ASSESSING LAND DEGRADATION THROUGH A PARTICIPATORY APPROACH IN SELECTED VILLAGES OF THE KUNENE REGION, NAMIBIA: BRIDGING SCIENTIFIC AND LOCAL KNOWLEDGE BASES

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Abstract

While scientific methods for assessing land degradation are well established, they often overlook indigenous knowledge provided by local communities. This study utilized a participatory approach to assess land degradation in Otjamaungu and Otjimbundu villages in Kunene region, Namibia, which is among the regions considerably affected by land degradation. Communities identified sites that they perceived to represent five distinct degradation categories: very low, low, moderate, high, and very high. For each category, three sites were selected, and within each site, three plots measuring 20 m × 20 m were established. Vegetation assessments in each plot included measurements of species richness, species diversity, plant density, total basal area, regeneration capacity, and herbaceous cover. Soil assessment included compaction, soil erosion and fertility. Furthermore, local perceptions on land degradation was captured. Ecological results were compared with opinions and perceptions by the communities regarding degradation. The results indicated that community-defined degradation categories were strongly influenced by visible vegetation cover, with denser vegetation typically associated with lower degradation levels. Overall, scientific data largely aligned with community classifications. Quantitative data were analysed using R Studio, while qualitative data were analysed using thematic analysis. Significant differences in species richness, diversity, density, total basal area, herbaceous cover and regeneration capacity were observed between degradation categories in both villages ($P<0.05$). Interviews revealed that communities primarily perceived land degradation through its impact on livestock, central to their livelihoods, rather than through broader ecological consequences.. Perceptions of degradation varied within villages, with some individuals demonstrating limited understanding of its causes and manifestations . By combining scientific expertise with local knowledge, this study enhances the understanding of land degradation in the Kunene region, paving the way for more effective conservation and restoration efforts.

Key words: Land degradation, Degradation category, Local knowledge, Scientific knowledge, Pastoralists, Rangelands, Livestock

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Dedication

I want to dedicate this thesis to my family in Angola "Ehenge laShilungamwa", the village that raised my late father, my favorite person. He was who he was to me and to many others because of you. Your love and support shaped him into the man he became, and for that, I am forever grateful.

Thesis declaration

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Date: October 2025

Ndapanda Hasholo

1. Introduction

1.1. Background of the study

Land degradation poses significant challenges to global sustainability, affecting ecosystems, economies, and livelihoods (Ziadat et al., 2022; Hossain et al., 2020). For many years, land degradation has been widely acknowledged as a critical challenge for many communities worldwide. However, finding solutions remains a difficult task, often hindered by insufficient data (Blaikie & Brookfield, 2015; Berry et al., 2003; Web, 2001; Akhatar et al., 2001). The effects of land degradation are particularly severe for inhabitants of arid regions, especially small-scale farmers and those living in poverty, with climate change further intensifying the situation (Heuser, 2022; Gomiero, 2016; Kertész, 2009; Dregne, 2002).

Moreover, land degradation has complex implications that can lead to significant consequences for both the environment and the communities that rely on the affected areas (Margues et al., 2016). Some key implications associated with land degradation include loss of soil fertility, erosion and desertification, decline in biodiversity, water scarcity, climate change, socio-economic consequences, migration, and conflict. In addition, land degradation is acknowledged as a factor contributing to poverty, especially in developing countries because those living in poverty are often forced to extract increasingly scarce resources from already degraded land, deepening the degradation-poverty cycle. (Barbier & Hochard, 2018a; Barbier & Hochard, 2016b).

Many scholars (i.e., Feng et al., 2024; Adimassu et al., 2013; Kiani-Harchegani & Sadeghi, 2020) have emphasized the importance of assessing the extent of land degradation in various environments. According to Mitri et al. (2019) and Foster

(2006), understanding the extent and causes of land degradation not only enables better management of land resources, but also helps in identifying sustainable land management practices, such as afforestation, soil conservation, and sustainable agriculture, to restore degraded lands and prevent further degradation. Assessing the extent of land degradation typically involves evaluating various indicators to determine the decline in the quality and productivity of the land. Some key steps and methods commonly used in assessing land degradation include remote sensing, field surveys, land use analysis, local knowledge, and stakeholder engagement (Kapalanga, 2008; Stringer & Reed, 2007).

While various approaches have been established to assess land degradation, most assessments of environmental problems often rely on conventional scientific knowledge and overlook local knowledge and perspectives (Redman et al., 2004; Stocking & Murnaghan, 2000). This reliance on conventional scientific methods, while valuable, can result in assessments that fail to capture the lived experiences, priorities, and nuanced understanding of local communities. Consequently, important drivers and indicators of degradation recognized by local people may be overlooked, leading to less effective or inappropriate interventions (Aswani et al., 2018; Persson et al., 2018).

Nonetheless, in recent years, human elements have gained massive recognition in science (Damastuti & de Groot, 2019; Yiran et al., 2012; Stringer & Reed, 2007). The participatory approach has become an essential method for incorporating human perspectives. This approach encompasses a wide range of techniques that combine modern cartographic tools with participatory methods to capture and present the spatial knowledge of local communities (Denwood et al., 2022; Atia & Doherty, 2021; Marres & de Rijcke, 2020).

Where livelihoods are closely tied to natural ecosystems, which is the case for most inhabitants of the Kunene region in Namibia, the degradation of land resources is inevitable and will remain a critical concern (Bollig, 2016; Jones et al., 2013; de Klerk, 2004). Kunene region is renowned for its pastoralist communities, who frequently move their livestock in search of better grazing areas that have unfortunately become degraded over time. The region is characterized by its arid and semi-arid landscapes, which are vulnerable to land degradation due to factors such as climate variability, unsustainable land management practices, and population pressures (Bollig, 2016). In comparison to previous years, there has been a significant reduction in rainfall for over a decade, threatening the livelihoods of the communities (Inman et al., 2020a; Bollig & Gewald, 2000). Land degradation in Kunene region manifests in various forms, including soil erosion formations (e.g., rills, gullies), bare ground patchesand encroacher plants, land degradation indicator species , example *Pechuel-Loeschea leubnitziae* , a common local species, decreased biodiversity, and loss of vegetation cover. These processes threaten the sustainability of local livelihoods and have broader implications for ecosystem health, biodiversity conservation, and regional food security (Pringle, 2021).

Despite the studies conducted in Kunene region to assess land degradation (i.e., Inman et al., 2020a; Leggett et al., 2003; Becker & Jürgens, 2000), most studies lack the incorporation of local knowledge to holistically assess land degradation. Inman and Inman (2023) contended that the difficulty in resolving ecological issues may not primarily stem from a deficiency in knowledge; instead, it often originates from the approaches we utilize in addressing challenges like land degradation. According to Ainsworth et al. (2020), integrating local knowledge into scientific assessments has proven highly effective in identifying root causes and resolving many environmental issues. Many studies that have adopted a participatory approach (i.e., Malakar & Roy, 2024; Forrester et al., 2015; Kirui et al., 2021) in environmental problem assessments have obtained better insights that are useful in solving environmental problems than either approach (quantitative and qualitative methods) could have achieved alone (Kirui et al.,2021).

Equally important, the participatory approach serves as a strong instrument enabling remote and marginalized communities to visually articulate their presence, ensuring that their local insights and viewpoints are brought to the forefront for governmental authorities and decision-makers to consider (Denwood et al., 2022). It is, therefore, imperative to holistically assess land degradation to understand and address it. This is critical for sustainable development, environmental conservation, and the well-being of communities (Lim et al., 2021).

1.2. Statement of the problem

Kunene region in Namibia is facing the challenge of land degradation, which poses considerable threats to the environment and the well-being of its inhabitants. Although scientific approaches have been traditionally employed to assess and combat land degradation, there is a notable gap in incorporating valuable local knowledge and perspectives of the affected communities into these assessments (Raymond et al., 2010). Stringer and Reed (2007) strongly agree that addressing these challenges necessitates a comprehensive approach that bridges the gap between scientific expertise and local knowledge. Communities typically have a deeper understanding of the issues affecting their villages and the surrounding regions, and for this reason, scientific research alone may not fully provide critical evidence to inform interventions and policies aimed at addressing them. Thus, to effectively combat land degradation and safeguard the environment and livelihoods in the Kunene Region, there is an urgent need for participatory approach and assessments that integrate scientific and local perspectives.

1.3. Research objectives

The main objective of the study was to assess land degradation manifestations and processes in the selected villages of the Kunene region, through a participatory approach. By integrating scientific and traditional knowledge, the study aims to highlight the value of local perspectives often overlooked in environmental assessments.

Specific objectives:

1. Compare plant species richness, diversity, composition, density and total basal area in different degradation levels (very high, high, moderate, low, very low degradation) and determine the regeneration capacity of each level.

2. Analyse soil erosion, infiltration rates, nitrogen, and carbon levels in different degradation levels (very high, high, moderate, low, and very low degradation).

3. Document local traditional knowledge about the soil, plants, and fauna in relation to land degradation.

4. Capture the perceptions and experiences of local communities regarding land degradation, including its causes and impacts on their livelihoods.

5. Compare how local and scientific knowledge complement each other in identifying and understanding land degradation patterns in Kunene region.

1.4. Significance of the study

This study offers a unique opportunity to bridge the gap between scientific and local knowledge bases. By integrating scientific expertise with traditional knowledge held by the local communities, this study has the potential to contribute to a more accurate and comprehensive understanding of land degradation in the Kunene Region, leading to more effective conservation and restoration efforts. Local communities often possess deep, place-based knowledge that can reveal subtle environmental changes overlooked by conventional scientific techniques. Recognizing and incorporating this knowledge can lead to more sustainable and culturally sensitive land management solutions. Moreover, the study's outcomes can serve as a model for similar research initiatives in other regions facing land degradation and other environmental challenges.

1.5. Limitations of the study

The scope of the study and depth was constrained by available resources, such as time and personnel. This could have limited the comprehensiveness of the research. Land degradation can be influenced by various external factors like climate change, economic development, and policy changes. These factors were not fully accounted for in the study. Furthermore, the study did not incorporate pre-degradation environmental baselines such as geology, elevation, geomorphology, or vegetation zones when selecting sites. Although all sites within each village were situated relatively close to one another and occurred under the same climatic regime and livelihood systems, subtle differences in biophysical attributes such as slope position or parent material may still exist and could influence vegetation and soil properties independently of degradation processes.

While the selected ecological indicators offered valuable insights, alternative degradation indicators such as functional diversity, vegetation structure, and ecosystem health metrics and remote sensing data could have enhanced the spatial and functional scope of the study.

1.6. Delimitations of the study

The study is limited to two villages in the Kunene Region, namely: Otjamaungu and Otjimbundu. The study focuses on community perceptions of land degradation through participatory approach.

2. Literature review

2.1. What is land degradation?

The definition of land degradation differs from study to study. Safriel (2007) noted the struggle of tracing the origins of the term “land degradation,” as it is now widely used with various overarching definitions. Generally, land degradation is referred to as a decline in the quality and productivity of land as a result of human activities and natural processes (Eswaran et al., 2019). Olsson et al. (2019) defined land degradation as “ a negative trend in land condition, caused by direct or indirect human-induced processes including anthropogenic climate change, expressed as a long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or value to humans.

Blaikie and Bookfield (2015) view land degradation as a complex issue influenced by an interplay of ecological, social, and economic factors. They argue that land degradation occurs as a “silent crawl”, subtly progressing in ways that are often overlooked until the effects are severe. They suggest that the challenges in managing land degradation stem from a lack of understanding of these multifaceted causes and the intricate relationships between human activities and environmental changes. Land degradation is, therefore, multifaceted and lacks a singular, easily identifiable characteristic (Safriel, 2007).

Bai et al. (2008) assessed land degradation globally using a proxy method to address key questions that remain scientifically unresolved: Is land degradation a worldwide concern or a series of localized issues? Which areas experience the most severe impacts, and to what extent? Is it predominantly a challenge in arid regions? Is it primarily linked to agricultural activities? Are population growth and poverty significant factors contributing to it? Their study found that, generally, biomass changes are not solely due to land degradation; they are influenced by other factors, including rainfall and land-use changes. However, in most Asian countries, land degradation is highly contributed by escalating human populations requiring more land to be cleared for shelter and unsustainable agricultural practices. The study also accounted for poor rainfall as a major factor to land degradation in Southern African.

So then, land degradation remains a subjective concept shaped by varying perceptions of what constitutes "degradation" and what baseline of land health is ideal, and different stakeholders may define degradation based on their values, needs, and priorities. In this study, I have adopted Bai et al., (2008) definition of land degradation, which states that "land degradation is a long-term decline in the functionality and productivity of an ecosystem due to disturbances that the land struggles to naturally recover from without external assistance."

2.2. Land degradation in Southern Africa

In eight out of ten countries in Southern Africa, most people live in communal rangelands and rely heavily on subsistence farming (McGranahan & Kirkman, 2013). Rangelands are crucial for the livelihoods of rural communities as they provide grazing land for livestock, food, and income (Slayi & Thamaga, 2024; Msangi, 2007). However, overgrazing, erosion, deforestation, climate change, and poor land management are degrading these ecosystems, reducing their productivity and worsening poverty particularly for pastoral communities. Land degradation in these communal rangelands, therefore, poses major challenges to environmental sustainability, agricultural productivity, and local livelihoods.

Slayi et al. (2024) reviewed the drivers and consequences of land degradation on livestock productivity in Southern Africa. The study found that the link between land degradation and livestock productivity particularly in rangelands is complex. Degraded lands lead to poor forage, reduced water availability, and increased livestock vulnerability to disease, reducing growth, reproduction, and survival. Mitigation strategies such as rotational grazing, agroforestry, and soil conservation show promise but depend on socio-economic factors, policies, and community involvement, emphasizing the need for tailored rangeland management (Slayi et al., 2024). The study further highlighted the socio-economic impacts of reduced livestock productivity due to land degradation. Decreased livestock yields lower household income, worsening food insecurity as purchasing power declines (McGranahan & Kirkman, 2013). In Zimbabwe, reduced productivity increases poverty, forcing greater reliance on food aid and eroding self-sufficiency (Mashizha & Tirivangasi, 2025. Similarly, in Namibia and South Africa, reduced livestock productivity forces communities to abandon pastoralism, decreasing food security, dietary diversity, and traditional cultural practices. In Botswana, declining livestock productivity has led to a shift toward subsistence farming, a less reliable livelihood that heightens hunger risks during crop failures (Slayi et al. (2024).

Msangi (2007) noted that some drylands in Southern Africa are marked by bare landscapes and deep gullies, which are challenging to reclaim. Frequent droughts worsen land degradation, making management difficult, especially with differing land tenure systems, high poverty, and low literacy levels among rural populations. Despite this, the limited data availability results in widely differing views on the extent and cost of damage caused by land degradation in dry lands (Stringer & Reed, 2007).

2.3. Land degradation in Namibia

Land degradation is a significant issue in Namibia, impacting communities across the country (Klintenberg & Seely, 2004). Namibia is considered the driest country in Sub-Saharan Africa, characterized by its arid and semi-arid climate. Namibia's environment is threatened by land degradation, mainly in the form of soil erosion, deforestation, desertification and loss of biodiversity. This is a major concern, as 50.5% of Namibia's population resides in the communal areas and rely primarily on subsistence farming and limited natural resources for their livelihoods (Namibia Statistics Agency, 2023).

Natural factors such as low and unpredictable rainfall and frequent droughts exacerbate soil vulnerability and vegetation loss, accelerating desertification. Human-induced factors, including overgrazing, unsustainable agricultural practices, deforestation and urban expansion, further intensify these impacts (Mendelsohn et al., 2002). However, overgrazing remains severe a challenge especially in the rangelands, as excessive livestock grazing reduces vegetation cover, exposing the top soil to erosion by wind and water (Ward et al., 2000). `

Bush encroachment is another issue in Namibia, serving as an indicator of land degradation, often driven by overgrazing. Over the past years, many rangelands in Namibia have been susceptible to land degradation in the form of bush encroachment at the expense of palatable perennial grasses (Lohman et al., 2014). Communities have, however, strategized this problem by harvesting the encroacher bush for energy and charcoal production, helping rehabilitate land (Hamunyela, 2019).

Land degradation has far-reaching environmental, social, and economic impacts. It depletes soil fertility, lowers agricultural productivity. According to Heuser (2022) and Gomiero (2016), the impacts are severe for poor rural regions and low-income countries, where livelihoods are dependent on agriculture. On a social level, land degradation worsens food insecurity, particularly in rural areas, driving migration to urban areas and placing significant strain on urban infrastructure and resources (Reid et al., 2007; UNEP, 2019). Zdruli (2010) argued that land degradation can be effectively addressed if appropriate policy measures are implemented and, crucially, if both local communities and scientists actively contribute to and participate in the development process.

Nevertheless, Namibia is actively addressing land degradation through implementations of policies that are set to empower communities to sustainably manage their natural resources while benefiting economically from conservation. These policies are guided by a strong policy framework such as the National Action Plan (NAP) under the United Convention to Combat Desertification (UNCCD) and the Community-Based Natural Resources Management (CBNRM) program (Blackie & Tarr, 2000; Ruppel & Ruppel-Schlichting, 2011). Equally important, Namibia supports land restoration through research on indigenous plants, traditional practices, and partnerships between academics and policymakers, ensuring strategies are research-driven (Blackie & Tarr, 2000).

Even though efforts have been made, land degradation still remains a critical challenge in Namibia. To effectively combat land degradation in Namibia and build ecological and economic resilience, it is imperative to encourage stronger stakeholder collaboration, increased funding, and stricter enforcement of sustainable practices.

