vegetation types and species associations, but notable differences in disturbance levels were observed. Matooi, Makuli, and Kathuma appeared more disturbed compared to Nzaui, Malibani, Mutula, and Nthangu, which showed relatively less disturbance. Specifically, Makuli stood out with the fewest *O. lanceolata* individuals compared to the other sampled localities.

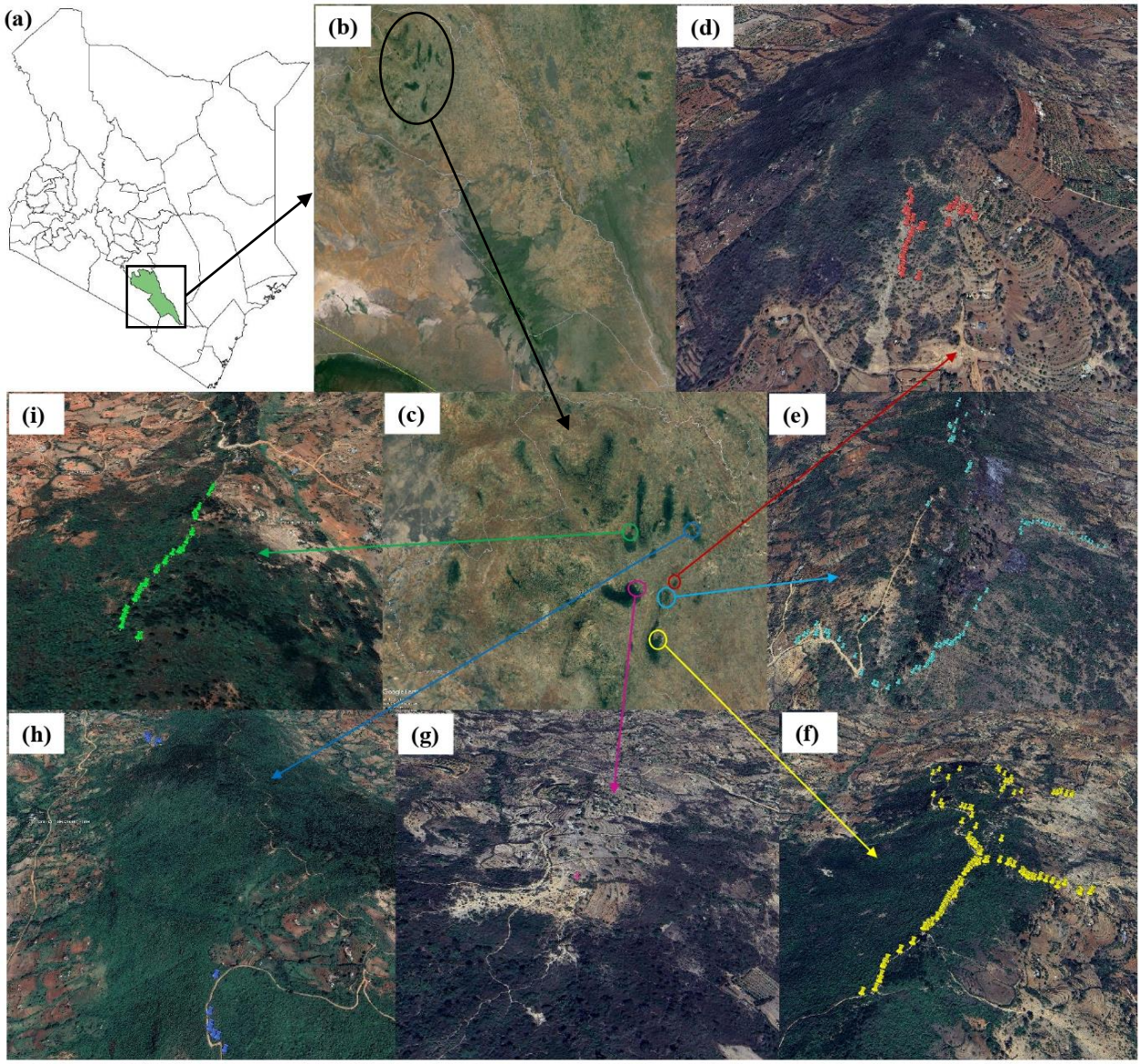

Figure 9: (a) Map of Kenya highlighting Makueni County in green; (b) Outline of Makueni County; (c) Forest patches and sites where *O. lanceolata* was sampled; (d) Malibani; (e) Matooi Hill; (f) Nzaui; (g) Makuli; (h) Nthangu; and (i) Mutula sites. © Google Earth

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We observed fewer than 20 mature individuals of the target species across the six localities in Makueni County. In addition, several host plants were observed among the identified *O. lanceolata* populations (Table 1). These host plants play crucial roles in the ecosystem, providing habitat, sustenance, and support for the growth and reproduction of the species.