2.4. Pastoralism and land degradation challenges among the Himba people in Kunene region

The Kunene region in Namibia, where pastoralism has been practiced for generations, faces severe impacts from land degradation. Moreover, most residents rely on livestock for their livelihoods, but their herd sizes have drastically declined due to poor grazing conditions and harsh environmental factors (Heita et al., 2024). With lower literacy levels than other regions, Kunene's land management practices are largely shaped by traditional knowledge passed down through generations (Bollig, 2016). However, as climate change worsens the effects of land degradation, tackling these issues may increasingly call for scientific approaches beyond traditional methods and potentially combining both knowledge systems.

Land degradation in the Kunene region is evident through gullies, barren patches, poor regeneration capacity of woody plants, compacted soil, bush encroachment, lack of herbaceous cover, and the spread of invasive species (Vallejo et al., 2024. Pringle & Pringle, 2021; Inman et al., 2020b). Pringle and Pringle (2021), assessed the perspectives of environmental changes of local communities in villages surrounding Opuwo in Kunene region. The study found that according to oral testimonies, the land was once covered with perennial grasses, and any existing gullies were small and rare, with little expansion. They further noted that many community members clearly recall the better conditions of the past and deeply understand the factors that contributed to the degradation of their lands.

One of the most prominent pastoralist groups in Kunene region is the Himba people. The Himba have lived off the land for centuries, herding cattle, goats, and sheep across the semi-arid plains. So, pastoralism is central to the Himba culture (Bollig 1997). Livestock is not just their livelihood, it is their identity, a symbol of wealth, a connection to their ancestors, and a way of survival (Inman, 2024; Bollig, 2013; Heita et al., 2024). Today, their traditional way of life is under threat due to increased environmental pressures coupled with climatic variability.

Historically, the Himba have well adapted to Kunene's harsh environment. Their deep knowledge of the land helped them survive in an area where rainfall is unpredictable. They move their livestock across vast distances with change in seasons, in search of grazing lands and water sources and this strategy allowed grazing lands to recover from intense grazing (Heita et al., 2024). However, in recent years, the strategy raised doubts about the potential of the pastoralist lifestyle to endure amidst the shifting climate conditions and environmental degradation (Heita et al., 2024; Shikangalah, 2019).

According to Bollig (1998b), the colonial encapsulation policies threatened the livelihoods of the pastoralists in Kunene region, forcing them to employ subsistence farming without permission to trade livestock. As a result, the land has been heavily grazed by large herds of livestock. Moreover, artificial water points (e.g., boreholes) and boundaries disrupted their grazing patterns, forcing them to overuse and over graze certain areas. Eventually, this led to overgrazing, soil erosion, and loss of healthy vegetation, contributing to widespread land degradation (Muller et al., 2007; Bollig, 1998b).

At present, the signs of land degradation in Kunene are everywhere. The presence of bush encroachment, declining native grasses replaced mainly by bushy-encroacher species inedible or less nutritious to cattle (e.g., *Colophospermum mopane)* (Bollig, 1997). Eroded top soil and bare soil patches are particularly common near villages and water points. Despite the Himba's deep understanding of their environment having rich knowledge of which plants serve as food, medicine, or fodder, today, even they struggle to cope with these changes (Inman et al., 2020a). Inman et al. (2020a) argue that community perceptions of land degradation often differ from scientific assessments. For example, while scientists may classify bush encroachment as a form of land degradation, local communities might view it positively due to its provision of valuable fodder for livestock. Such differences highlight the importance of collaboration between local communities and experts.

Climate change is exacerbating land degradation, resulting in recurring and severe droughts, threatening food security, water availability, and grazing land for their livestock. Today, vast lands of Kunene are severely degraded and the prospect for pastoralism is failing due to land degradation and climate change.

2.5. Manifestations of land degradation

Manifestations of land degradation refer to the observable effects or symptoms that indicate the deterioration of land quality and productivity (Chabrillat, 2006; Dzihani, 2001). These manifestations include various environmental changes and disturbances such as soil erosion, loss of soil fertility, desertification, deforestation, salinization, waterlogging, loss of biodiversity, and degradation of vegetation cover (Bojórquez-Tapia et al., 2013).

Soil erosion, defined as the process of removing soil from its original location, is particularly a major cause of land degradation worldwide (Chalise et al., 2019; Eswaran et al., 2019). It occurs naturally but can be accelerated by human activities, such as deforestation, overgrazing, and inappropriate agricultural practices (Pimentel, 2006). Soil erosion is well known to be linked to land degradation because it leads to the loss of fertile topsoil, reduced soil quality, decreased water retention capacity, and increased soil vulnerability to droughts and floods. In addition, soil erosion affects soil structure (forming gullies and fissures), resulting in compacted soils and reduced water infiltration (Knapen & Poe sen, 2010; Pimentel, 2006).

Loss of soil fertility refers to the depletion of the ability of soil to support healthy plant growth (Lal, 2015). Soil fertility loss often accompanies soil erosion, leading to the loss of fertile topsoil and exposing less productive subsoil. This further contributes to desertification, turning once fertile lands into barren desert-like areas (Van Mansvelt, 2017). Moreover, degraded soils with low fertility struggle to support diverse plant and microbial communities. This can lead to a decline in biodiversity, affecting the overall land health. Reduced soil carbon is another manifestation of land degradation (Lal, 2004). On the other hand, compacted soils restrict root penetration and growth, limiting access to nutrients and water deeper in the soil profile. In addition, compacted soils have fewer pores for water to move through, leading to increased surface runoff and reduced water infiltration rates (Das et al., 2023).

Soil carbon is the organic carbon in soil, deriving from plant and animal decomposition such as roots, leaves, and organic compounds (Lal, 2015). It plays a crucial role in soil fertility, ecosystem functioning, and climate regulation. Soil properties, such as texture, mineral composition, pH, and drainage, influence soil carbon storage. In addition, according to Mujiyo et al. (2021), soils with reduced clay content and organic matter tend to have lower carbon levels.

According to Xie et al. (2020), land degradation indicator plants are species that exhibit specific characteristics and behaviors in response to environmental stressors associated with land degradation. These plants can serve as early warning signals, helping to identify areas where soil quality, vegetation health, or ecosystem functionality is declining (Kuria et al., 2019). A common example of a land degradation indicator plant is the *Pechuel-Loeschea leubnitziae,* an encroacher shrub found particularly in Southern Sub-Saharan Africa (Noble et al., 2021).

2.6. Land degradation assessment methods

The methods and outcomes utilized to assess land degradation differ from one study to another. Land degradation assessment is essential for understanding the decline in land quality, which impacts ecosystems, biodiversity, agriculture, and human livelihoods (UNEP, 2008). As degradation accelerates due to unsustainable land use, climate change, deforestation, and overgrazing, effective assessment methods are critical for identifying affected areas, measuring degradation severity, and informing restoration efforts (Eswaran et al., 2019; UNEP, 2008).

Assessment techniques vary depending on the scale of analysis — global, regional, local, or field-level and may involve a combination of expert evaluations, land user perspectives, field-based monitoring, remote sensing, and modelling approaches (Kapalanga, 2008). Recently, studies (i.e. AbdelRahman, 2023; Dharumarajan et al., 2022) have widely utilised remote sensing and GIS to monitor land degradation by tracking changes in land cover, vegetation health, and soil properties. However, since remote sensing mainly captures vegetation changes, many scientists advise combining it with ground data for accurate results (El Baroudy, 2011; Szabó et al., 1998).

Modelling methods have been established to assess land degradation by using data and simulations to predict degradation patterns, causes, and impacts, aiding in scenario analysis and management planning (Turner et al., 2016). They are specifically designed to assess soil erosion caused by either water or wind. Modelling techniques such as the Universal Soil Loss Equation (USLE) and the Pan-European Soil Erosion Risk Assessment (PESERA) are widely used, especially on a global and regional scale (Kapalanga, 2008).

Assessment methods for dry lands have also been established (discussed in a Review of Land Degradation Assessment Methods by Kapalanga (2008). A common example is the Land Degradation Assessment in Drylands (LADA) methodology. LADA uses a participatory, country-driven approach, utilizing rural appraisals, expert assessments, field measurements, remote sensing, GIS, and data-sharing technologies. It considers biophysical and socio-economic factors, aiming to enhance methodologies for monitoring land degradation. (Koohafkan et al., 2003; LADA project document, 2005). LADA methodology is based on the assumption that the causes, status, and impact of land degradation can be determined and assessed simultaneously. Despite this, scientists argue that assessing land degradation in arid rangelands is challenging due to short-term rainfall variations, diverse landscapes, and the difficulty of sampling vast areas (Koohafkan et al., 2003). Although science offers valuable data to guide management strategies, local knowledge of ecosystems and land degradation is socially rooted and context-specific, which scientific assessments do not always capture (Reed and Stringer, 2006).

While many techniques exist for assessing land degradation, many researchers stress that assessing land degradation is challenging, as multiple forms of degradation can appear in one area. This complexity prevents the use of uniform tools, techniques, and methods across different types of degradation (Kapalanga, 2008).

2.7. Integration of local and scientific knowledge in environmental assessments: Participatory approaches

Lowe et al. (2009) and Brosius (2006) argued that most ecological problems are complex, and pure ecology may not effectively address and manage such problems. To date, scientific knowledge has provided invaluable insights into the extent of land degradation; however, little attention has been given to local knowledge that could complement scientific knowledge (Ballard et al., 2008). On the other hand, early research on land degradation assessment primarily focused on scientific methodologies, often overlooking the valuable insights and observations of local communities. Nonetheless, in recent years, there has been a growing recognition of the need to integrate local knowledge into land degradation assessment methods to enhance their accuracy, relevance, and legitimacy (Lowe et al., 2009).

Participatory approaches, such as Participatory Rural Appraisal (PRA) and Participatory Geographic Information Systems (PGIS), have emerged as effective tools for engaging local communities in the assessment process and incorporating their knowledge and perspectives (Jankowski, 2009; Chambers, 2006). Through collaborative mapping exercises, interviews, and transect walks, researchers and communities co-produce spatial data and narratives that capture both scientific and local understandings of land degradation dynamics. Moreover, integrating indigenous knowledge systems into scientific methodologies enriches the assessment process by providing context-specific insights, identifying overlooked indicators, and fostering community ownership of the findings (Denwood et al., 2022; Stringer & Reed, 2007).

According to Shawoo and Thorn (2019), local knowledge, as cited in Berkes (2008, p.8), is defined as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.” According to Chambers (2006), a community’s perspective offers a grassroots-level understanding of land degradation, which may differ significantly from that of scientists. He argues that communities possess a good understanding of how land degradation has affected the welfare of villagers at the village level, provided that the true representative of the group is selected for the kind of data needed.

According to Raymond et al. (2010), integrating local knowledge into ecological science can provide a more comprehensive understanding of environmental problems because ecological problems require a more holistic approach, and incorporating local and scientific knowledge could fill this gap. A study by Lowe et al. (2016) employed a participatory approach to capture the perspectives of the communities on the management and utilization of forest resources. The study found that, at most times, the local people were not engaged in decision-making, and they felt that their feelings and inputs were ignored. Other scholars (e.g., Kirui et al., 2021) used a participatory approach to assess and identify land degradation hotspots in selected countries in Eastern Africa. The study revealed that quantitative data provided important information on what was on the ground. On the other hand, qualitative data from the interviews captured useful perceptions of local people, and added depth and contextual understanding that was useful in land management strategies.

In Botswana, Reed et al. (2008) assessed the extent of land degradation in selected villages of Botswana using a participatory approach, “sketching maps”. The communities drew maps identifying areas portraying different categories of land degradation within their villages due to human-induced activities rather than climatic conditions. The study found that though the land experts had similar views, their views also varied greatly among members of the same communities and across different communities. While this was the case, the authors strongly support the inclusion of indigenous knowledge in environmental assessments, which they deemed greatly lacking in Botswana.

Notwithstanding, while local knowledge is valuable for understanding community-specific issues, it may not be sufficient for addressing complex challenges that require interdisciplinary, cross-cultural, or global perspectives. This is because local knowledge may not accurately represent the diversity within a community. Assuming that everyone within a specific locality shares the same beliefs, practices, or preferences can lead to an impression of homogeneity and oversimplification. Additionally, local communities may lack the resources, such as access to education, technology, or diverse perspectives needed to broaden their knowledge base beyond the local context (Zurba & Papadopoulos, 2023; Pringle, 2021; Usher 2000).

3. RESEARCH METHODS

3.1. Study setting

The study was conducted in Otjamaungu and Otjimbundu villages (Figure 1), located within the Epupa constituency of the Kunene region, Namibia. Kunene region is situated in the north western part of Namibia, bordering the Atlantic Ocean in the west and sharing a border with Angola to the north, with the perennial river (Kunene River). The two villages are situated approximately 60 kilometres apart along this river.

These villages were purposefully selected due to their location in a semi-arid environment exhibiting visible and varying degrees of land degradation, which allowed for the assessment of degradation levels within each village context. Both communities rely heavily on natural resources and livestock, making them suitable for exploring the interactions between land degradation and local livelihoods. Moreover, the villages have been involved in ongoing research initiatives in which the researcher has actively participated—such as establishing community gardens and supporting data collection for related studies. This prior engagement helped foster strong community relationships, which in turn facilitated smoother study implementation and enhanced local participation. Importantly, efforts were made to ensure that both sites share similar climatic zones (semi-arid), livelihood systems (pastoralism), and ecological pressures (e.g., drought and grazing intensity). Furthermore, the villages are both located within the same administrative constituency and along the Kunene River corridor, thus minimizing large-scale environmental heterogeneity..

Kunene region experiences a desert climate, characterized by erratic annual rainfall, ranging from 50mm to 400mm, along with extreme temperatures that can reach up to 35°C in summer and drop to 5°C in winter (Brunotte et al., 2009). According to Lendelvo (2018), the community's reliance on natural resources makes it particularly vulnerable to climate variability, often causing severe recurrent droughts and floods. The rainfall variability of the recent past may persist into the future.

The region has a surface area of 115,260 square kilometres, making it the second-largest region in the country. The landscape is characterized by rugged terrain, including mountainous areas, alluvial plains, and ephemeral rivers that flow only after sufficient rainfall in their catchment areas. These rivers support important habitats and are rich in biodiversity. However, the growing human and livestock populations, along with ongoing development, have led to an increasing demand for man-made boreholes (Lendelvo et al., 2024).

According to statistics from the 2023 Population and Housing Census, the population of Kunene region stands at 120,762 (this is an increase from 86,856 people recorded during the 2011 census) (Oyedele & Haifene, 2024). The key economic activity in the region is livestock rearing, herding mainly goats, sheep, and cattle. Awlthough livestock production plays a vital role in supporting livelihoods, its growth is hindered by various challenges, including severe water scarcity, grazing, and the prevalence of diseases (Eiki et al., 2022).

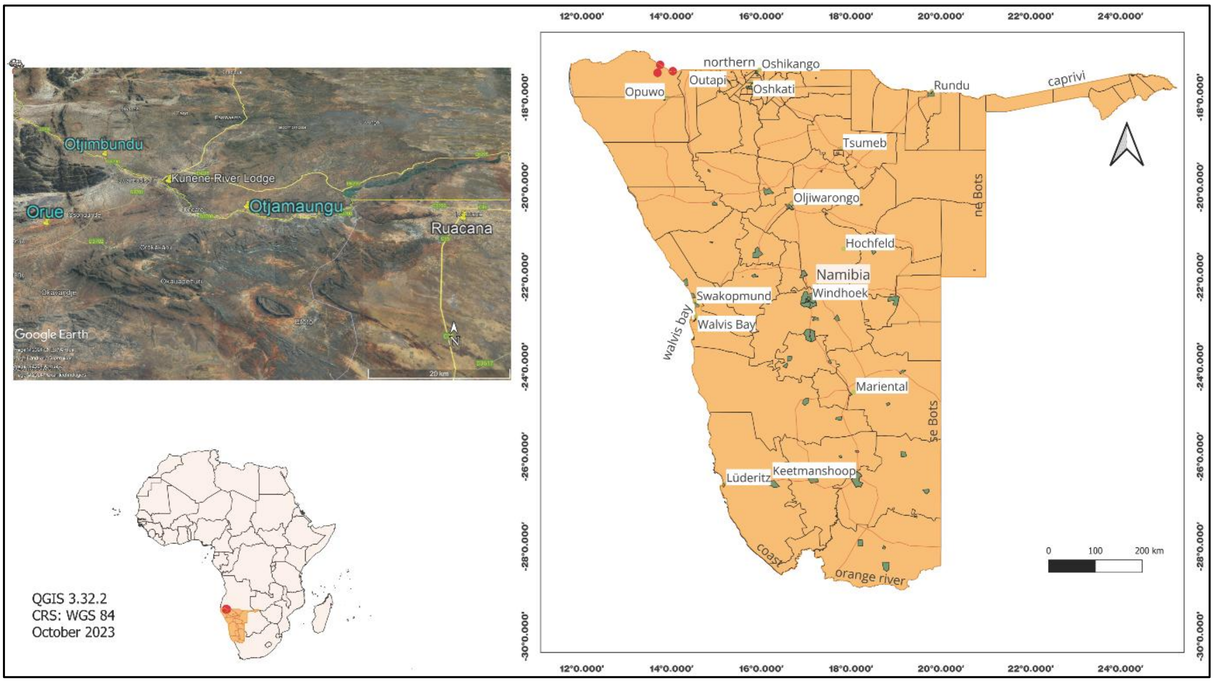

Figure 1: Location of the study areas (Otjamaungu and Otjimbundu villages) (top left), map of Africa (bottom left), and map of Namibia showing different constituencies and

towns (right). The locations of the villages (study sites) are indicated in red, map created in QGIS (Adopted from Inman, 2024).

3.2. Data collection

The data was collected after the rainy season (April-May 2024). The study adopted a mixed-methods research design, combining quantitative and qualitative approaches to assess land degradation in the selected villages of Kunene Region. The study primarily relied on participatory approah of vegetation and soil attributes to integrate scientific and local knowledge.

3.2.1. Participatory assessment of vegetation, soil and perceptions

This study adopted a community-based approach to assess land degradation by combining participatory field assessments with in-depth interviews. Community respondents, aged 20 to 75 years, were briefed on the study's aims and methods. The researcher provided an overview of "land degradation," clarifying the expectations of community involvement in both field-based observations and interview discussions.

Community members collaborated with the researcher to identify visible signs of land degradation and classify areas into five perceived levels: very high, high, moderate, low, and very low. Sketches were created to reflect anticipated features in each category, encouraging a shared understanding without researcher influence. Participants were rotated daily by age and gender to ensure diverse views.

In addition, in-depth, face-to-face interviews were conducted with 15 purposively selected individuals (aged 20–75) in each village to provide detailed insights into perceptions of land degradation, its causes, impacts, and historical changes. Interviews were conducted privately to avoid bias, with responses recorded for analysis.

Questions focused on the definition, causes, indicators, impacts on livelihoods, and existing local rules related to land degradation. Both qualitative methods (local knowledge and expert assessments) and quantitative measures (scientific metrics) were applied to evaluate the identified areas, as detailed in the following sections.

For anonymity, respondents are referred to by codes, example M1 or F5, where "M" and "F" indicate male and female, respectively, and the number denotes the sequence in which they were interviewed (e.g., M1 = first male respondent).

3.2.1.1. Vegetation surveys

The community members selected three sites representing each degradation category. At each site, three plots of 20m by 20m were randomly established, at least 50m apart. So, each degradation category was replicated three times, and nine plots per degradation category were sampled. Sites of the same degradation category were at least 3km apart. In each plot, all the woody species occurring were identified and recorded with their height DBH (diameter at breast height) (DBH at 1.37m from the ground) or DRC (diameter at root collar) (DRC for trees below 1.37m) (Magarik et al., 2020). The communities identified the plants, and the names of the plants were provided in their native language. The herbaceous cover was visually estimated by demarcating a $1m^2$ quadrat at the corners of each plot (Gillet et al., 1999).

The regeneration capacity was assessed by counting the number of mature trees, saplings, and seedlings in each sampled plot. Based on their DBH, individuals were classified as mature trees if their DBH was $\geq$ 31.5 cm, as saplings if their DBH ranged from 10.5 to 31.4 cm, and as seedlings if their DBH was less than 10.5 cm (Ballabha et al., 2013). To ensure accurate interpretation of regeneration results, the perennial invasive bush *Pechuel-Loeschea leubnitziae* (well adapted in degraded soils) was excluded from this classification and represented in a separate category.

At each sampling point, the community members shared information on the sampled plants in the context of degradation, including changes in the abundance of species, invasion, and dominance.

3.2.1.2. Soil erosion assessment

At each site, the area between the three plots (within a radius of 100m) was assessed for soil erosion by identifying the types of soil erosion (rill/gully, terracette, sheet, and scalding) present, counting each soil erosion type and measuring the sizes of each soil erosion type in terms of how much ground they cover as well as the depth (Frankl et al., 2013). The following formula was used to calculate the size of a typical gully: $Gully\ Volume\ (L) = \text{Length} \times \text{Width} \times\ \text{Depth}$.

3.2.1.3. Soil fertility

To determine soil fertility, soil samples were collected at each corner of the plot at 0–15 cm depth using a soil auger. The samples were analyzed for pH, organic carbon, organic matter, NPK, magnesium, and soil structure at the laboratory of the Ministry of Agriculture, Water and Land Reform. These variables were selected because they are widely recognized indicators of soil health and land degradation, influencing nutrient availability, soil productivity, and vegetation growth (Bhowmik et al., 2019).

3.2.1.4 Soil compaction

Soil compaction was also determined indirectly by conducting a water infiltration test (Castellano & Valone, 2007). The four holes where soil samples were collected were filled with water (until saturation), and the time taken for water to infiltrate and disappear into the soil was recorded with a stopwatch.

Very low degradation

Low degradation

Moderate degradation

High degradation

Very high degradation

Figure 2: Sites representing five different degradation categories as perceived by the communities in Otjamaungu and Otjimbundu villages in Kunene region

Figure 3: Communities participating in the interviews and field work in Otjamaungu and Otjimbundu village in Kunene region

3.3. Data processing and analysis

3.3.1. Vegetation data

3.3.1.1. Species diversity

Species diversity was calculated using the Shannon-Wiener Species Diversity Index (Shannon & Wiener 1963), applying the formula: $H' = -\sum (p_i \ln p_i)$, where: H' =

Shannon-Wiener Diversity Index, **Σ** = Summation (sum over all species), pi = Proportion of individuals belonging to species *i* (i.e., *pi* = *ni* / *N*, where *ni* is the number of individuals of species *i*, and *N* is the total number of individuals of all species), ln = Natural logarithm (log base *e*). Species diversity values were then tested for normality using a Shapiro-Wilk test.

where the data did not meet the assumptions of normality and equal variances, a Kruskal-Wallis test (a non-parametric alternative to one-way ANOVA) was used to compare the medians of species diversity values across the five degradation categories. Where significant differences were found, a pairwise comparison was thereafter performed to do a pairwise comparison.

3.3.1.2. Species richness

A Generalized Linear Model (GLM) in R Studio (R Core Team, 2024) was performed to test for significant differences in species richness among the degradation categories. The model used *Poisson* distribution suitable for count data with a log function. Where significant differences were found, an *emmeans* function was performed to do a pairwise comparison.

3.3.1.3. Total basal area and density

Basal area was calculated using the formula: $basal\ area = \frac{\pi \times ((\mathrm{DBH}\ /\ 2)^2)}{10000}$; where: DBH= is the diameter at breast height (in cm) and π = 3.1416. Density of woody species was calculated using the formula: $density\ per\ hectare = \frac{\text{Number of species in the plot}}{\text{Area of the plot } (\mathrm{m}^2)} \times 10000.$

A Generalized Linear Model (GLM) in R Studio (R Core Team, 2024) was performed to test for significant differences in total basal area. Since the data was continuous and zero inflated, the GLM was treated with a *Tweedie distribution*, suitable for continuous and zero inflated data. Where degradation categories were found to be significantly different, multiple pairwise comparisons were done using Tukey's HSD test.

To test for significant differences in density among degradation categories, a GLM in R Studio (R Core Team, 2024) was performed. The density values were count data and hence, the GLM was treated with a *poisson distribution* and a log link function (suited for count data). Where degradation categories were found to be significantly different, multiple pairwise comparisons were done using Tukey's HSD test.

3.3.1.4. Regeneration capacity

The regeneration capacity of each degradation category was assessed by comparing the density of mature trees with the density of seedlings and saplings. Individuals of each species were considered as a mature tree if their DBH ≥ 31.5cm, as a sapling if their DRC ranged from 10.5 to 31.4 cm, and as a seedling if their DRC was less than 10.5 cm (Ballabha et al., 2013). The following criteria, established by Shankar (2000) was used to determine the regeneration status of degradation categories. Good regeneration was indicated if the number of seedlings > number of saplings > number of mature trees; fair regeneration if the number of seedlings > number of saplings ≤ number of trees; and poor regeneration if a species was present only in the sapling stage, with no seedlings present. If a species was represented only by mature trees, it was considered not regenerating. A species was considered not regenerating if it was represented only by saplings and/or seedlings, with no mature trees present.

3.3.1.5. Herbaceous cover

A Generalized Linear Model (GLM) in R Studio (R Core Team, 2024) was treated with a *Tweedie distribution* (suited for continuous and zero inflated data) to test for significant differences in herbaceous cover among degradation categories. Where degradation categories were found to be significantly different, multiple pairwise comparisons were done using Tukey’s HSD test.

3.3. 2. Soil data

3.3.2.1. Soil compaction

A Generalized Linear Model (GLM) in R Studio (R Core Team, 2024) was fitted using a *Gamma distribution* with a log function to test for significant differences in the water infiltration rates. Where significant differences occurred, a multiple pairwise comparisons were done using Tukey’s HSD test.

3.3.2.2. Soil erosion

A Generalized Linear Model (GLM) in R Studio (R Core Team, 2024) was fitted with a *Gaussian family* to test for significant differences in the volume of soil erosion formations among degradation categories. Where degradation categories were found to be significantly different, multiple pairwise comparisons were done using Tukey’s HSD test.

3.3.2.3. Soil properties

The Kruskal-Wallis test (a non-parametric alternative to one-way ANOVA) was used to compare the medians of soil properties across the five degradation categories. This test is suitable for data that do not meet the assumptions of normality and equal variances. So, soil property data were first checked for normality and homogeneity of variances to determine the appropriate statistical tests. Non-parametric tests were chosen due to deviations from normality, as indicated by the use of the Kruskal-Wallis test. Significance levels (P-values) were used to determine whether the differences among degradation categories were statistically significant. A threshold of $P < 0.05$ was applied to identify significant results.

Furthermore, a canonical correspondence analysis (CCA- a constrained unimodal ordination method, widely used as an analytical method) was performed in PAST 5 Software to examine the relationships between the distribution patterns of woody plant species and soil attributes. The CCA was performed on a matrix of species binary data and an explanatory data set from different plots and degradation categories. Explanatory data set for the CCA consisted of soil variables. The Monte Carlo permutation tests were run in the CCA to test for the significance of the observed soil variables.

4. RESULTS

4.1. Analysis of land degradation types and levels in selected villages of the kunene Region): Vegetation assessment

4.1.1. Floristic Composition and diversity

A total of 1762 individuals representing 21 species from 10 families were recorded in the selected villages (Otjamaungu and Otjimbundu). More species were recorded in the Burseraceae family (4 species), followed by the Combretaceae and Fabaceae families (3 species each). The Malvaceae, Capparaceae, and Bignoniaceae families each recorded 2 species, while the Ebenaceae, Asteraceae, Anacardiaceae, Olacaceae, and Moringaceae families recorded 1 species each. Species which recorded high abundance (dominant) included *Colophospermum mopane*, *Rhigozum brevispinosum, Catophractes alexandri* and *Terminalia prunioides*. In contrast, species which recorded low abundance (rare) included *Boscia albitrunca*, *Combretum imberbe, Dichrostachys cinerea*, *Vachelia nilotica*, *Grewia bicolor*, *Grewia flava*, *Ximenia americana* and *Moringa ovalifolia.*

Otjamaungu village recorded a total number of 720 individuals, representing 20 species (species richness) from 10 families, of which 272 were recorded in the very low degradation category, 210 in the low degradation category, 170 in the moderate degradation category, 57 in the high degradation category and 11 in the very high degradation category. Otjimbundu village recorded a total of 1042 individuals representing 12 species from 8 families, of which 337 were recorded in the very low degradation category, 281 in the low degradation category, 162 in the moderate degradation category, 123 in the high degradation category and 139 in the very high degradation category.

In Otjamaungu village, a significant difference in species richness was observed among degradation categories ($F=42.65$, $df=4$, $P<0.05$). The highest species richness was recorded in the low degradation category, while high and very high degradation categories recorded the lowest (Figure 4A). Significant pairwise differences were observed between high and low degradation categories ($Z=-4.374$, $P<0.001$), high and very low degradation categories ($Z=-3.402$, $P<0.01$), low and moderate degradation categories ($Z=4.145$, $P<0.001$), low and very high degradation categories ($Z=4.566$, $P<0.001$), moderate and very low degradation categories ($Z=-3.102$, $P<0.05$) and between very high and very low degradation categories ($Z=-3.682$, $P<0.01$).

In Otjimbundu village, the species richness was significantly different among degradation categories ($F=23.37$, $P<0.05$). The very low degradation category recorded the highest species richness (Figure 4B), and the very high degradation category recorded the lowest. Significant pairwise differences were observed between high and low degradation categories ($Z=-3.548$, $P<0.01$), high and very low degradation categories ($Z=-3.874$, $P<0.01$), low and very high degradation categories ($Z=4.711$, $P<0.001$), moderate and very high degradation categories ($Z=3.211$, $P<0.05$) and between very high and very low degradation categories ($Z=-4.959$, $P<0.001$).

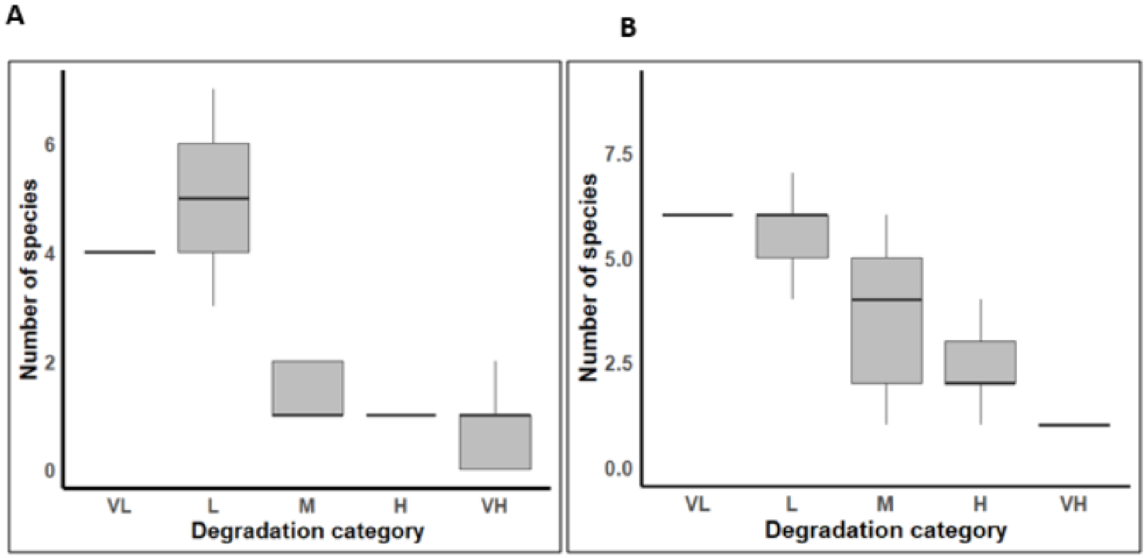

Figure 4: Number of species recorded in the five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

In Otjamaungu village, the species diversity was significantly different among degradation categories (X^2 =35.033, d f=4, p<0.05). Species diversity was highest in the low degradation category and lowest in the high and very high degradation categories (Figure 5A). Significant pairwise differences were observed between very low and high degradation categories (P<0.001), low and high degradation categories (P<0.001), very low and moderate degradation categories (P<0.001), very low and very high degradation categories (P<0.001), low and moderate degradation categories (P<0.001) and between low and very high degradation categories (P<0.001).

In Otjimbundu village, the species diversity was significantly different among degradation categories (X^2 =27.775, df=4, p<0.05). The low degradation category recorded the highest diversity, and the lowest species diversity was recorded in the very high degradation category (Figure 5B). Significant pairwise differences were observed between high and low degradation categories (P<0.05), high and very low degradation categories (P<0.05), low and very high degradation categories (P<0.01), moderate and very high degradation categories (P<0.05) and between very high and very low degradation categories (P<0.01).

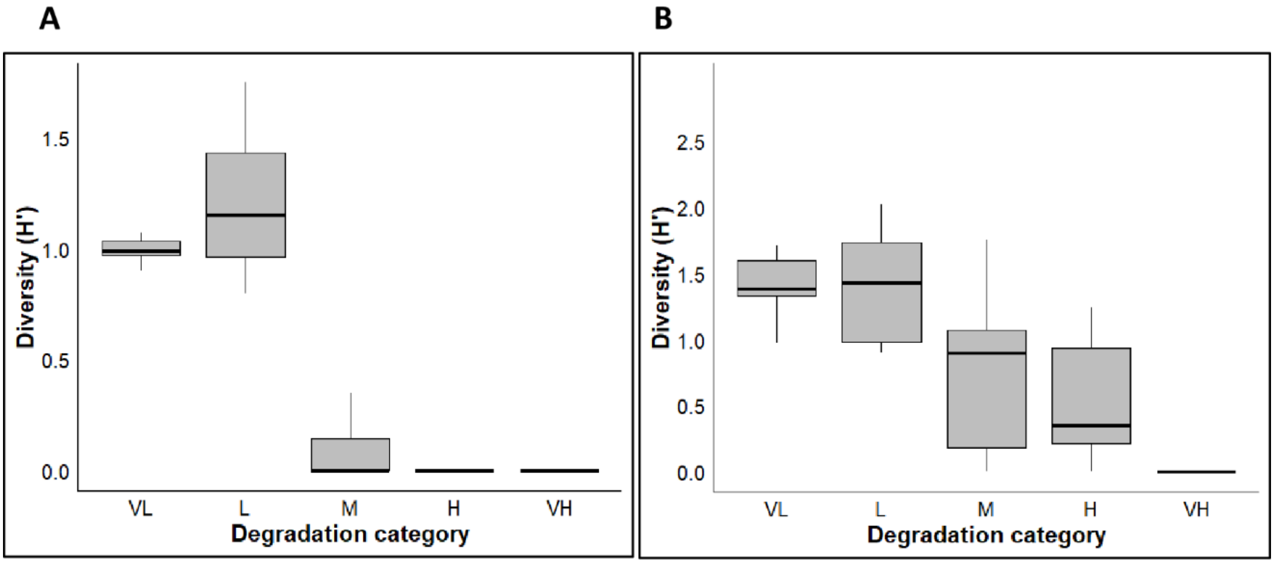

Figure 5: Species diversity of woody plants compared in five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.1.2. Total basal area and density

In Otjamaungu village, a significant difference in the total basal area was observed among degradation categories (F=3. 562, df=4, P<0.05). The highest mean total basal area was recorded in the high degradation category (0.0344 m^2/ha), and the lowest was found in the very low degradation category (0.0046 m^2/ha) (Figure 8A). Significant pairwise differences were observed between high and moderate degradation categories (Z=3.011, P<0.05), high and very low degradation categories (Z=4.562, P<0.001), low and very low degradation categories (Z=3.418, P<0.01) and between very high and very low degradation categories (Z=2.991, P<0.05).