Table 1: Host plants observed in the sampled *O. lanceolata* populations

No.	Family	Species
1	Fabaceae	*Vachellia hockii*
2	Fabaceae	*Dichrostachys cinerea*
3	Salicaceae	*Flacourtia indica*
4	Penaeaceae	*Olinia rochetiana*
5	Rhamnaceae	*Rhamnus prinoides*
6	Anacardiaceae	*Searsia natalensis*
7	Anacardiaceae	*Searsia pyroides var. pyroides*
8	Polygalaceae	*Securidaca longepedunculata*
9	Rubiaceae	*Vangueria infausta*
10	Combretaceae	*Terminalia brownii*
11	Ericaceae	*Agarista salicifolia*
12	Fabaceae	*Albizia glaberrima*
13	Francoaceae	*Bersama abyssinica*
14	Fabaceae	*Brachystegia spiciformis*
15	Combretaceae	*Combretum zeyheri*
16	Ebenaceae	*Euclea divinorum*
17	Proteaceae	*Faurea saligna*
18	Rutaceae	*Harrisonia abyssinica*
19	Primulaceae	*Myrsine melanophloeos*
20	Oleaceae	*Schrebera alata*
21	Fabaceae	*Senna singueana*
22	Fabaceae	*Ormocarpum kirkii*
23	Ochnaceae	*Ochna holstii*
24	Sapindaceae	*Dodonaea viscosa*

Despite their hemiparasitism relationship with the target species, some of these host plants provide ecosystem goods and services in the target species' habitats. They include;

1) *Dodonaea viscosa*: This species is used for the reforestation of degraded areas as it is an aggressive colonizer and an excellent soil stabilizer due to its spreading fibrous roots and canopy.
2) *Faurea saligna*: This tree serves as a windbreak and its leaves as mulch. Its flowers produce nectar, which honey bees use to produce honey, thereby supporting apiculture.

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3) *Brachystegia spiciformis*: Its leaves are used as livestock feed, and its flowers provide nectar to bees.
4) *Bersama abyssinica*: It is an agroforestry tree, and its flowers support bee forage.
5) *Albizia glaberrima*: Its leaves provide food for livestock, its flowers provide forage for bees, and its roots aid in nitrogen fixation in the soil.
6) *Terminalia brownii*: It is a valuable, drought-tolerant, and multipurpose agroforestry plant.
7) *Rhamnus prinoides*: The tree acts as a windbreak and prevents erosion, particularly along stream banks.
8) *Dichrostachys cinerea*: It is an agroforestry tree that helps to control soil erosion and facilitate revegetation. Its leaves are used as manure and fertilizer, while its roots are used for nitrogen fixation, hence improving soil fertility and structure.

Some of the threatened and endemic plant species found in and near *O. lanceolata* habitats include:

1) Endangered species: *Millettia vatkei*.
2) Vulnerable species: *Eragrostis ambleia*, *Englerina drummondii*, *Euphorbia friesiorum*, *Pavetta teitana*, *Rytigynia eickii*, and *Uvariodendron anisatum*.
3) Near-threatened species: *Aloe deserti*.
4) Species native to Kenya only: *Adenia metriosiphon*, *Cyphostemma jiguu*, *Dyschoriste keniensis subsp. keniensis*, *Euphorbia friesiorum*, *Millettia vatkei*, *Pavetta teitana*, *Thunbergia napperae*, *Uvariodendron anisatum*, and *Vernonia subscandens*.
5) Species native to Kenya and Tanzania only: *Adenia wightiana subsp. africana*, *Aloe deserti*, *Barleria eranthemoides var. agnewii*, *Barleria inclusa*, *Chamaecrista usambarensis*, *Cyphostemma maranguense*, *Englerina drummondii*, *Hermannia uhligii*, *Vangueria schumanniana*, *Rothmannia fischeri subsp. verdcourtii*, *Rytigynia eickii*, *Sida massaica*, and *Vernonia galamensis* subsp. *nairobensis*.
6) Species native to Kenya and Ethiopia only: *Aloe lateritia var. graminicola*.
7) Species native to Kenya and Somalia only: *Eragrostis ambleia*.
8) Species native to Kenya, Tanzania, and Somalia only: *Grewia plagiophylla* and *Ipomoea wightii var. kilimandschari*.
9) Species native to Kenya, Ethiopia, and Tanzania only: *Erythrina burttii*, *Ammannia kilimandscharica*, and *Sphaeranthus bullatus*.
10) Species native to Kenya, Uganda, and Tanzania only: *Monanthotaxis parvifolia subsp. kenyensis*, *Ochna ovata*, and *Uvaria scheffleri*.
11) Species native to Kenya, Ethiopia, Malawi, and Tanzania only: *Dracaena suffruticosa*, and *Turraea mombassana*.
12) Species native to Kenya, Tanzania, and Zambia only: *Sphaeranthus kirkii var. cyathuloides*.
13) Species native to Kenya, Sudan, and Uganda only: *Vachellia elatior*.