In Otjimbundu village, there was no significant difference in total basal area among degradation categories (F=0.707, P>0.05). The mean total basal area was generally similar among the degradation categories. While the graph indicates some variation in standing total basal area among the groups, statistical analysis suggests that these differences are not significant and could be due to random variation rather than a consistent or meaningful effect (Figure 8B).

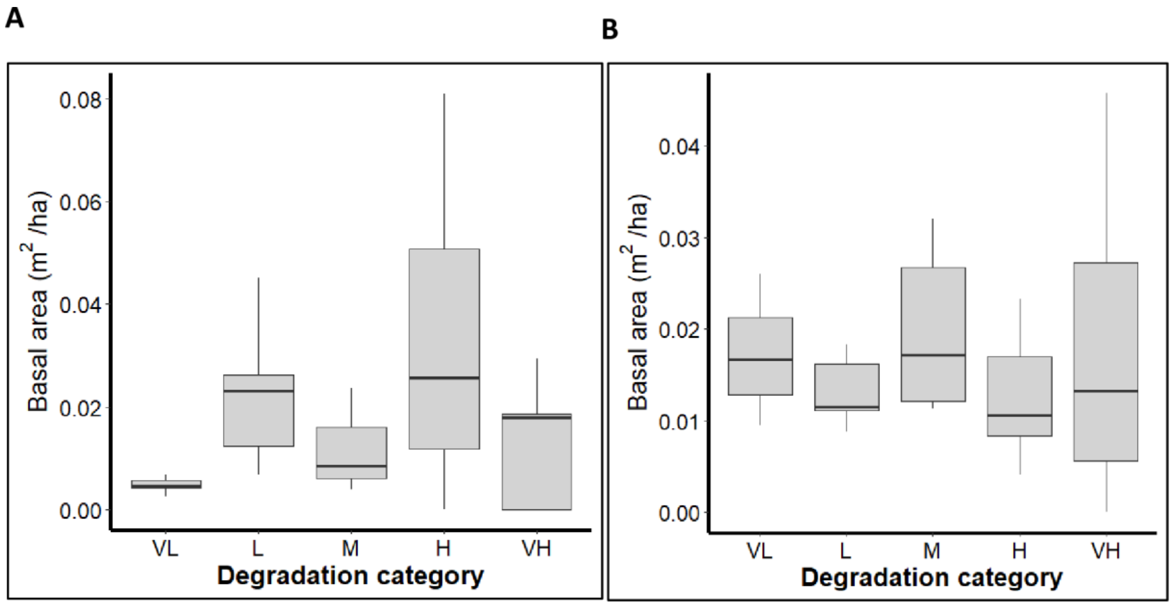

Figure 6: Total basal area of woody plants in five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

In Otjamaungu village, density was significantly different among degradation categories ($F=14.62$, $P<0.001$). The density was highest in the very low degradation category (755.5 per ha) and lowest in the very high degradation category (30.56 per ha) (Figure 6A). Significant pairwise differences were observed between high and low degradation categories ($Z=-43.658$, $P<0.001$), high and moderate degradation categories ($Z=-356.98$, $P<0.001$), high and very high degradation categories ($Z=24.978$, $P<0.001$), high and very low degradation categories ($Z=-53.640$, $P<0.001$) low and moderate degradation categories ($Z=10.241$, $P<0.001$), low and very high degradation categories ($Z=47.675$, $P<0.001$), low and very low degradation categories ($Z=-14.081$, $P<0.001$), moderate and very high degradation categories ($Z=44.002$, P<0.001), moderate and very low (Z=-24.036, P<0.001) and between very high and very low degradation categories (Z=-52.154, P<0.001).

In Otjimbundu village, density was significantly different among degradation categories (F=4.308, df= 4, P<0.05). The very low degradation category recorded the highest species density per ha (936.11), and the lowest was recorded in the high degradation category (341.67) (Figure 6B). Significant pairwise differences were observed between high and low degradation categories (df=4, Z=-38.208, P<0.001), high and moderate degradation categories (Z=-11.514, P<0.001), high and very high degradation categories (Z=-4.940, P<0.001), high and very low degradation categories (Z=-47.838, P<0.001), low and moderate degradation categories (Z=27.915, P<0.001), low and very high degradation categories (Z=33.941, P<0.001), low and very low degradation categories (Z=-11.248, P<0.001), moderate and very high degradation categories (Z=6.622, P<0.001), moderate and very low degradation categories (Z=-38.308, P<0.001) and between very high and very low degradation categories (Z=-43.929, P<0.001).

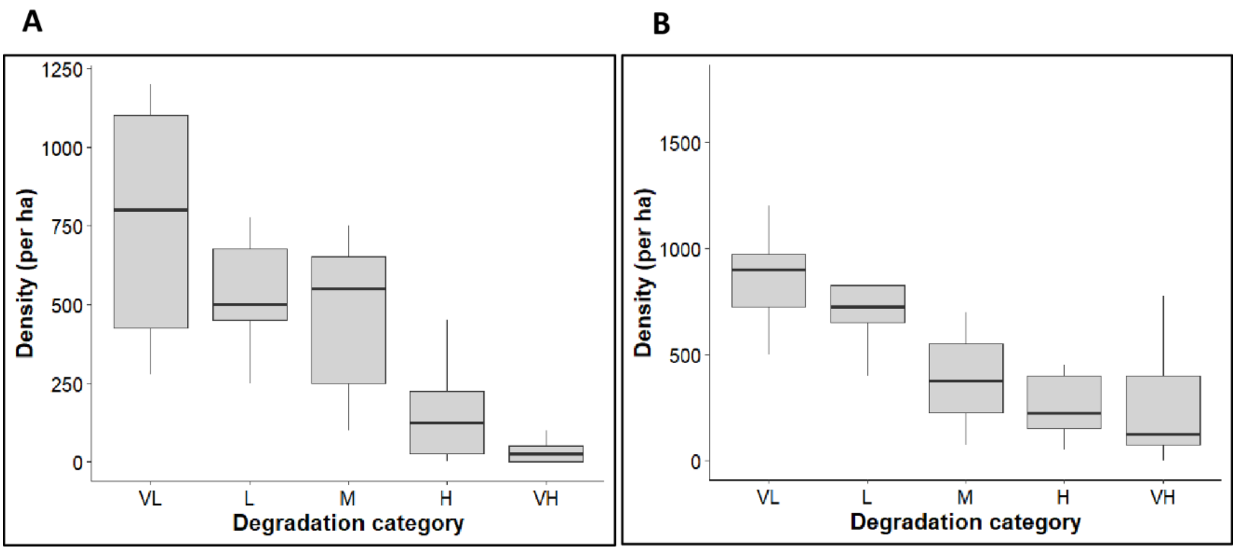

Figure 7: Species density of woody plants compared among five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.1.3. Regeneration capacity

In Otjamaungu village, the regeneration status was "poor" in the very low, low, moderate and high degradation categories because the mature trees recorded the highest density compared to seedlings and saplings (Figure 7A). The regeneration status was "fair" in the very high degradation category because it recorded a high density of saplings compared to mature trees. . The invasion bush, *Pechuel-loeschea leubnitziae*, dominated the very high degradation category.

In Otjimbundu village, the regeneration status was "poor" across degradation categories because mature trees recorded the highest density compared to seedlings and saplings. (Figure 7B). The high degradation category was dominated by a high density of *Pechuel-loeschea leubnitziae*.

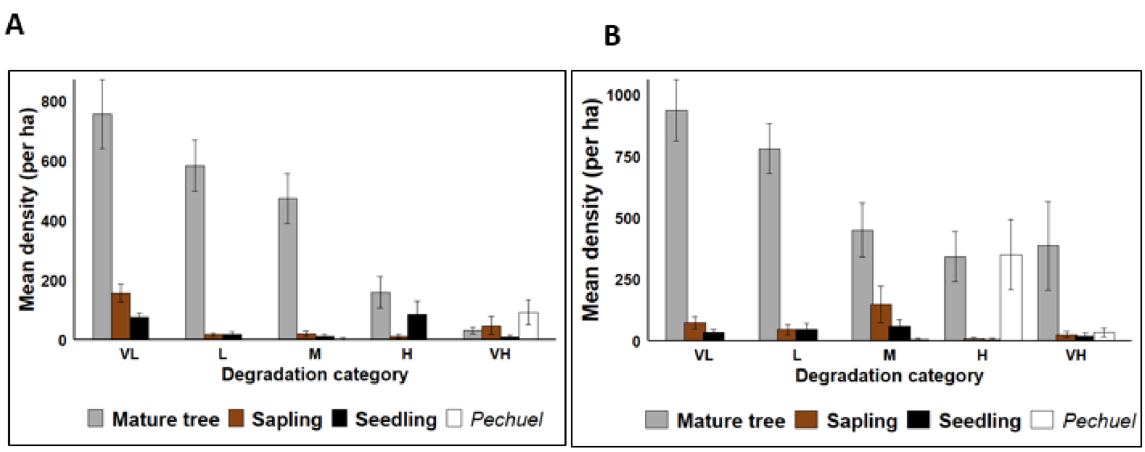

Figure 8: Mean (±SE) density of plant life stages found in the five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.1.4. Herbaceous cover

In Otjamaungu village, herbaceous cover was significantly different among degradation categories ($F=23.07$, $df=4$, $P<0.001$). The herbaceous cover was found to be highest in the very low degradation category (65.31%) and lowest in the very high degradation category (5.14%) (Figure 9A). Significant pairwise differences were observed between high and moderate degradation categories ($Z=3.461$, $P<0.01$), high and very high degradation categories ($Z=3.950$, $P<0.001$), low and moderate degradation categories ($Z=2.720$, $P<0.05$), low and very high degradation categories ($Z=3.237$, $P<0.05$), low and very low degradation categories ($Z=-3.292$, $P<0.01$), moderate and very low degradation categories ($Z=-5.630$, $P<0.001$) and between very high and very low degradation categories ($Z=-6.016$, $P<0.001$).

In Otjimbundu village, herbaceous cover was also significantly different among degradation categories ($F=8.09$, $df=4$, $P<0.001$). The very low degradation category recorded the highest herbaceous cover (77%), and the lowest was recorded in the high degradation category (21.5%) (Figure 9B). Significant pairwise differences were found between high and low degradation categories ($Z=-3.477$, $P<0.01$), high and very low degradation categories ($Z=-4.285$, $P<0.001$), low and very high degradation categories ($Z=3.733$, $P<0.01$), moderate and very low degradation categories ($Z=-3.293$, $P<0.01$) and between very high and very low degradation categories ($Z=-4.532$, $P<0.001$).

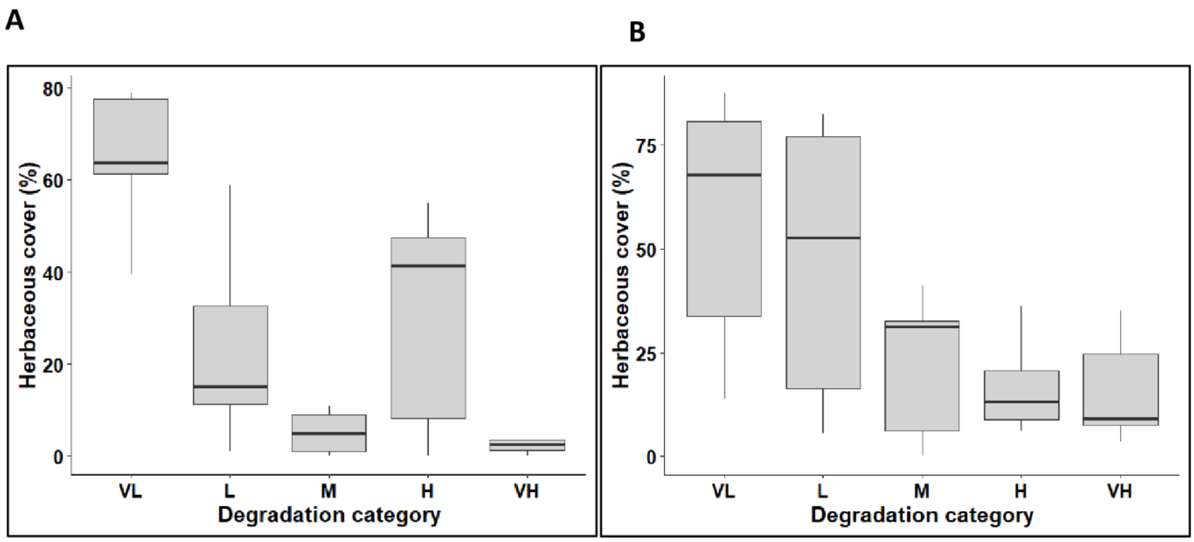

Figure 9: Herbaceous cover (%) found in the five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.2. Soil assessment

4.2.1. Soil erosion

The volume of soil erosion formations in Otjamaungu village was not significantly different among degradation categories ($F=1.579$, $df=4$, $P>0.05$). However, very low and low degradation categories significantly had low volume compared to other degradation categories ($t=-3.922$, $p<0.01$), ($t=-2.216$, $P<0.05$). The highest volume was recorded in the very high degradation category, and the lowest was in the very low degradation category (Figure 10A).

Similarly, there was no significant difference in the volume of soil erosion formations in Otjimbundu village among degradation categories ($F=0.272$, $df=4$, $P>0.5$). The high degradation category had the highest volume while low degradation category recorded the lowest (Figure 10B).

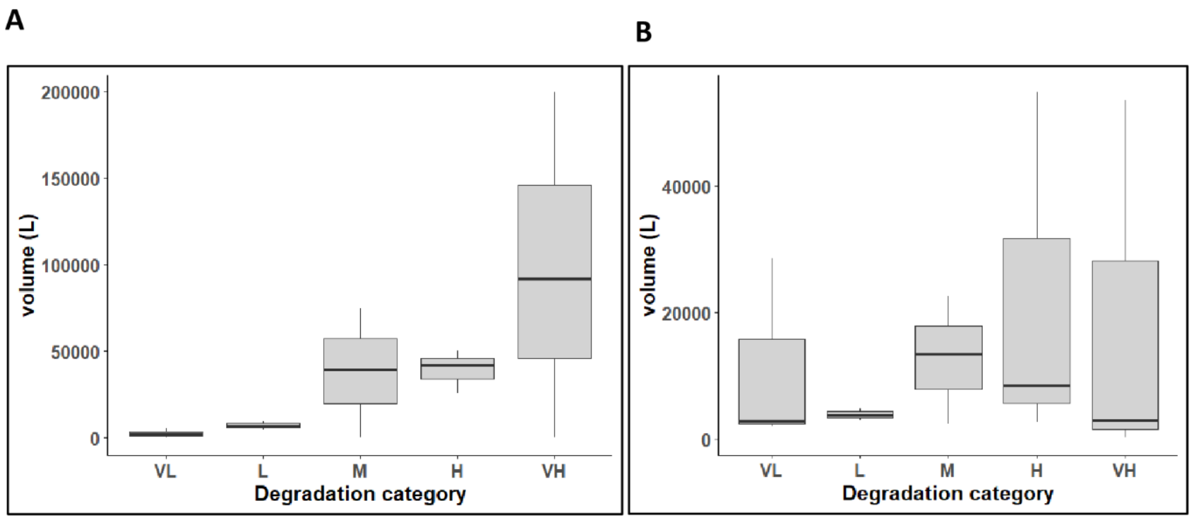

Figure 10: Sizes (volume in liters) of soil erosion formations across five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.2.2. Soil compaction (water infiltration rates)

In Otjamaungu village, the water infiltration rate was significantly different among degradation categories ($F=3.556$, $df=4$, $P<0.05$). The infiltration rate was highest in the moderate degradation category and lowest in the very low degradation category (Figure 11A). Significant pairwise comparison was observed between low and high degradation categories ($Z=3.094$, $P<0.05$), moderate and high degradation categories ($Z=2.805$, $P<0.05$), very high and low degradation categories ($Z=-3.372$, $P<0.01$), very low and low degradation categories ($Z=-3.312$, $P<0.01$), very high and moderate degradation categories ($Z=-3.084$, $P<0.05$) and between very low and moderate degradation categories ($Z=-3.024$, $P<0.05$).

In Otjimbundu village, water infiltration rate was significantly different among degradation categories ($F=2.58$, $P<0.05$). The water infiltration rate was highest in the very high degradation category and lowest in the very low degradation category (Figure 11B). The low degradation category was statistically different in infiltration rate from the baseline ($t=-2.046$, $P<0.05$).

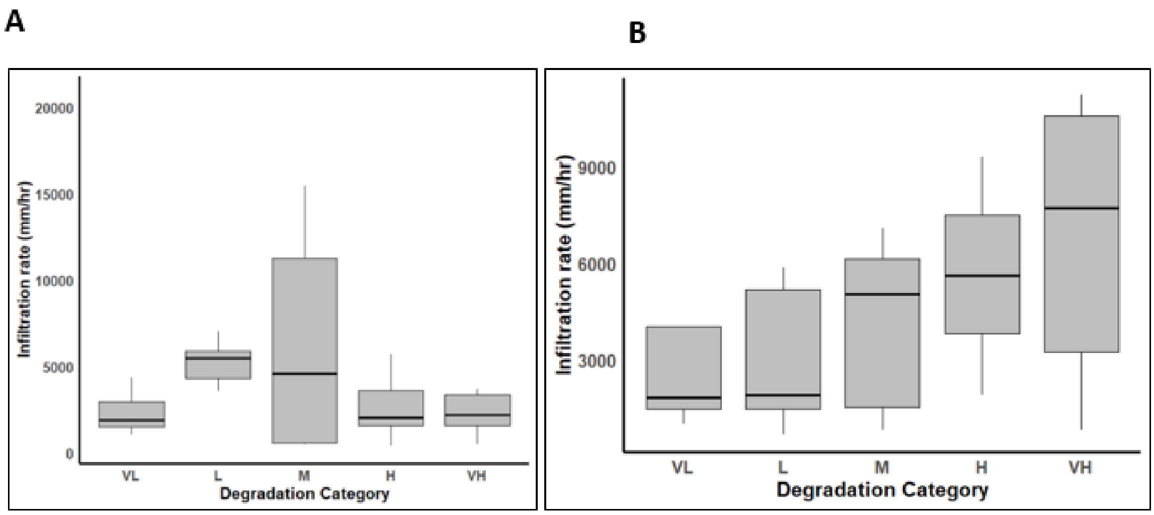

Figure 11: Infiltration rate of the water to completely infiltrate into the soil, recorded in the five degradation categories in Otjamaungu village (A) and Otjimbundu village (B)

4.3. Soil properties

Otjamaungu village:

The analysis of soil properties across degradation categories revealed significant differences in electrical conductivity (EC) and pH, while other properties showed no significant variation. EC values were highest in the high degradation category (46.07 dS/m) and lowest in the Very Low degradation category (3.76 dS/m), with the differences being statistically significant (P = 0.002). Similarly, pH varied significantly across categories (P = 0.0006), with values ranging from 8.09 in the Low degradation category to 8.75 in the Very High degradation category. In contrast, properties such as clay, silt, sand, nitrogen, and organic carbon content did not show statistically significant differences among the degradation categories, despite observable trends. Clay content ranged from 7.53% in the Low degradation category to 10.29% in the High degradation category, while silt content varied between 11.72%

(moderate degradation) and 20.24% (high degradation). Sand content was highest in the moderate degradation category (78.90%) and lowest in the high degradation category (69.49%). Nitrogen and organic carbon content showed subtle trends, with nitrogen levels ranging from 0.251% (high degradation) to 0.311% (low degradation) and organic carbon ranging from 0.630% (high degradation) to 0.807% (Low degradation).

Otjimbundu village:

The analysis of soil properties across degradation categories revealed significant differences for clay content, sand content, organic carbon (OC), and pH, while nitrogen and electrical conductivity (EC) showed no significant variation. Clay content decreased significantly with increasing degradation, ranging from 16.40% in the Very Low (VL) degradation category to 7.34% in the Very High (VH) category ($P < 0.001$). Sand content, on the other hand, increased significantly with degradation, ranging from 61.57% (VL) to 76.30% (VH) ($P < 0.00012$). Similarly, organic carbon content decreased significantly as degradation increased, with values ranging from 0.945% (VL) to 0.543% (VH) ($P < 0.001$). pH levels also exhibited significant differences ($P < 0.001$), increasing from 7.94 (Low degradation) to 8.78 (VH degradation).

In contrast, nitrogen content did not vary significantly across degradation categories ($P = 0.413$), with mean values remaining relatively consistent (0.196%-0.238%). Electrical conductivity (EC) also showed no significant differences ($P = 0.678$), except for outlier observations in the VH category, which included extremely high maximum values likely skewing the mean. These results highlight how clay, sand, OC, and pH are strongly influenced by degradation levels, with clear trends, while nitrogen and EC remain stable across the categories.

4.3.1. Canonical Correspondence Analysis (CCA) : Otjamaungu village

The CCA analysis shows a total variation of 6.81 (table 3), with explanatory variables accounting for 40.2% of the variation in species distribution. However, the adjusted explained variation is only 0.4%, suggesting low explanatory power after accounting for confounding factors, which may imply that other unmeasured factors influence species distribution ($F=1.0$, $P>0.05$). The permutation test for all axes yielded a pseudo-F value of 1.0 with a P-value of 0.426, indicating that the explanatory variables do not significantly explain the variation in species distribution.

The results of CCA ordination are presented in Figure 12. There is a strong linear relation of pH with the high degraded sites. These sites are mostly associated with the dominance of species such as *Pechuel-loechea leubnitzie* (Pechleub) and *Colophospermum mopane* (ColpMopn). The very low and low degradation sites have a strong linear relation with organic matter (OM) and organic carbon (OC). Species such as *Terminalia prunioides* (Terminal), *Grewia flava* (GrewFlav), *Boscia abitrunca* (BoscAlbt), *Combretum apiculatum* (CombApic), *Commiphora* glaucescens (CommGlau) and *Commiphora glandulosa* (CommGlan) occurred in these sites. Some low degradation sites have linear relations with clay and silt, where species such as *Diospyros mespiliformis* (Diosmes), *Catophractes alexandri* (CatpAlex) and *Grewia bicolor* (GrewBicl) are found. Moderate sites are mostly distributed around the centre of the plot, indicating a more intermediate soil composition without linear relations with environmental variables.

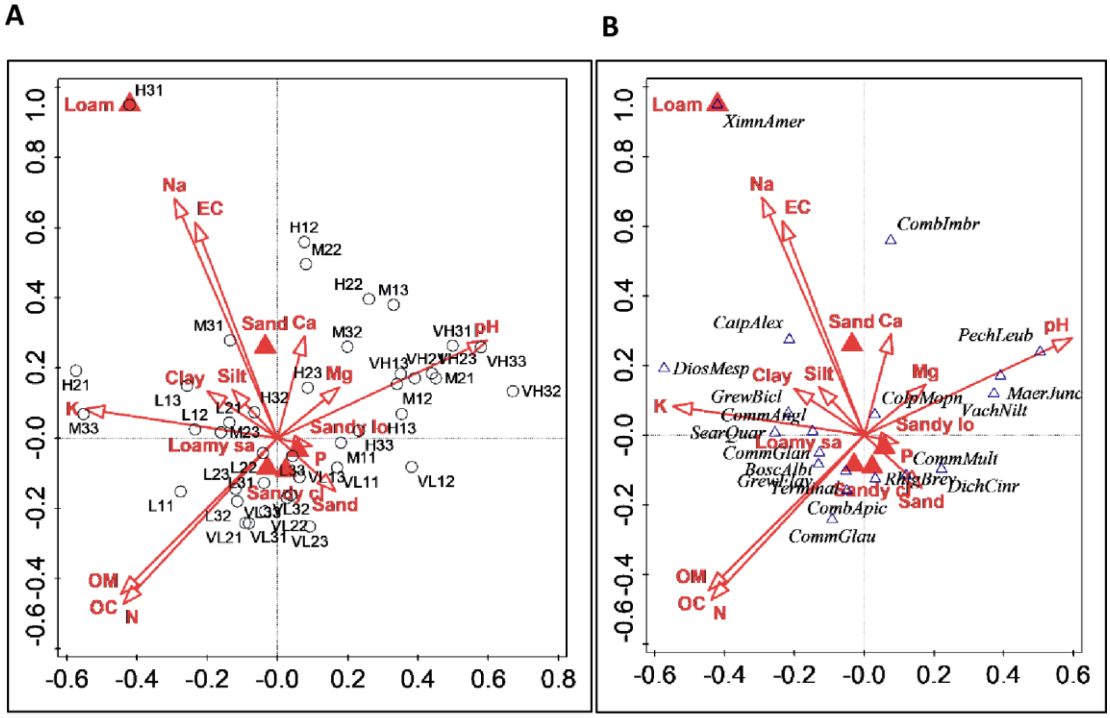

Figure 12: Canonical correspondence analysis (CCA) ordination illustrating the relationships between degradation categories and soil variables (A) and between woody species and soil variables (B). In the plots, arrows represent soil variables, circles denote degradation categories, and triangles represent woody species. The species are labelled using the first four letters of the generic name followed by the last four letters of the specific name.

4.3.2. Canonical Correspondence Analysis (CCA) : Otjimbundu village

According to the CCA results, axis 1, with an eigenvalue of 0.4327, explains 23.5% of the variation in species distribution, while axis 2, with an eigenvalue of 0.1420, contributes 7.7% to the total variation explained. Together, these two axes account for a cumulative explained variation of 31.21% and capture 65.72% of the fitted variation, indicating that they represent a significant portion of the relationship between species and environmental variables. Additionally, the high pseudo-canonical correlations (axis 1 = 0.7893, Axis 2 = 0.8135) demonstrates strong associations between species distributions and environmental gradients represented by these axes. In the forward selection results of the CCA analysis , organic carbon (OC) emerged as the primary variable explaining 14.8% of the variation, with a significant contribution ($p<0.05$, after adjustment). Other variables contributed low percentages that were not statistically significant after adjustment ($P>0.05$).

The results of the CCA are presented in Figure 13. The high degradation sites have linear relations with sandy soil and electrical conductivity (EC). Species such as *Colophospermum mopane* (Cmopan), *Pechuel-loechea leubnitzie* (Pleubn) are correlated with these sites. Low degradation sites have linear relations with organic matter (OM), organic carbon (OC), silt and clay. Species such as *Grewia flava* (GFlava), *Commiphora multijuga* (CMulg), *Moringa ovalifolia* (MOvalf) and *Boscia albitrunca* (BAlbit) are found near these sites. Moderate degradation sites are located around the center of the plot, indicating less or neutral relations with environmental variables.

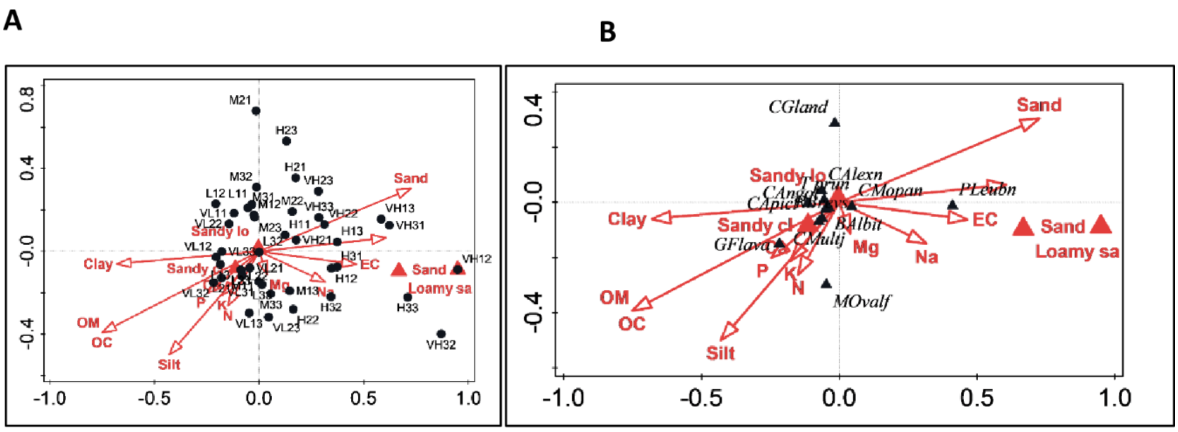

Figure 13: Canonical correspondence analysis (CCA) ordination illustrating the relationships between degradation categories and soil variables (A) and between woody species and soil variables (B). In the plots, arrows represent soil variables,

circles denote degradation categories, and triangles represent woody species. The species are labelled using the first letter

4.4. Interviews (qualitative data) results

4.4.2. Local traditional knowledge about the soil, plants, and fauna in relation to land degradation

Respondents across both Otjamaungu and Otjimbundu villages expressed concern over the condition of the soil, flora and fauna, noting clear signs of land degradation. Their views on soil, fauna and flora are presented in Table 1 and described below.

4.4.2.1. Communities' perception of the soil

In Otjamaungu village, some communities understood degraded soil to be unproductive and poor in quality, unable to support seed germination. Some have described the soil as having "lost value" or "poor in nutrients", especially in areas where vegetation no longer grows. The communities also pointed out that the drying of their land is associated with reduced rainfall, which leads to drought and poor soil quality, hindering plant growth (Table 1).

In Otjimbundu village, some respondents emphasized that land degradation results in soil that lacks essential nutrients, which hampers plant growth and reducing species abundance, indicating a local understanding of the critical relationship between soil health and vegetation. Some respondents specifically mentioned erosion of topsoil, highlighting awareness of physical soil degradation and its impact on agricultural potential (Table 1).

4.4.2.2. Communities' perception of the flora

In Otjamaungu village, plants are seen as a key indicator of healthy land, and their absence is repeatedly mentioned as a sign of land degradation (Table 1). Equally, grasses are considered crucial for livestock, and their decline or absence is strongly linked to the idea of land degradation . Some communities also added that the drying up of plants and reduced plant species abundance are often attributed to poor rainfall .

Similarly, in Otjimbundu village, respondents often pointed to the absence of plants, particularly woody species and grass, as a major indicator of land degradation . Many also associated this degradation with insufficient rainfall, while some emphasized the importance of water in supporting vegetation growth . Additionally, deforestation, driven by population pressures and the need for more land clearance for shelter, was recognized as a significant contributor to land degradation (Table 1).

4.4.2.3. Communities' perception of the fauna

In both villages, animals or livestock were mostly mentioned in terms of the impacts of land degradation (Table 1). In Otjamaungu village, many mentioned that their livestock is directly affected by land degradation due to the loss of grazing areas . The communities reasoned that the land becomes degraded, it no longer provides sufficient food for livestock, leading to livestock hunger and mortality .

In Otjimbundu village, the loss of vegetation as a result of land degradation is positively linked to the well-being of local fauna, as several respondents highlighted that degraded land provides insufficient food for animals (Table 1). Some have noted manifestations of land degradation, visible through the loss of grass and trees, worsened by poor rainfall .

Table 1: Perception of land degradation in terms of soil, flora and fauna in the selected villages

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village
Soil quality and degradation	*-"Land degradation is when the soil has become dry and does not receive good rainfall." (F3)* *- "The quality of the land is poor, even when seeds are sown, they do not germinate." (M8)* *- "Land degradation is the land that is poor in nutrients, which hampers plant growth." (F5)*	*- "The soil has lost nutrients and topsoil erosion has reduced its ability to support plant growth." (F3)* *- "It is land with no nutrients to support plants, and seeds do not grow well due to poor soil quality." (M1, F7)* *- "The soil is degraded due to drought and livestock settlements, impacting plant germination." (M4)*
Flora (vegetation loss: trees and grass)	*- "Degraded land is land that lacks trees, grass, and seeds are not able to germinate in it." (M1)* *- "Land degradation is when the land does not produce plants or has poor germination capacity." (M2, M3)* *- "The land has lost its trees and grass due to poor rainfall." (M6, M7)* *- "The absence of plants, especially trees and grass, is a clear sign of land degradation." (M9)*	*- "Land degradation is visible through the loss of grass and trees, which has worsened due to poor rainfall." (F1, F4)* *- "The land has become dry and can no longer support tree or grass growth due to deforestation." (M6, M7)* *- "It is the land that no longer has grass and plants due to poor vegetation growth from deforestation." (M8)*
Fauna (impact on livestock and wildlife)	*- "Land degradation is when the land no longer supports livestock because it lacks food and grazing areas." (F1)* *- "The degraded land has become unsuitable for grazing due to the loss of vegetation." (M10)* *- "Overgrazing by livestock has worsened land degradation, leading to loss of food for animals." (M3, M4)*	*- "Degraded land provides insufficient food for animals, impacting local wildlife and livestock." (F3, F5)* *- "Land degradation, worsened by drought and settlements, leads to less grazing for livestock." (M4)* *- "The reduction in vegetation impacts animals, leaving them without sufficient food or grazing land." (F5)*

4.4.3. Perceptions and experiences of local communities regarding land degradation, including its causes and impacts on their livelihoods

4.4.3.1. Community perception of whether land degradation is occurring in their area or not.

Table 2 summarises respondents' views on whether or not land degradation is perceived to be occurring in their area. Respondents from both Otjamaungu and Otjimbundu villages consistently reported clear signs of land degradation, primarily characterized by loss of vegetation, reduced grazing land, declining agricultural productivity, and diminished water availability.

In both villages, the most frequently mentioned manifestation was the loss of vegetation, especially trees, grasses, and locally important species such as *Terminalia prunioides*, *Catophractes alexandri*, and Commiphora spp. Respondents described areas that were once abundant in vegetation as now barren, with visible drying of trees and a notable decline in plant species abundance. In Otjamaungu, several participants linked these observations to poor soil conditions, reduced rainfall, and an inability of plants to regenerate. Similar observations were echoed in Otjimbundu, where respondents highlighted the disappearance of vegetation in mountainous and lowland areas alike (Table 2).