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3.2. Threats facing *O. lanceolata*

3.2.1. Deforestation

The clearing of *O. lanceolata* habitats for agriculture, urbanization, or logging, among other anthropogenic perturbations (Figure 10), profoundly impacts habitat loss and degradation for the species. This process has significant ecological consequences on the species and its associated flora. It directly reduces available habitat for the species and its host plants, diminishing their population size and genetic diversity. Consequently, heightened competition for resources and space occurs, resulting in decreased growth rates and reproduction. Moreover, deforestation disrupts the ecological balance within the species' habitats, affecting interactions between the species and its host plants. Many plant species, including potential hosts, rely on *O. lanceolata* for ecological functions such as pollination, seed dispersal, and habitat provision. As a result, loss of the species disrupts these ecological relationships.

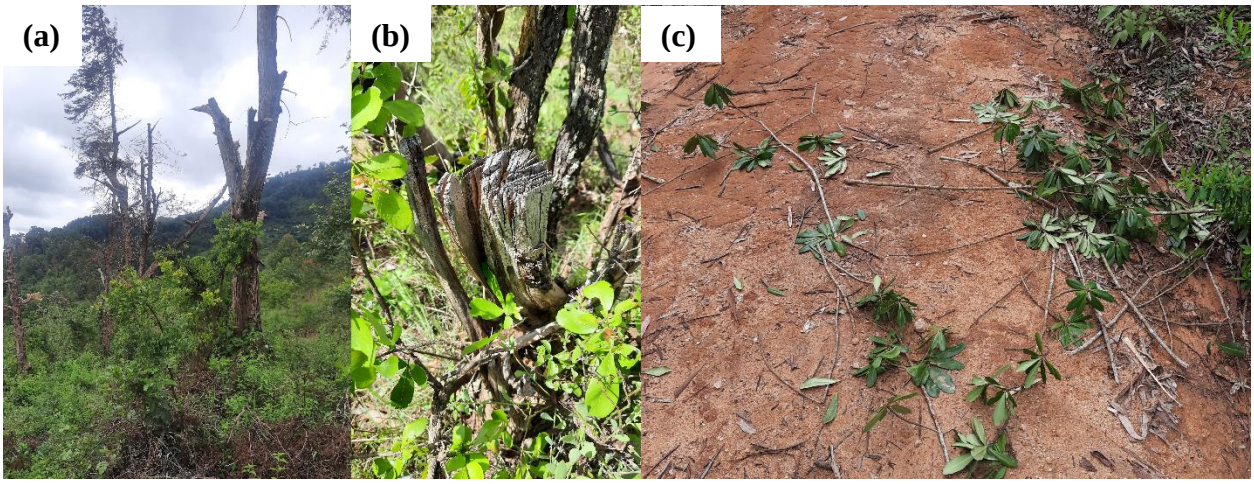

Figure 10: Deforestation of: (a) *O. lanceolata* habitat in Nzaui; (b) its species; and (c) its host plant, *Myrsine melanophloeos*

Deforestation resulted in soil erosion and degradation, directly impacting the growth of *O. lanceolata* and its host plants. The natural vegetation acts as a protective cover, reducing the impact of rainfall on the soil surface. Without this cover, raindrops directly strike the soil, dislodging soil particles and increasing erosion. The deforested areas experience higher rates of surface runoff due to fewer trees intercepting rainfall and absorbing water. This increased runoff has led to greater soil erosion, with flowing water carrying away soil particles and creating channels and gullies. Additionally, the deforested areas are vulnerable to wind erosion, as the absence of vegetation allows the wind to easily pick up and transport loose soil particles, contributing to soil loss and degradation in *O. lanceolata* habitats. These habitats often occur on slopes, where soil erosion is exacerbated by gravity and runoff during rainfall events. The frequent surface run-offs in these habitats evolve into rill erosion, characterized by the formation of small channels or rills on the soil surface. Over time, these rills deepen and widen, leading to the formation of deep gullies within the habitat (Figure 11).

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As water flows through the landscape, it picks up soil particles and carries them downstream, gradually eroding the soil and creating larger channels. This process is exacerbated by the lack of vegetation cover within these habitats, which would normally help stabilize the soil and reduce erosion. As gullies form, they further accelerate the erosion process, as water becomes concentrated in these channels, leading to even greater soil loss. Ultimately, this cycle of erosion results in significant habitat degradation, impacting the overall health and stability of *O. lanceolata* habitats.