Table 2: Communities' perception of whether land degradation was occurring in the selected villages

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village

Land degradation manifestation : Loss of vegetation- grass, plants	"*Yes, it is happening. I walk around where there were many trees in the past, but they are not here anymore. Even grass that our sheep was grazing on has died.*" M2 "*Yes, it is happening here. Even if you take seeds and germinate them in the soil, they will not germinate, the soil has lost value.*" M3 "*Yes, it is happening because the trees are not growing anymore, there is not enough grass, some plants do not grow anymore and some have become dry.*" F3 "*Yes, it is happening. This is because some areas were abundant in trees, and now there are no trees anymore. Some plants have also reduced in number, such as Catophractes alexandri, Terminalia prunioides, and also a reduction in grass cover. Even when it rains, it is only some areas that grow grass while some do not anymore*." M8 "*Yes, our land is becoming dry, and there has been a drastic reduction in plant species abundance in some areas of the village*." M9 "*Yes, because we have lost some important trees that were abundant but now they are very few. Trees such as Terminalia pruinoides and the Commiphora species*." M10	"*There are some areas that have become bare, with no trees at all*." M1 "*Some areas no longer have many trees like in the past*." F2 "*Drying of trees, loss of grass, and bare patches that once had many trees*." F3 "*Some areas have no trees and grass anymore like they were in the past.*" F4 "*Some areas have lost a lot of trees, especially on the mountains.*" F5 "*Some places have no trees anymore*." F6 "*Some areas have become dry with no trees*." M6 "*The trees here are dying due to drought*." M7 "*Before the drought, some areas had many trees*." M6
Land degradation manifestation: loss of grazing land	"*Yes, it is happening because when we sent the goats to graze on the mountains, they return as if they have not tasted any food at all.*" F1 "*Yes, it is happening. We have lost so much livestock and left us in*	"*There is no more sufficient food for our livestock*." M2 "*The food for our livestock has reduced*." F7

	hunger. The food in the wild for humans and livestock has become scarce." M7 "*Yes, our land is becoming dry. It gets very hot now compared to the past. There is also no more enough grass for our cattle to graze.*" F5	
Land degradation manifestation: No/poor yields	"*Yes, because as you can see, our fields and gardens are not producing any food." M5* "*Yes, it is occurring here. This is because, nowadays, the trees are not producing anything in terms of food, especially the berries and marula trees. The plants are also not able to produce enough food for the cattle.*" F2	
Land degradation manifestation : No water	*Yes, it is happening because if you go to the mountains, there is no more springs of water* " M6	
No evidence of land degradation	"*No, I have not seen signs of land degradation occurring around here.*" M1	"*No, the land around here is not degraded, we do not have the land that has become dry*" F1 "*In my village, it is not occurring as we still have many trees and grass*" M 4 "*Around here, our land is still in a good condition, we have even received better rains this year.*" M5

4.4.3.2. Communities' perception on the of causes of land degradation

In Otjamaungu village, while most respondents (87%) had some knowledge about the causes of land degradation, about 13% were unaware of the factors contributing to it (as shown in Table 3). The majority of the respondents (80%) mentioned poor rainfall as the main cause of land degradation. They believe reduced or poor rainfall deteriorates the soil nutrients causing a reduction in plant growth. Some respondents (33%) mentioned that land degradation is caused by deforestation as a result of population growth, while 40% stated that it is caused by overgrazing, especially households that own large herds of cattle and goats.

In Otjimbundu village, most respondents (60%) believe that land degradation is caused by poor rainfall, hindering plant growth and accelerating droughts. Some of the respondents (40%) believe it is caused by cutting down too many trees as a result of population increase. Some respondents (53%) believe land degradation is caused by overgrazing including too many goats or livestock stepping on the soil, exhausting the nutrients.

Table 3: Communities' perception on what causes land degradation in their communities

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village
Poor rainfall	"*It is caused by poor rainfall. It is also caused by deforestation*." M1 "*It is caused by poor rainfall*." F3 "*Poor rainfall causes land degradation as the trees do not grow anymore*." F1 "*When it does not rain well, the land becomes unproductive*." F2 "*Because the rainfall has become very poor now*." M4 "*Poor rainfall and overgrazing. There is also an*	"*Poor rainfall also makes the environment dry*." M1 "*It is the poor rainfall.*" F2 "*It is caused by poor rainfall, deforestation, and people keeping too much livestock in one area for grazing*." F3 "*It is when there is drought, as a result of poor rainfall*." M2 "*It is caused by poor rainfall and also a lot of livestock, resulting in vegetation loss and exposing us to too much heat from the sun*." F5

	increase in the population of humans, hence more trees are also cut down to make houses." M5 "*It is caused by overgrazing and reduced rainfalls over the years*." M6 "*It is the poor rainfall, deforestation, and overgrazing that are causing land degradation*." M7 "*It is because of poor rainfall, overgrazing, and deforestation*." M8 "*It is caused by nature, when the rains are poor. We cannot make it rain, however, we are hopeful that God will send us good rains, just like in the past*." M9 "*It is the poor rains. I do not know why it does not rain well anymore*." F5 "*It is caused by poor rainfalls, the plants become dry, and we do not get enough grass, resulting in our livestock dying and leaving us in poverty."* M10 "*I am not really sure, however, poor rainfalls usually cause droughts, reducing food for the livestock*." M2	"*Poor rainfall also causes land degradation as well as overgrazing*." F6 "Poor rainfall also means less food for the livestock causing them to die." F7 "*It is caused by poor rainfall.*" M6 "*It is caused by poor rainfall because the plants do not germinate nor grow*." F7 "*It is caused by poor rains, resulting in droughts that kill our livestock and leave us in poverty*." M8
Deforestation	"*It is caused by deforestation*." M1 "*People are also cutting down too many trees, causing deforestation*." F2 "*There is also an increase in the population of humans,*	"*It is caused by the cutting down of trees*." M1 "*When people cut down too many trees, causing the land to die*." M2 "*It is caused by poor rainfall, deforestation, and people*

	hence more trees are also cut down to make houses." M5 "*It is the poor rainfall, deforestation, and overgrazing that are causing land degradation*." M7 "*It is because of poor rainfall, overgrazing, and deforestation*." M8	*keeping too much livestock in one area for grazing*." F3 "*It is caused by people cutting down too many trees*." F4 "*It is caused by deforestation*." M6 "*The floods also come and wash down soil nutrients into the river*." M7
Over grazing	"*It is caused by overgrazing, some people own large herds of livestock that is grazing*." M3 "*There is also an increase in numbers of livestock, and the environment cannot support them*." M4 "*Poor rainfall and overgrazing*." M5 "*It is caused by overgrazing and reduced rainfalls over the years.*" M6 "*It is the poor rainfall, deforestation, and overgrazing that are causing land degradation*." M7 "*It is because of poor rainfall, overgrazing, and deforestation*." M8	"*Mostly it is the goats that deteriorate the soil as a result of grazing, unlike the cattle. The springboks also degrade the land by stepping and running over it*." F1 "*Animals also cause land degradation as a result of grazing and many footsteps."* M1 "*They come here and graze their livestock anywhere*." F2 "*People keeping too much livestock in one area for grazing*." F3 "*It is caused by people cutting down too many trees and also keeping too many goats in one area, resulting in overgrazing*." F4 "*It is caused by poor grazing methods and inappropriate settlements*." M3 "*Poor rainfall also causes land degradation as well as overgrazing*." F6 "*Increase in human and livestock population, putting more pressure on the natural resources*." M7

		"*It is when the soil has too much salt in it, causing poor germination and reducing plant growth. Also caused by overgrazing and deforestation*." M4
Uncertainty		"*I am also wondering what could be the cause of degrading lands. Is it maybe poor rainfalls or what is causing it*?" M5

4.4.3.3. Community perceptions of the duration of land degradation impacts

The respondents were asked to share how long they have been experiencing the impacts of land degradation in their respective villages as discussed in Table 4.

In Otjamaungu village, the majority of respondents (40%) reported experiencing land degradation since 2007. Some respondents (27%) recalled it beginning in 2017, while 13% identified 2013 as the starting year. Additionally, 7% of respondents mentioned 2012, 2019, or the early 2000s as the time they first noticed its effects.

In Otjimbundu village, most respondents (27%) reported experiencing the impacts of land degradation for the first time in 2012. Others recalled it beginning in 2007 (20%) and 2021 (13%). Additionally, 7% cited various years, including 2001, 2004, 2006, 2008, and 2018, while 7% were uncertain about when it first occurred.

Table 4: Perception of how long the respondents have been experiencing the impacts of land degradation on their land

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village
Since 2001	"*It has started since in the 2000s until now.*" M2	"*Since 2001.*" M2

Since 2004		"*It has been approximately 10 years now, since 2004*." F5
Since 2006	"*Since 2006 the environment has been changing from good to bad*." M8	"*The poor rainfall have started since the year 2006, and a reduction in vegetation."* F4
2007	"*Since 2007, our land has become bad*." F1 "*It has started since 2007, the rain has been very poor over the years*." F2 "*It has started since 2007, until now*." M5 "*It has started since 2007*." M6 "*Since the year 2007*." F5 "*The rain started reducing since 2007, however, the bad droughts began around 2017*." M10	"*Since the year 2007*." M3 "*The rain has started reducing since 2007 until now*." M4 "*The rain was plenty growing up, but since 2007 until now it has been poor*." M6
since 2008		"*Since the year 2007, 2008 until now. Since 2008, people have been relocating from their areas to our land for grazing because their food or land have become dry*." F3
Since 2012	"*Since the year 2012."* M9	"*Since the year 2012."* M1 *"Since 2012 until now*." M7 "*The bad droughts have started since 2012*." F7 "*The change in rainfall patterns started around 2012*." F1
Since 2013	*"The changes in our environment began since the year 2013*." M3	

	"*When I was growing up, our land was not degraded this much, but now it is. It has been approximately 11 years since our land changed to bad."* M1	
Since 2016	"*It has started quite a long time ago, however the severe droughts began since the year 2016*." F4	
Since 2017	"*I am not really sure of the year, but I would say it has been around 7 years now (since 2017)*." M4 "*Since the year 2017*." M7 "*The bad droughts began around* 2017." M10 "*I am not really sure of the year, but I would say it has been around 7 years now (since 2017)*." M4	
Since 2018		"*Since the year 2018*." M8
Since 2019	"*For five years now, our land has been bad*." F3	
Since 2021		"*Since the year 2021, the rain has reduced and food for animals has also reduced*." Male 5 "*Since 2021 the environment has been changing as a result of poor rainfall*." F6
Uncertain		"*Rain has been fluctuating over the past years*." F7

4.4.3.4. Communities' perception of indicators of land degradation

Table 5 below presents insights into the community's perceived indicators of land degradation in two villages: Otjamaungu and Otjimbundu.

In Otjamaungu village, the most commonly mentioned indicator is poor rainfall (47%), causing droughts. Some respondents (40%) cited the loss of vegetation, with a high light on specific species such as *Combretum apiculatum, Terminalia prunioides, Catophractes alexandri,* grewia species, *Faidherbia albida, Rhigozum brevisponosum, Berchemia discolor,* Commiphora and Moringa species. Some also noted the increase in *Pechuel loeschea leubnitziae* which has replaced the palatable species. While 40% of the respondents mentioned the loss of wildlife.

In Otjimbundu village, the majority of the respondents (40%) mentioned the loss of vegetation as a key indicator of land degradation. They highlighted the decline in grass cover, crucial for livestock grazing and a reduction in plant species richness, particularly the grewia species and the *Boscia albitrunca*. Other respondents (33%) also mentioned poor rainfall as a contributing factor to land degradation, which dries the environment, limits grass and plant growth, and restricts species richness. Consequently, the grass necessary for livestock grazing typically only flourishes during the rainy season. Additionally, 13% respondents reported a decline in wildlife, such as cheetahs, which have migrated from their land due to increased hunger. On the other hand, 7% mentioned poor soil nutrients as a land degradation indicator, that even when they sow seeds, they do not germinate.

Table 5: Perceived indicators of land degradation by the communities

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village

Loss of vegetation	"*The environment has lost many trees and the grass, especially Catophractes alexandri. There is also a lot of Pechuel loeschea leubnitziae shrubs that have now actually replaced the grass.*" M2 "*There are many trees that have reduced in number such as Catophractes alexandri, Terminalia pruinoides, Grewia species and Faidherbia albida."* M5 "*Some trees like Combretum apiculatum, Terminalia Pruinoides and Rhigozum brevispinosum are now very few in number because the land is no longer productive."* M4 "*Some trees have also reduced in number such as Berchemia discolor, and most Commiphora species*." F5 "*The Commiphora species such as Commiphora multijuga, Terminalia Pruinoides and Grewia species have also become very few as a result of land degradation*." M8	"*Reduction in plant number and species richness*." M1 "*It is the poor growth of grass especially on the mountains. Even the wild animals such as springboks, jackals, and zebras have relocated to other areas because of poor food availability*." F2 "*It is the reduction in number of animals because of the drought and also reduced number of trees. Some trees such as Grewia species, Boscia albitrunca, and Terminalia prunioides have become few. Succulent plants such as the Aloe vera have drastically become few and it is medicine for humans. Some animals like rabbits, springboks, and kudus have also become few. The birds have also reduced in number*." M2 "*When there are no trees and nor grazing grass. The wild animals have also relocated while some have died as a result of hunger. However, we still have cheetahs that are also killing/feeding on our livestock. We have trees such as Terminalia prunioides, Catophractes alexandri and Commiphora multijuga that were many; however, they have now decreased in number. Mopane (Colophospermum mopane) is plenty, it grows well in all seasons."* M3 "*It is poor rainfall and more animals overgrazing, especially from other villages." F5* "*A reduction in plant species richness, or drying and dying of big trees as a result of poor rainfall."* M8

Reduction in wildlife	"*Some animals have left our land such as wild animals due to poor grazing e.g. elephants, springboks and kudus*." M3 "*Wild animals have also migrated from our lands to other villages where there is enough food for them. These animals include elephants, kudus and zebras.*" F5 "*Most wild animals have migrated from our land to other areas far from here, such as Opuwo, looking for better grazing*." M8 "*Wild animals such as kudus, zebras, and rabbits have become few as a result of hunger."* M10 "*It is when the land has lost grass and plants. It is also shown by the wild animals that have migrated from our land such as Kudu, elephants, zebras, because there is no enough food for them*." M7	"*The wild animals have also relocated while some have died as a result of hunger. However, we still have cheetahs that are also killing/feeding on our livestock*." M3 "*It is when there is no grass causing animal migrations in search for better grazing*." M7
Poor rainfall	"*Drought symbolizes land degradation. Even when it rains, some areas still do not germinate plants*." M4 "*It is when it does not rain very well. When I was growing up, it was raining well, unlike now*." F2 "*It is caused by poor rainfall and also overgrazing as well as deforestation*." M6 "*Poor rainfall is causing land degradation*." F5	"*I would say it is indicated by poor rainfall causing the environment to become dry. Food for both animals and humans reduces*." F1 "*It is when the rain is poor, the environment becomes dry, especially the grass. It is only during the rainy season one can see grass*." F4 "*Poor rainfall that causes dryness of the land. The grass does not grow and animals die due to hunger*." F7

	"*When it does not rain well and the soil becomes poor in nutrients that plants struggle to grow and survive*." M9 "*The plants have become dry. The cattle have died because of hunger and there has been devastating droughts over the years*." F3 "*The rain was plenty growing up, but since 2007 until now it has been poor*." M6	"*It is indicated by a reduction in vegetation, usually caused by poor rainfall. There is not enough food for our livestock, causing them to die*." M6 "*A reduction in plant species richness, or drying and dying of big trees as a result of poor rainfall*." M8
Poor soil nutrients		"*It is when the soil becomes poor in nutrients that even when we grow our crops they do not germinate unless one adds fertilizer to the soil*." F3

4.4.3.5. Perceived impacts of land degradation on the livelihoods of communities

Table 6 below presents the responses from Otjamaungu village and Otjimbundu village regarding the effects of land degradation on their livelihoods.

In Otjamaungu village, 60% of respondents reported significant impacts on food sources for both humans and livestock. They highlighted a decline in livestock feed, leading to livestock mortality, their primary food source. Previously, they could sell livestock for sufficient income to buy essentials, but now, losses force them to sell at lower prices or turn to crop farming, which was once uncommon. Additionally, 7% mentioned having to buy food from stores, a shift from their previous reliance on livestock. Another 20% observed a decline in fruit production and vegetation. Seven percent (7%) feared certain plants might become extinct, affecting future generations. Medicinal plants like Aloe vera have also diminished. Thirteen percent (13%) of respondents reported declining soil fertility, leading to lower crop yields and poor seed germination, impacting food supplies. Another 7% noted increased sun intensity, exacerbated by the loss of large shade trees.

In Otjimbundu village, the focus was primarily on livestock and its impact on food supply. Majority of the respondents (53%) cited the effects of land degradation on livestock, which is crucial for their survival. The community is suffering from livestock deaths due to drought, with some (7%) expressing concerns about the survival of future generations if the drought conditions persist. Other respondents (27%) mentioned the reduction in vegetation, arguing that many important plants, including *Catophractes alexandri, Terminalia prunioides*, *Berchemia discolor*, and various Grewia species, have declined. These plants are essential for both livestock and human food sources. Additionally, some respondents (13%) highlighted the impact of poor soil nutrients on plant germination, resulting in lower crop yields..

Table 6: Perceptions of the impacts of land degradation on the communities' livelihoods

Supporting quotes		
Theme	Otjamaungu village	Otjimbundu village

Food insecurity due to livestock loss	"*We are impacted in a negative way because we survive on livestock for meat and milk but now it is dying from hunger. The cow dung has also reduced, leaving us with nothing else to build our rooms with.*" M2 "*I am impacted in a bad way because I have lost so much livestock especially my cattle that provide us with meat and milk. At present, we are left with almost nothing to eat and forced to sell our remaining livestock at cheaper prices so we can at least buy maize meal*" M7 *"I am affected in a very bad way because my cattle and sheep have died and now I am only left with goats. I was surviving on the meat and milk, but now life has become difficult*" M8	"*It affects me negatively because my livestock, which provides us with food, is dying of hunger.*" F2 "*Land degradation affects me in a bad because I rely on livestock for survival. If it does not rain, the livestock will die, leaving me without meat and milk to sustain myself.*" F5 "*It affects me negatively because we used to depend on livestock for our survival, but now the livestock is dying due to poor grazing.*" F6 "*It affects me severely because our livestock is struggling to survive as a result of poor grazing growth, leaving us with no food to eat.*" M6 *"I am affected in a bad way because poor rainfall cause a reduction in food of our livestock. When our livestock die, we find it very difficult to survive*" M7 "*It affects me badly because we highly survive on goats, cattle, and sheep for meat and milk. Now, our livestock keeps dying, leaving us in absolute hunger.*" F7
Income loss	"*I am affected badly because I would sell my livestock to buy*	"*We are affected very badly because the food for our livestock has*

	necessities such as clothes. I also get meat and milk from it, however, livestock has been dying due to droughts."M4	*become scarce and even the jackals are hunting our livestock. We also used to sell our livestock to buy food such as maize meal, but now our livestock is dying of hunger*." F3
Shift to crop farming	"*Land degradation has affected me in a bad way because my livestock died and I am left with almost nothing to eat. We are now forced to make gardens to grow crops which we never had to do in the past as meat and milk was sufficient*." M9 "*The impacts are bad. Every year we are hopeful for good rains, we have even began to cultivate in our fields but the rain was still not sufficient, hence, our crops are dying. I cannot even stress enough on the continuous dying of our livestock as a result of poor grazing." M10* "*I am impacted in a bad way because I lost my livestock as a result of hunger. I am now surviving on crop farming, but I do not even work in my field anymore because of poor rainfall over the years*." M3	
Decline in wild food	"*It is affecting me negatively because growing up, we would enjoy wild fruits such as*	"*If there is poor rainfall, there is also no food for us and our livestock. Plants like B. discolor*

	berries from the trees growing on the mountains, but these trees are not even growing to produce fruits anymore on our land and this is because the soil has lost quality to grow these plants. In addition, land degradation has caused livestock deaths from hunger and we survive on meat and also selling."F1 "*It affects us severely because the land is becoming increasingly dry. The plants on the mountains are withering, and they are essential for providing food for both animals and people. Additionally, we are forced to travel long distances in search of good grazing for our livestock.*" F3 "*Land degradation is affecting me in a bad way because we can no longer harvest fruits as we used to; the trees no longer produce fruits as abundantly as they did in the past.*" F5	*(berry trees) and Grewia species provide us with food, but they are becoming few. Even when we grow our crops, they do not germinate because of poor soil fertility.*" M4
Compelled to buy food from the shops	"*Land degradation is affecting me severely because we can no longer grow sorghum for consumption, and we now have very few livestock. Currently, we are even forced to buy food from the shops, which was not*	

	necessary in the past." M5	
Unprecedented flooding	"*I am deeply affected because I am not surviving as I did in the past. The land has become poor in quality, and areas that never experienced flooding are now prone to it. Additionally, my livestock is struggling to survive due to inadequate grazing*." F2	
Wildlife displacement	"*It is bad because we have lost our trees, and even the wild animals have migrated due to the scarcity of food on our land*." M6	"*Affected in a bad way because we do not have enough grazing anymore. Even the wild animals have also relocated due to hunger*." M5
Extinction of plant species	"*The abundance of some tree species has significantly declined, if not extinct. Our children may never grow up to know them. Additionally, the soil is no longer as fertile as it was and struggles to support plant growth.*" F4	"*It is affecting me in a bad way because deforestation is deteriorating the soil in terms of nutrients. Some trees such as C. alexandri,etc. we use them for food, especially for our animals, however, these trees have become few.*" M1
Increased sun intensity	"*The impacts are bad because it has also become too hot. We are losing big trees that*	

	provide us with shade, making the sun heat severe." M9	
Fear for future generations' survival		"*We are negatively impacted because I am afraid how the future will be like for our future generations if we keep receiving poor rains. There will be no enough livestock for them to survive on.*" M8
Decline in medicinal plants		"*It has affected me in a bad way. Most of our important plants have reduced in number, especially plants we use for medicinal purposes. An example is the Aloe."* M2
Decline in livestock grazing		"*Impacted in a bad way because trees like T. prunioides, C.multijuga, C. alexandri have reduced in abundance, and these are very important trees especially for our livestock grazing."* M3 "*There is no enough food for both people and our livestock anymore as a result of land degradation.*" F4
Loss of soil fertility		"*Degraded land affects us in a bad way. Even when we germinate plants, they grow very poorly because the soil is depleted of nutrients.*" F1

4.4.3.6. Perceptions of interventions at community levels to reduce the impacts of land degradation

Finally, respondents were asked about laws implemented to combat land degradation in their communities (Table 7). In Otjamaungu village, most respondents (47%) reported using a seasonal grazing rotation method, which is widely followed, passed down through generations. During summer, livestock are grazed in the village, taking advantage of the abundant grass from rainfall. In autumn, when grass becomes scarce, livestock are moved to the mountains for grazing, allowing village grass to recover. Some respondents (40%) mentioned a law restricting excessive and uncessary cutting of trees, particularly species such as *Catophractes alexandri*, *Terminalia prunioides*, and commiphora species, which are valuable and highly nutritious for livestock and crucial medicinal properties. They argued that these species have drastically reduced in numbe. However, *Colophospermum mopane*, which is plentiful and regenerates well, is allowed to be cut and utilized, mostly for shelter. Other respondents (7%) stated that no laws have been enforced because some individuals do not comply, leading to unrestricted use of natural resources.

Similarly, in Otjimbundu village, the majority of respondents (53%) mentioned the law of seasonal grazing rotation, a practice passed down through generations. This system allows them to graze livestock in the village during the summer when the grass is abundant, and then move them to the mountains in autumn to let the grass in the village recover. Additionally, 47% of respondents highlighted a law that limits tree cutting. Specific trees, such as *Sclerocarya birrea*, *Combretum apiculatum*,*Terminalia prunioides, Catophractes alexandri,* and Commiphora species, are currently protected due to their significance for both people and livestock. They have, however, advised the use of *Colophospermum mopane* trees because it is plentiful on their land. They use it especially for building shelter. While these laws are intended to preserve the environment and protect their livelihoods, some respondents noted that not everyone follows them.

Table 7: Perceptions of interventions at community levels to reduce the impacts of land degradation in the selected villages

	Supporting quotes	
Theme	Otjamaungu village	Otjimbundu village
Seasonal grazing rotation	"*We have established rules for grazing our livestock. During the summer, grazing is allowed within our village, but during the dry seasons, everyone is required to take their livestock to graze in neighbouring villages. This practice helps the grass in our village to recover and grow. Many people agree with this rule*".M7 "*We have a rule of grazing our livestock at home during the summer and at Omatheratundu in the mountains during autumn to allow the grass at home to recover. We also agreed to avoid cutting down too many commiphora and pruinoides species, as they have become scarce"*.F3 "*We all agree to move our livestock to other areas periodically to allow the grass to recover. When someone new is seeking grazing land, they are given guidance on where they can graze.* M3 "*We have agreed to graze our livestock at home during the*	"*We have implemented a law of grazing in designated areas during different seasons to allow the land to recover. However, some people do not follow these rules, particularly the Himba people, who are known for having larger herds of livestock.*" F1 "*We have rules to graze our livestock here at home in summer, while in autumn we all take our livestock to the far places to allow grass at home to recover.*" M1 "*We have implemented laws designating specific areas for goats and others for cattle to graze. However, not everyone follows these rules, and some people mix the livestock.*"F2 "*We have agreed to graze our animals at home during summer when grass is abundant, and move them farther away in autumn to areas where grass is still plentiful, while keeping only the lactating animals at home. This strategy has worked well for us for many years,*

	summer. In autumn, we move to the mountain areas for grazing to allow the grass at home to recover. Once it has recovered, we return to graze at home again. Most people support this practice". M4 "*We have agreed to graze our animals at home during the summer while the grass remains sufficient. However, in autumn, we will move to the mountains, keeping only lactating livestock at home to allow the grass to recover*".M9 "*We have a place called Omatheratundu, where we only take our livestock for grazing in May. Everyone must return home in January after the grass has recovered, allowing it to grow again in Omatheratundu*." F1 "*We have a place called Omatheratundu, where we only take our livestock for grazing in May. Everyone must return home in January after the grass has recovered, allowing it to grow again in Omatheratundu*." M10	*although it is increasingly challenged by declining rainfall*." F3 "*We have laws that regulate grazing in different areas during various seasons to allow the soil to recover.*" M2 "*We have implemented laws to keep animals in one area and rotate them to other areas to allow the grass to recover. However, not everyone complies with these regulations*." F4 "*We have established laws on livestock grazing: during summer, we keep livestock at home, and in autumn, we move them to other areas to allow the land to recover. Most people have agreed to this practice*." M3 "*We have established a law that requires people to graze in one area until November and then move to other areas to allow the grass to recover. While some people adhere to these rules, others do not*." M6
Restrictions on cutting down trees	"*We have agreed on certain rules, including avoiding unnecessary tree cutting as this can negatively affect our environment*." M1 "*We have established laws to limit the cutting of C. alexandri trees, as they are highly nutritious for our goats. Many people adhere to this rule."*M6	"*We have established laws prohibiting the cutting down of T. pruinoides trees, as they are becoming scarce. Only C. mopane trees, which are plentiful, may be cut down for use. People have agreed to this, as we are now seeing a reduction in the number of T. pruinoides trees*." M4"*Trees like C. angolensis, T. pruinoides, and C. imberbe should not be cut down. Only*

	"*We have established a few laws, including avoiding the cutting of T. pruinoide, C. multijuga, and C. alexandri trees, as they serve as essential sources of food for both livestock and people*." F5 "*We decided not to cut down trees without a valid reason and rather make use of mopane trees because they are still abundant compared to other tree species." F2* "*We have agreed to make use of mopane trees for building our houses because they are abundant and grow widely, unlike some plants that are difficult to germinate or grow in most areas. Everyone adheres to this rule*." M5 "*We have agreed to carefully choose settlement locations while considering the vegetation. We have also agreed to use mopane trees, as they are still abundant compared to other species*." M8	*C. mopane trees should be used, mainly for building our houses*." M5 "*We have established laws that anyone wanting to build a new house must cut down specific trees and know where to harvest them from.*" F5 "*We have established laws that prohibit the cutting down of trees like commiphora species. Only the Mopane trees, which are plentiful, can be cut down for building houses*." F6 "*We have laws prohibiting the cutting down of commiphora species, C. alexandri, and others. Anyone who cuts them down must pay a fine. We should instead make use of Mopane trees to build our houses.*" M7 "*We have laws that prevent the unnecessary cutting down of trees. Anyone found cutting down trees without a valid reason is fined." F7* "We *have agreed not to cut down trees such as T. pruinoides and F. albida, as they are already becoming scarce and are an important source of food*." M8
No laws implemented	"*We have not introduced laws because even when we hold meetings to discuss laws aimed at protecting our environment, not everyone follows or agrees to the rules*." F4	

4.5. Comparison of how local and scientific knowledge complement each other in identifying and understanding land degradation patterns in Kunene region.

The table below (Table 8), shows the comparison between scientific findings and local perceptions regarding land degradation in Otjamaungu and Otjimbundu villages. While some findings strongly complimented both knowledge systems, some were partially matched.

Both scientific data and local perceptions aligned on several aspects of land degradation. On species composition, both sources found that invader and unpalatable species like *Colophospermum mopane* and *Pechuel-loeschea leubnitziae* thrive in degraded areas, while key species such as *Terminalia prunioides* and *Catophractes alexandri* that are important to the communities and their livestock decline. This shows a shared understanding of species shifts due to degradation. Similarly, on species richness, both sources confirmed fewer species in highly degraded areas, supporting the negative impacts of degradation on biodiversity. Species diversity is lower in degraded areas according to both scientific results and local observations, though the low degradation areas still show higher diversity, which partially aligns with the scientific data. On species density, both highlight a reduction in tree and grass density in degraded areas, further supporting the loss of vegetation due to degradation.

On species regeneration, both sources agreed on fewer saplings and seedlings in degraded areas, with grazing pressure and drought as key impediments to growth. For herbaceous cover, both sources noted the highest cover in areas of very low degradation, with locals particularly observing a loss of grasses essential for livestock grazing.

The results on soil erosion revealed that the highly degraded areas showed more signs of eroded top soil and high volume of gullies compared to low degraded areas. The communities in both villages have viewed the issue of soil erosion as primarily caused by natural factors. On the other hand, soil compaction and infiltration rates aligned with both sources noting increased compaction in degraded areas, though locals emphasized livestock trampling as the cause. Regarding soil pH, scientific findings showed more alkaline soils in degraded areas, while the communities mentioned poor soil quality but have not focused on pH, resulting in a partial match. For organic carbon (OC), both agree on a decrease in degraded soils, making them nutrient-poor. Finally, both knowledge sources reported an increase in sand content in degraded areas, and the communities described the soil as sandy and unsuitable for the germination of crops and this aligns with scientific.

Table 8: Comparison of scientific results and local knowledge on land degradation in Otjamaungu and Otjimbundu villages

Aspect tested	**Scientific findings**	**Scientific Trend**	**Local Perception**	**Alignment**
Species composition	Dominance of encroacher and unpalatable species (*Colophospermum mopane*, *Pechuel-loeschea leubnitziae*) in high degradation areas.	**Decreased with** degradation	Loss of key species like *Terminalia prunioides, Catophractes alexandri*; *Commiphora angolensis*, *Commiphora multijuga* increase in shrubs.	✓ Matches
Species richness	Fewer species in high degradation categories. Highest richness in low/very low degradation categories.	**Decreased with** degradation	Noted fewer tree and grass species, particularly in degraded areas.	✓ Matches

Species diversity	Highest in low degradation areas; lowest in high/very high degradation areas. The low degradation category recorded a high species diversity compared to very high degradation category.	**Decreased** with degradation	Noted loss of diverse species, especially trees and grasses important for grazing.	✓ Partial match
Species density	Lower density in high/very high degradation categories.	**Decreased** with degradation	Observed fewer trees and grass, particularly in areas heavily grazed or deforested.	✓ Matches
Regeneration (Saplings/Seedlings)	Fewer saplings and seedlings in high/very high degradation areas.	**Decreased** with degradation	Recognized fewer young trees; grazing pressure and drought prevent new growth.	✓ Matches
Herbaceous cover	Highest in very low degradation areas; lowest in high/very high degradation categories.	**Decreased** with degradation	Observed loss of grasses needed for livestock grazing.	✓ Matches
Soil erosion	Higher erosion volume in high degradation areas; less erosion in very low degradation.	**Increased** with degradation	No direct mention of soil erosion. Rather viewed as natural formations	✓ Partial match
Soil compaction (Infiltration Rate)	Compaction increased with degradation, reducing water infiltration rates.	**Increased** with degradation	No direct mention of compacted soil. However, noted soil damage by livestock trampling.	✓ Partial match
Soil pH	pH increased in high degradation areas (more alkaline soils).	**Increased** with degradation	No direct mention of pH; focus on poor soil quality and plant growth.	✓ Partial Match
Organic carbon (OC)	Lower OC in high degradation areas, highest in very	**Decreased** with degradation	Recognized soil as losing nutrients, making it poor for plant growth.	✓ Matches

	low degradation categories.			
Clay content	Decreased clay content in high degradation areas, particularly in Otjimbundu.	**Generally decreased** with degradation	No direct mention of clay but described soil as loose and eroded.	✅ Partial Match
Sand content	Increased sand content in high degradation categories, particularly in Otjimbundu.	**Generally increased** with degradation	Noted soil erosion and loss of fertility; soil described as sandy and poor for crops.	✅ Matches

5. DISCUSSION

Overview of findings

The analysis of land degradation in Otjamaungu and Otjimbundu villages in Kunene Region shows clear patterns in species composition, vegetation diversity, regeneration, soil properties, and erosion across degradation categories. The results confirm that degradation has serious negative effects, particularly in categories classified as *high* and *very high degradation*. Combining scientific measurements and local perceptions reveals a consistent understanding of how land degradation manifests and affects local livelihoods. This discussion examines what these findings mean, explains the observed patterns, and compares them with results from similar studies.

5.1. Floristic composition and diversity

In both villages, species diversity varied across different degradation categories. Surprisingly, the low degradation category in both villages recorded the highest species diversity, contrary to expectations that the very low degradation category would have recorded the highest diversity as perceiped by the communities. Communities likely perceived the very low degradation category based on the high density of woody species compared to the low degradation category. This aligns with Inman et al. (2020), who reported that communities in Kunene associate degradation with a lower density of woody species. Studies such as Kassahum and Smit (2008) in Ethiopia also found that pastoralists attributed degradation to factors such as reduced vegetation cover and loss of palatable species. In Otjamaungu, although the very low degradation category exhibited high species density, species richness was lower, ultimately reducing overall diversity. While the total number of individual plants was high, these sites were often dominated by a few species, resulting in a lack of homogeneous distribution.

Overall, the very low and low degradation areas recorded a high species diversity compared to other degradation categories and this could be because they were mostly found near or on the mountains, far from the communities' homesteads as observed during the field assessment. Communities may have utilized plants closer to home, avoiding distant and mountainous areas (Inman, 2020a; Sainnemekh et al., 2022; Bedunah & Angerer, 2012; Zerga, 2015). These areas were perceived to have high species richness and abundance, aligning with ecological results.

The moderate degradation category had a lower species diversity compared to low and high degradation category, but it was higher than species diversity in high and very high degradation categories, in both villages. The communities perceived this category as moderately degraded due to a noticeable reduction in vegetation cover, reduced species richness and a drastic reduction in herbaceous cover. Observed human activities, such as plant cutting and fencing for new houses, indicated ongoing disturbances. As noted by Mussa et al. (2016b), semi-arid rangelands face continuous threats from overgrazing, population pressures, and development, leading to further encroachment into low degradation areas for new development.

Species diversity was lowest in the high and very high degradation categories in both villages.. In Otjamaugu village, the high and very high degradation categories recorded almost a similar diversity index. In this village, the communities struggled to make a clear distinction between the two categories due to vast degraded areas that seemed similar based on the vegetation cover. The high degradation category was characterized by very low vegetation cover, dominated by the unpalatable *Pechuel-Loeschea leubnitziae*. Severe degradation in arid and semi-arid regions is primarily due to high grazing intensity, which alters plant composition over time by favouring less palatable and fast-establishing species (Zerga, 2015). The highly degraded areas were marked by bare patches and *Pechuel-Loeschea leubnitziae,* a problematic weed colonizing disturbed sandy, alkaline soils (Tedder et al., 2015; Kangombe, 2010).