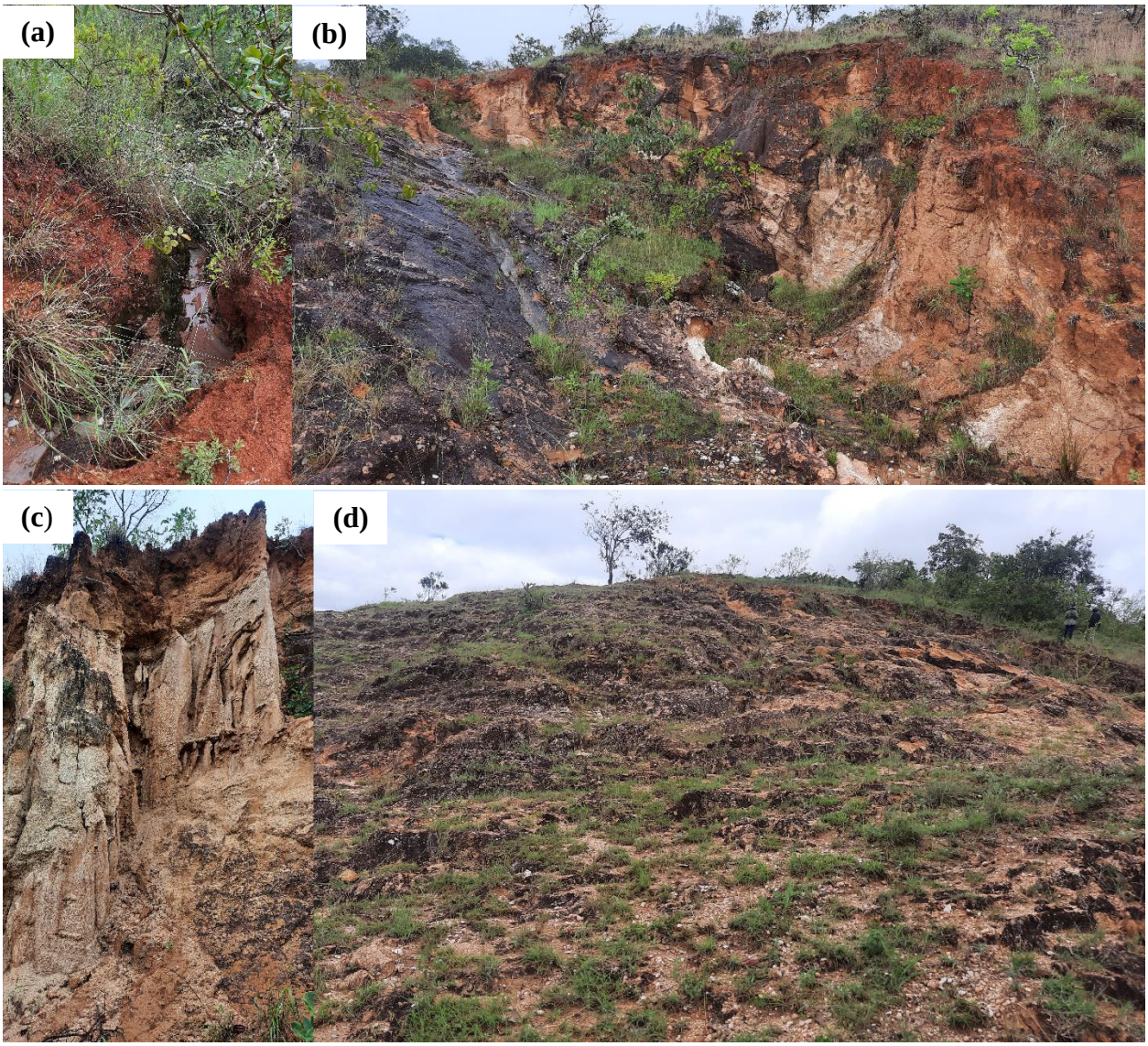

Figure 11: (a) Widened rills; (b) Deep gullies; (c, d) Degraded *O. lanceolata* habitats

Overall, deforestation of *O. lanceolata* habitats has far-reaching consequences for the species, its associated flora, and the overall ecosystem. Conservation efforts aimed at mitigating deforestation and promoting habitat restoration are crucial for the long-term survival and ecological resilience of *O. lanceolata* and its associated plant community.

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3.2.2. Urbanization

The expansion of roads poses a significant risk to the survival of *O. lanceolata* individuals in Makueni County. It involves clearing vegetation along the roadside, including habitats where *O. lanceolata* grows (Figure 12). This habitat loss directly reduces available space for *O. lanceolata* populations, leading to a decline in their overall population size. Moreover, the fragmentation of habitats caused by roads isolates *O. lanceolata* populations, restricting gene flow and increasing vulnerability to genetic drift and inbreeding depression. Additionally, road expansion increases the risk of habitat degradation through soil compaction, pollution, and disturbance. The construction of roads often involves heavy machinery and equipment, which can compact the soil and disrupt natural soil structure. This compaction reduces soil porosity and infiltration capacity, leading to increased surface runoff and erosion. Furthermore, the deposition of pollutants such as oil, chemicals, and debris from vehicles contaminates soil and water bodies adjacent to the roads, further degrading *O. lanceolata* habitats.

Figure 12: *O. lanceolata* individuals endangered by road construction in Kathuma locality En route to Matooi Hill

Road expansion poses a multifaceted threat to the survival of *O. lanceolata* individuals in the study area, including habitat loss, fragmentation, and degradation. Effective mitigation measures, such as habitat restoration, road planning, and wildlife corridors, are essential to minimize the impact of road expansion on *O. lanceolata* populations and ensure their long-term survival.

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3.2.3. Introduction of Non-Native Species

Eucalyptus and *Hesperocyparis lusitanica* plantations were observed within *O. lanceolata* habitats in Matooi hills and Nzaui localities, respectively, potentially significantly impacting the growth and survival of the species and its host plants. These effects can manifest in various ways, including competition for resources and habitat alteration. The introduced species compete with the target species and its host plants for essential resources such as water, nutrients, and sunlight. If the introduced species are more aggressive or have higher resource requirements, they can outcompete *O. lanceolata* and its host plants, leading to reduced growth and survival rates. Additionally, they can alter the physical structure and composition of the habitats, further negatively impacting the growth and establishment of the target species and its host plants.

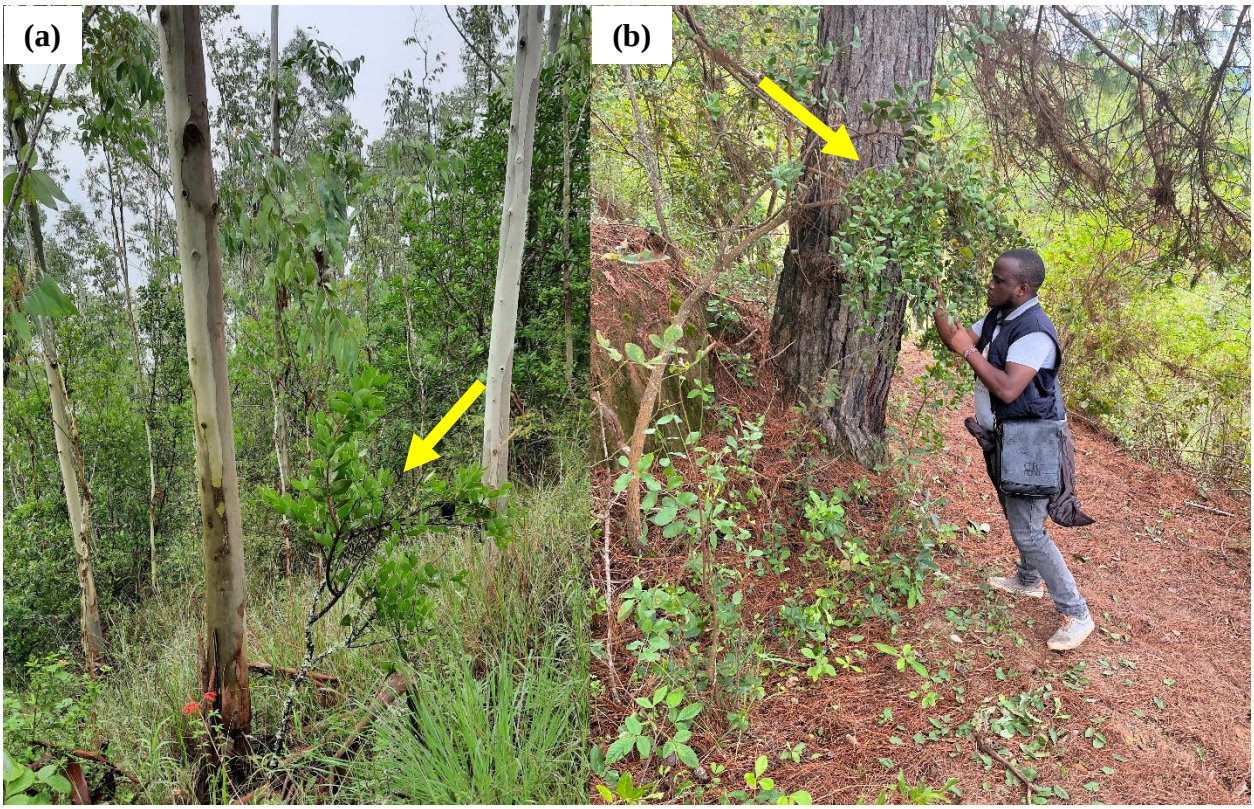

Figure 13: *Eucalyptus sp*. (a) and *H. lusitanica* (b) plantations within an *O. lanceolata* habitat. *O. lanceolata* individuals are indicated by yellow arrows

Overall, the effects of introduced species on *O. lanceolata* and its host plants can be detrimental, potentially leading to population declines, loss of genetic diversity, and ecosystem disruption. Therefore, it is essential to carefully monitor and manage introduced species to mitigate their impacts on native plant communities.

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3.2.4. Firewood Collection and Charcoal Burning

These anthropogenic activities have profound effects on the species, its host plants, and the integrity of their habitats. This practice involves the harvesting and burning of the species' wood to produce charcoal for fuel, often for cooking and heating purposes. As a result, it directly contributes to the reduced population size of the species as well as the loss and degradation of its habitats. These activities pose significant threats to the conservation of the species and the preservation of its natural habitats. Efforts to mitigate the effects of these anthropogenic perturbations include promoting alternative fuel sources and raising awareness among local communities about the importance of conserving *O. lanceolata* and its associated ecosystems.

Figure 14: (a) Firewood collection and (b) charcoal burning of *O. lanceolata* and its host plants by the local community

3.2.5. Illegal Harvesting and Trade

In Kenya, *O. lanceolata* is safeguarded by the president's order, as per Legal Notice No 3176 of 2007, under the Forests Act of 2005, which aims to develop sustainable harvesting methods for the species. Additionally, laws such as the Wildlife Act Cap. 376, the Environment and Management Coordination Act of 1999, and The Constitution of Kenya (2010) regulate the exploitation of this species.

The project team observed unauthorized harvesting, transportation and commercialization of *O. lanceolata* with the consent and involvement of the local community (Figure 14), in violation of national and international laws and regulations. Unaware of the high value of the species, the villagers are lured to cut the trees and sell at a low price of US$100 per full 4-wheel double cabin. During the interviews, the project team observed that the illegal traffickers were made aware of the locations of the sandalwood populations by the villagers for easy harvesting. The illegal loggers use unsustainable and destructive methods, such as clear-cutting or selective logging. Over 100 live and dead stumps of the locally endangered species were identified. The team also noticed that some of the pieces of sandalwood from the study area were transported from the study area to the coastal region through the Emali route for shipping.

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They are then traded on the black market, where they are sold to consumers, manufacturers, and distributors. This illegal activity poses significant threats to the existence of the species, its ecosystems, biodiversity, and sustainable development efforts. Its impact is far-reaching and has serious environmental, social, and economic consequences. Deforestation and habitat loss resulting from illegal logging of the species contribute to climate change, disrupt ecosystem services, and threaten the livelihoods of millions of people who depend on forests for their survival. Furthermore, the loss of biodiversity associated with illegal logging can have cascading effects on ecosystem health and resilience.

Figure 15: Unpacking of the confiscated pieces of *O. lanceolata* by the Directorate of Criminal Investigations (DCI)

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3.3. Illegal Trade Prevention Strategy for *O. lanceolata*

This evidence-based strategy serves as a blueprint for local communities, conservation agencies, county and national authorities to mitigate the illegal harvesting, transportation, and sale of *O. lanceolata*. The development of this strategy for *O. lanceolata* engaged various stakeholders, including the local community, representatives of community groups, village elders, county authorities, conservation agencies, and invited senior researchers. This strategy followed various steps including:

3.3.1. Definition of the Target Illegal Activity

This strategy aims to reduce the illegal harvesting of *O. lanceolata* by illegal loggers in Makueni County.

3.3.2. Description of the Current Situation

To develop this strategy, it was crucial to gain a comprehensive understanding of the current circumstances surrounding this CITES-listed species. This involved analyzing the processes, individuals, locations, and timings associated with the illegal harvesting, transportation, and sale of the species, as well as evaluating the effectiveness of existing interventions.

A crime script for the illegal activity surrounding *O. lanceolata* was formulated by the project team in collaboration with stakeholders, including trained members of community groups (Table 2; page 23). This script provides a detailed account of the sequential actions and decision-making procedures involved in carrying out the illegal activity, covering all individuals, locations, and timeframes. It thoroughly addresses the entire progression of activities, from preparation and pre-activity phases to the execution of the illegal behavior and subsequent post-activity stages.

3.3.3. Improved Understanding of the Situation

During the preparation phase of our investigation, specific habitats of *O. lanceolata* were identified, setting the stage for subsequent actions. Harvesting activities, a critical aspect of the illegal trade, are typically carried out during daylight hours to evade detection. Within the local community, individuals are tasked with identifying mature trees suitable for harvesting, often during the dry season when access to habitats is more feasible. Illegal loggers, often recruited locally or from nearby areas, employ various tools, such as axes and machetes, to fell these trees. Once harvested, the logs undergo trimming and preparation for transportation.

The harvesting process involves the assistance of community members, some of whom participate in exchange for compensation or other incentives. Middlemen play a crucial role in the illegal trade by establishing connections with potential buyers interested in purchasing *O. lanceolata* products. To avoid detection, transportation of harvested logs primarily occurs during the nighttime or early morning hours. The logs are loaded onto trucks, pickups, or other vehicles, with efforts made to conceal them during transit. Upon reaching designated storage facilities, the logs are hidden or camouflaged to prevent interception by authorities at inspection points.

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Sales transactions take place at various times, dictated by market demand and product availability. Middlemen negotiate prices with buyers, with transactions involving cash payments or alternative forms of compensation. The products, ranging from raw logs to processed materials, find their way into various markets where they are utilized for purposes such as pharmaceutical products, fragrances, carvings, or ornamental decorations. These processes constitute the intricate chain of events involved in the illegal harvesting, transportation, and sale of *O. lanceolata*, highlighting the complexity and challenges faced in combating this illegal trade.

The potential extinction of the species looms imminent unless stringent measures are implemented to regulate its international trade. The species has emerged in global markets as a substitute for traditional sandalwood oil sourced from Asia and Australia, which has been historically valued for its fragrance, medicinal properties, religious significance, and woodcraft potential. This increased demand for sandalwood oil, coupled with the limited supply and strict regulations of its traditional sources, has led to the exploitation of East African sandalwood as a preferred alternative. With sandalwood species in India and China under state protection, attention has shifted to East African sandalwood, resulting in its overexploitation in the region. Unlike traditional source countries where control systems ensure sustainable harvesting of true sandalwood through artificial propagation, certification, and legislation, such mechanisms are absent for *O. lanceolata*. Inadequate regulatory mechanisms and enforcement of existing protections exacerbate the threats facing the species. Weak governance, corruption, and a lack of resources hinder effective conservation measures, allowing unsustainable exploitation to persist. Urgent regulation of its international trade is imperative to safeguard its survival in the wild. This necessitates international cooperation under the Convention on International Trade in Endangered Species of Flora and Fauna (CITES).

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Table 2: A crime script demonstrating the sequence of events before, during and after the illegal logging of *O. lanceolata*

Stage	Steps	Where/Place	When/Time	Who/People	Source
Preparation	• Planning and coordination with stakeholders • Allocate resources such as equipment, communication devices, and funds, as well as logistical arrangements • Training of investigation team members on evidence collection and interviewing • Identification of target areas and specific locations	• Ngutwa Primary School	• 1-2 months	• Project Team • Locals and community groups • Kenya Forest Service (KFS) • Wote Police Authorities	• Focus group discussions with the stakeholders
Pre-activity	• Briefing of the investigation team on objectives and procedures • Finalization of the field activity plan • Equipment and material preparation • Confirmation of legal permissions and permits	• Wote Police Station • Ngutwa Primary School	• 2 weeks	• Project Team • Wote Police Authorities • Kenya Forest Service (KFS) • Locals and Community groups	• Focus group discussions with the stakeholders
Illegal activity	• Identification of illegal harvesting, transportation, or sale activities • Surveillance and monitoring of targeted locations • Collection of evidence through observation, photography, and documentation • Identification and apprehension of individuals involved in illegal activities • Seizure of illegally harvested or transported specimens	• Matooi • Nzaui • Makuli • Malibani • Mutula • Nthangu	• 2.5 months	• Project Team • Kenya Forest Service Rangers • Trained community members • Wote Police Authorities	• Interviews with members of the local community • Interviews with Kenya Forest Service rangers • Focus group discussions with community groups and site guardians
Post activity	• Secure storage and documentation of seized evidence	• Matooi, • Nzaui • Makuli • Malibani • Mutula • Nthangu	• 1.5 months	• Wote Police Authorities	• Interviews with Wote Police authorities

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Stage	Steps	Where/Place	When/Time	Who/People	Source
Post activity	• Compilation of investigation findings and evidence • Reporting to relevant authorities and stakeholders • Legal proceedings and enforcement actions against perpetrators • Follow-up monitoring and evaluation of enforcement outcomes • Public awareness and community engagement on the consequences of illegal activities • Review and reflection on investigative processes and outcomes for future improvements	• Wote Police Station • Ngutwa Primary School	N/A	• Kenya Forest Service Rangers • Project Team • Trained community members	• Interviews with Kenya Forest Service Rangers • Interviews with the local community and members of community groups

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3.3.4. Developed and Refined Interventions

The project team, in collaboration with stakeholders and local communities, developed a comprehensive set of interventions aimed at reducing the illegal harvesting of *O. lanceolata* by illegal loggers. These refined strategies incorporate a multifaceted approach, addressing key aspects of the illegal trade chain, from habitat identification to transportation and sale. Through rigorous habitat protection measures, community engagement initiatives, strengthened law enforcement efforts, and alternative livelihood programs, the interventions seek to disrupt the illegal trade network and mitigate the ecological and socio-economic impacts of illegal logging of the species. By fostering collaboration and leveraging local knowledge and resources, these interventions aim to safeguard the biodiversity of the species' habitats while promoting sustainable conservation practices and livelihood opportunities for local communities in Makueni County.

These interventions include:

1) **Habitat Protection and Monitoring:** Implement strict surveillance and protection measures in identified *O. lanceolata* habitats. Utilize technology such as remote sensing and drones for continuous monitoring to deter illegal activities.
2) **Community Engagement and Education:** Conduct awareness campaigns within local communities to educate residents about the ecological importance of *O. lanceolata* and the consequences of illegal harvesting. Foster a sense of stewardship and ownership among community members to discourage involvement in illicit activities.
3) **Strengthening Law Enforcement:** Enhance collaboration between law enforcement agencies, community leaders, and conservation organizations to strengthen enforcement efforts. Deploy dedicated patrols and checkpoints during critical harvesting periods to intercept illegal loggers and transporters.
4) **Alternative Livelihoods:** Introduce alternative income-generating activities for community members involved in illegal logging, offering sustainable alternatives to alleviate economic pressures. Provide training and support for livelihood diversification initiatives such as eco-tourism, agroforestry, or sustainable agriculture.
5) **Supply Chain Disruption:** Target the middlemen and buyers involved in the illegal trade through intelligence gathering and undercover operations. Disrupt the supply chain by intercepting communication channels, conducting sting operations, and seizing illegal goods, thereby deterring further illegal activities.
6) **Legislative Support:** Advocate for stricter enforcement of existing laws and regulations protecting the species and its habitats. Lobby for amendments to legislation to impose harsher penalties for offenders and provide greater protection for endangered species.
7) **International Collaboration:** Engage with international stakeholders, including neighboring countries and global conservation organizations, to address cross-border issues and share best practices in combating illegal wildlife trade. Collaborate on intelligence-sharing mechanisms and joint enforcement operations to disrupt transnational criminal networks involved in illegal logging.

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3.4. Paper log Briquettes: An Alternative Fuel Source and an Economic Venture

The trained community groups possess the capacity and confidence to manufacture, distribute, and market affordable fuel-grade briquettes to both community members and the general public. By transitioning to the use of paper log briquettes as a sustainable fuel alternative, the unsustainable reliance on *O. lanceolata* and its host plants for fuel purposes is significantly reduced. Not only are these briquettes cost-effective and environmentally friendly, but they also served as a source of income for the community groups involved.

Figure 16: A sample of a paper log briquette produced by the local community members for fuel use

At least 50 community members have successfully shifted away from the unsustainable practice of utilizing African sandalwood as fuel, opting instead for the use of paper log briquettes. This transition marks a significant step towards environmental conservation and sustainable resource management within the community. The success of this study lies in its ability to promote paper log briquettes as a viable long-term fuel solution while simultaneously creating income-generating opportunities for local residents. However, to ensure widespread adoption of paper log briquettes and facilitate the transition of more community members away from unsustainable fuel practices, further outreach initiatives are deemed necessary. Continued community engagement and education programs will be essential in raising awareness about the benefits of paper log briquettes and encouraging broader participation in this sustainable fuel and income-generating venture. Through collaborative efforts and ongoing support, the promotion of paper log briquettes can continue to drive positive environmental and socio-economic change within the community.

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Chapter Four: Conclusions and Recommendations

4.1. Conclusions

In this study, we investigated various aspects related to the conservation and sustainable management of *O. lanceolata*. Through comprehensive baseline surveys and field assessments, we identified the key threats facing this species. These findings underscore the urgent need for effective conservation strategies to safeguard this species and its habitats. One significant outcome of our study was the development of a refined illegal wildlife trade prevention strategy tailored specifically for this species. By understanding the dynamics of the illegal trade and collaborating with stakeholders, we devised targeted interventions aimed at reducing the illegal harvesting, transportation, and sale of this CITES-listed species. Additionally, we successfully promoted the adoption of paper log briquettes as an alternative fuel source and an income-generating venture for local communities.

4.2. Recommendations

Based on our findings, we propose several recommendations to further enhance the conservation and sustainable management of *O. lanceolata*:

1) ***Strengthen enforcement efforts:*** Law enforcement agencies should increase patrols and surveillance in key *O. lanceolata* habitats to deter illegal harvesting and trade activities. Collaboration between local authorities and conservation organizations is crucial for effective enforcement.
2) ***Community empowerment:*** Continued engagement with local communities is essential for building awareness and fostering stewardship of *O. lanceolata* habitats. Providing training and capacity-building initiatives will empower communities to actively participate in conservation efforts.
3) ***Sustainable livelihoods:*** Expand the implementation of alternative income-generating activities, such as the production and sale of paper log briquettes, to reduce dependence on unsustainable harvesting of *O. lanceolata*. This approach promotes both environmental conservation and economic prosperity.
4) ***Long-term monitoring:*** Establish monitoring programs to assess the effectiveness of conservation interventions and track changes in *O. lanceolata* populations over time. Regular monitoring will enable adaptive management strategies to address emerging threats and challenges.

By implementing these recommendations in collaboration with relevant stakeholders, we can ensure the long-term survival and conservation of *O. lanceolata* and its unique ecosystems.

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