5.2. Species density and regeneration potential

A reduction in species density is usually attributed to human activities such as deforestation and overgrazing (Moleele & Perkins, 1998). The low density observed in moderate, high, and very high degradation categories in both villages could be related to continuous human activities, including daily trampling by humans and livestock, which hinders plant growth and regeneration (Amutenya, 2020). The high degradation sites in both villages are mostly located in lowlands near homesteads (as observed during field assessment), making them more vulnerable to human pressures and environmental factors.

The regeneration status was generally “poor” in both villages, as mature trees dominated low to moderate degradation areas, while sapling and seedling densities remained low. Factors such as low rainfall, moisture deficiency, seed predation, aging trees, and competition from herbaceous cover are common contributors to poor regeneration in rangelands (Fay & Schultz, 2009). The highly degraded areas, particularly in Otjimbundu village, seedling and sapling densities were further suppressed by the invasive bush *Pechuel-loeschea leubnitziae,* which is linked to poor soil nutrients and high pH. In addition, overgrazing, soil compaction, and drought also hindered regeneration, mirroring findings from other degraded rangelands (Inman, 2020). Additionally, human activities like uncontrolled fires, overgrazing, and lopping can exacerbate regeneration challenges, creating an ecosystem vulnerable to climate shifts, pests, and diseases (Malik et al., 2016; Shiferaw et al., 2019).

Interestingly, the high degradation category in Otjamaungu village showed a fair regeneration capacity, with saplings recording the highest density. This may be due to degradation processes, such as soil erosion and overgrazing, which expose buried seeds and create favorable conditions for germination. However, mature trees often suffer from logging, and seedlings struggle to establish due to continuous nutrient loss (Amutenya, 2020).

5.3. Total basal area and herbaceous cover

In degraded areas, overgrazing, soil erosion, and poor soil conditions lead to sparse or absent herbaceous cover, reducing competition for resources such as water, nutrients, and sunlight. This allows the remaining large trees to dominate and increase the basal area (Mitchard et al., 2011; Abate et al., 2012; Peltzer & Köchy, 2001). Ecological succession in heavily degraded areas may also favor the growth of woody species over herbaceous plants post-disturbance (Horn, 1974). In contrast, in less degraded areas, abundant herbaceous cover, due to lower grazing pressure and higher soil organic carbon (SOC), fosters competition, potentially limiting the basal growth of woody species. Some studies suggest that woody plants may outcompete herbaceous vegetation due to their larger shoot mass and shading effect, which reduces light availability and affects herbaceous productivity and growth (Peltzer & Köchy, 2001).

Herbaceous cover was highest in the very low degradation category and significantly reduced in high and very high degradation areas. In Otjamaungu, herbaceous cover dropped from 65.31% in the very low degradation category to 5.14% in the very high degradation category. A similar pattern was observed in Otjimbundu, where herbaceous cover declined from 77% to 21.5%. This decline reflects the cumulative impact of soil compaction, overgrazing, and drought (Snyman, 2005).

The loss of herbaceous cover poses a significant challenge for pastoral communities reliant on grasslands for livestock grazing. Community members expressed concerns about reduced grazing areas and livestock malnutrition, aligning with scientific findings. These observations are consistent with studies by Oñate et al. (2014), which found that herbaceous cover in degraded rangelands decreases significantly due to persistent grazing pressure and poor rainfall.

5.4. Soil erosion and compaction

The results indicate that soil erosion and compaction increased with higher degradation categories. In highly degraded areas, infiltration rates were lower, revealing significant soil compaction. Local community observations aligned with these findings, describing degraded soils as hard, eroded, and nutrient-poor, consistent with studies by Shikangalah et al. (2017) and Buraka et al. (2024).

Soil erosion increased with degradation, with gullies expanding in degraded areas. Communities reported flooding during rainy seasons, which exacerbates soil loss and further depletes land productivity. The absence of vegetation cover in highly degraded areas contributed to the acceleration of erosion, as vegetation plays a crucial role in stabilizing soil and reducing runoff (Igwe et al., 2017; Vaezi & Sahandi, 2024).

Compaction was more pronounced in high and very high degradation areas, primarily due to continuous trampling by livestock and human activities. The frequently accessed areas near homesteads and kraals exhibited the highest compaction, leading to reduced pore spaces, restricted water infiltration, and impaired root growth (Nawaz et al., 2013; Saravi et al., 2005). Consequently, seedling emergence and vegetation regeneration were significantly hindered.

In moderate and high degradation areas, compaction was evident in stunted plant growth, particularly in species like *Colophospermum mopane*, which showed smaller and thinner trees compared to those in less degraded areas. Compacted soils can restrict root penetration, limiting access to water and nutrients, and ultimately reducing plant productivity (Getabalew & Alemeneth, 2019; Hu et al., 2021).

5.5. Soil properties

According to Dlamini et al. (2014), highly degraded soils tend to have reduced organic carbon or organic matter as a result of low vegetation cover that contributes to organic carbon. The reduction in organic carbon and organic matter affects soil fertility, structure, and its ability to sequester carbon, thereby exacerbating environmental challenges such as soil erosion, reduced agricultural productivity, and climate change.

The optimal pH range for most plants is 6-7, where most essential nutrients are easily accessible. At high pH, alkaline soils, nutrients become less available (Shifa, 2017). Species that are well adapted to harsh conditions usually dominate areas with high pH and this was observed in both villages, with high degraded categories dominated by

Pechuel-loechea leubnitzie and *Colophospermum mopane* that are well adapted to harsh conditions (Dlamini et al., 2014).

In addition, the high degraded categories recorded the highest clay soil content that may have contributed to poor plant growth. However, the CCA biplot illustrates that silt and clay have a more moderate influence on degradation categories. Clay-rich soils are prone to compaction, especially under heavy grazing or intensive agriculture, which reduces pore space and water infiltration (Osman, 2014). On the other hand, high levels of sand were recorded across all the degradation categories in both villages. According to Mnganga et al. (2011), rangelands, particularly in semi-arid regions, often have high sand content in the soil due to a combination of environmental, climatic, and soil formation factors. Physical weathering, such as wind or temperature prevails, producing coarser particles like sand. Silt was generally similar across degradation categories in both villages, ranging between 15 and 20%. According to Osman (2014) silt may not experience as drastic changes in its proportion in response to compaction or organic matter loss as clay or sand might. For example, while overgrazing or poor soil management may lead to more erosion of sand or changes in clay content, silt is often more stable within the soil texture and is not as significantly altered.

5.6. Documenting local traditional knowledge about the soil, plants, and fauna in relation to land degradation.

Across both villages, respondents overwhelmingly perceive land degradation through three main lenses: soil, flora, and fauna. For soils, local people described degraded land as unproductive or “poor in nutrients,” commonly associating decreased soil fertility with low rainfall and more frequent droughts. With respect to vegetation, the absence or withering of plants, especially key woody species and grasses, serves as an immediate sign of degradation. In terms of fauna, respondents focus on how diminished grazing areas adversely affect livestock and wildlife, sometimes leading to livestock mortality and forcing wild animals to migrate to better-resourced areas. The study reveals that local communities in Otjamaungu and Otjimbundu villages perceive land degradation primarily through changes in soil fertility, vegetation cover, and the health of livestock. The strongest perceived drivers include poor rainfall, overgrazing, and deforestation, aligning with observations reported in other semi-arid regions (e.g., Moleele & Perkins, 1998; Inman, 2020). The communities highlight a notable decline in woody species considered crucial for grazing, food, or medicinal uses, and widespread crop failures further underscore the severity of degradation impacts on local livelihoods. Communities feel the impacts of land degradation more through the loss of plants that provide food for them and their livestock. According to Stringer and Reed (2007), communities, especially in rangelands often attribute land degradation primarily to the loss of plants that provide them with essential resources and not necessary the overall being of the ecosystem. When these plants decline or disappear due to degradation, it directly impacts their food sources (for both people and livestock) and income. Cummings and Read (2016) stressed that when communities view plants primarily through the lens of essential services to their livelihoods**,** rather than as part of a broader ecosystem**,** it poses several negative environmental consequences. If communities prioritize plants that directly support livelihoods, they may neglect or disregard the importance of other plant species that contribute to overall biodiversity**.**

5.7. Perceptions and experiences of local communities regarding land degradation, including its causes and impacts on their livelihoods.

Communities in both villages have recognized the impacts of land degradation on their lands. The majority of the communities in both villages have experienced land degradation. Many respondents have observed these changes for over a decade, with some tracing them back to the early 2000 and more recently. During these years, the communities observed a significant reduction in rainfall, leading to devastating droughts. The livelihood impacts are severe, including livestock mortality, reduced availability of wild fruits, and a reliance on shop-bought foods. In addition, the diminishing pool of medicinal and shade-providing plant species compromises cultural traditions and community well-being. These changes highlight the vulnerability of local economies and ways of life when ecosystem services are depleted, echoing the well-documented link between land degradation and socio-economic challenges in semi-arid regions (Bogale et al., 2022; Yakob & Fekadu, 2016). They have highlighted the decline in vegetation cover as a key indicator of land degradation. According to Stocking and Murnahan (2000), plant loss is often one of the most visible signs of land degradation. It is more immediately noticeable to people, in contrast to other forms of degradation, such as soil compaction or changes in soil fertility, which may take longer to detect.

Apart from the general environmental changes, such as reduced vegetation growth and increasingly dry and hot climates, the communities have observed a drastic reduction in their livestock population, particularly cattle. Because livestock is integral to their culture, communities view land degradation through the lens of livestock loss, as it directly affects their livelihoods, cultural values, and food security, making livestock the central concern in the context of land degradation (Moyo et al., 2013; Tajikistan & Squires, 2012).

Respondents demonstrated detailed awareness of how climate and human activities interact to shape environmental conditions. Across both villages, they recognized how deforestation for shelter and fuel, along with grazing by large herds, reduces soil fertility and vegetation cover. Some respondents also highlighted the impacts of increasing population and settlement expansion. Importantly, local people noted the temporal dimension of these changes, tracing the onset of observable land degradation impacts to periods of especially poor rainfall (2007, 2012, 2017). This temporal awareness aligns with studies indicating that climatic shifts can trigger more rapid or more visible environmental deterioration in vulnerable semi-arid landscapes (Shikangalah & Mapani, 2020).

Both Otjamaungu and Otjimbundu villages practice seasonal grazing rotation, moving livestock between home and distant grazing grounds according to seasonal availability. This strategy aims to allow grass recovery and mitigate overgrazing, a management approach also seen in other pastoral communities across Africa. Another key practice is restricting the cutting of certain tree species considered crucial for fodder and medicinal uses, while permitting the harvesting of more abundant species like *Colophospermum mopane*. These interventions underscore the potential of community-based resource management, rooted in local traditions and ecological knowledge, to curb degradation. However, several residents pointed out inconsistent adherence, underscoring the challenges of collective action when herd sizes differ, enforcement is weak, or newer residents are unfamiliar with traditional rules. In addition, many are now being compelled to resort to crop farming despite having little experience. While some have started cultivating their fields and establishing gardens, they face challenges such as water scarcity, with even those living along the river struggling to access water due to the presence of crocodiles.

5.8. Comparison of how local and scientific knowledge complement each other in identifying and understanding land degradation patterns in Kunene region.

The communities' views on land degradation generally aligned with scientific data, particularly the perspectives of the communities on the least degraded areas, which showed high species richness, diversity, density, organic carbon, organic matter, and low soil erosion. These factors align with scientific findings that degradation increases as these aspects decline. (Dumbrell et al., 2008). In both villages, the moderate, high, and very high degradation categories matched the scientific perspective, with species diversity decreasing due to the reduction of woody plant species and herbaceous cover.

However, some differences emerged. For example, the communities' perception of the very low degradation category did not align with scientific findings. While scientific findings showed higher species diversity in the low degradation categories, communities perceived the very low degradation categories as the least degraded due to high species abundance. This suggests they prioritized tree abundance over species richness in assessing degradation. Many studies (e.g., Solomons et al., 2007; Abate et al., 2010; Seid et al., 2020) have shown that pastoralists, especially in rangelands, view land degradation based on the absence of plants grazed by livestock that they may at times, consider bush encroachment as a healthy ecosystem that benefits their livestock. Local communities often assess land health based on immediate benefits to their livelihoods, such as the availability of plants for grazing or medicinal use. In contrast, scientists see these areas as degraded due to the dominance of a few species, reducing ecological resilience. From a scientific standpoint, bush encroachment represents an increase in the density of woody plants at the expense of herbaceous vegetation, leading to ecosystem imbalances, even if it benefits livestock (Ayalew & Mulualem, 2018). Furthermore, communities often overlook slower, less visible signs of degradation, such as soil erosion and compaction. They tend to focus on the visible impacts, such as reduced pasture growth, while practices like grazing rotation may mask long-term soil degradation (Blaikie & Brookfield, 2015).

These differing perspectives on land degradation present challenges to addressing the issue effectively. Communities may not recognize or prioritize environmental problems until they see them as directly affecting their livelihoods. Bush encroachment, for instance, remains a problem in rangelands, where pastoralists, especially those herding goats, may not view it as an issue. Efforts to address land degradation, such as those in African rangelands, have often failed because they did not consider pastoralists' perceptions. There is often a lack of interaction between land users and researchers, leading to ineffective policies (Tokozwayo et al., 2018; Kiage, 2013).

Local communities, therefore, may focus more on short-term productivity and immediate challenges, such as food security and livestock health, rather than recognizing the cumulative impact of land degradation. This prompts critical questions: How can we address land degradation in rangelands where pastoralists may not immediately recognize the issue, or may take longer to notice it? How adaptable are pastoralists or land users in changing their practices to restore degraded lands? And for how long can their current practices support their livelihoods in the face of escalating land degradation and climate change?

6. CONCLUSIONS

The aim of this study was to assess the processes and manifestations of land degradation through participatory approach in selected villages in the Kunene region. The study sought to bridge the gap between scientific and local knowledge, emphasizing that local knowledge is often overlooked in environmental assessments. The findings revealed both similarities and differences between the two knowledge bases. The communities in both villages recognized land degradation as an increasing threat to their livelihoods, with vegetation loss and poor rainfall being identified as key indicators of land degradation. This perspective influenced how they categorized the severity of degradation. The study highlights clear patterns of land degradation in Otjamaungu and Otjimbundu villages, with severe impacts on species diversity, vegetation cover, soil properties, and local livelihoods. The findings confirm that degradation is most pronounced in high and very high degradation categories, where species richness and herbaceous cover decline significantly. Species diversity, richness, and density decreased along the degradation gradient, which generally aligned with scientific measures. Notably, the low degradation category exhibited the highest species diversity, contradicting community perceptions that associate degradation primarily with reduced woody vegetation. Additionally, aspects such as water infiltration rate and soil erosion volume were consistent with scientific perspectives.

Moreover, local perceptions of land degradation generally align with scientific observations, particularly regarding the effects of vegetation loss, soil fertility decline, and the negative impact on food security. However, few differences arise in how communities define degradation, often focusing on immediate livelihood concerns rather than long-term ecological changes. The discrepancy between scientific and local knowledge underscores the need for integrating both perspectives to develop more effective land management strategies that align with community priorities while ensuring ecological sustainability. Although the least degraded areas exhibited high species diversity and better soil quality, they are increasingly threatened by overgrazing and climate change. Should the situation persist, ongoing droughts will worsen the degradation of natural resources, putting the communities' livelihoods at even greater risk.

This study emphasizes the importance of incorporating local perspectives when addressing land degradation. Researchers, policymakers, and land restoration programs must collaborate with local communities to identify knowledge gaps and develop more effective solutions to tackle this urgent issue.

7. RECOMMENDATIONS

This study strongly recommends the use of participatory approach as an effective tool for understanding land degradation through the perspectives of the communities directly affected. This is because, communities may not perceive or interpret the effects of land degradation in the same way as conventional science.

The study further recommends that policy interventions should support locally led conservation efforts by integrating indigenous knowledge with scientific research. Government agencies and environmental organizations must collaborate with communities to develop adaptive land-use policies that consider both ecological and socio-economic factors. Incentive-based programs, such as payments for ecosystem services, could encourage sustainable land use while addressing economic vulnerabilities. Additionally, further research on climate-resilient rangeland management and alternative livelihoods will be essential to ensuring long-term sustainability in these semi-arid regions.

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9. Appendices

9.1. Table 9 and 10 showing descriptions of soil characteristics across all degradation categories in Otjamaungu and Otjimbundu villages:

Table 9: Descriptions of soil characteristics across all degradation categories in Otjamaungu village

Soil Property	Category	Mean	Min	Max	SE	Kruskal-Wallis P-Value
Clay	VL	8.244444	4.9	12.6	0.811396	0.6658680207
	L	7.533333	5.3	9.6	0.540062	
	M	9.388889	2.3	21.7	2.366282	
	H	10.28889	5.2	16.6	1.304527	
	VH	8.211111	4.7	15.4	1.071402	
Silt	VL	16.77778	12.4	26	1.316854	0.1225281067
	L	15.08889	5.8	28.7	2.659649	
	M	11.72222	2.6	17.7	1.944063	
	H	20.24444	5.6	37.1	3.645168	
	VH	19.44444	12.4	27.7	1.694526	
Sand	VL	74.97778	64.9	81.9	1.730027	0.3810367914
	L	77.38889	62.2	88.9	3.01977	
	M	78.9	60.6	94.9	4.146518	
	H	69.48889	51	89.3	4.706805	
	VH	72.33333	56.9	81.2	2.501055	
Nitrogen	VL	0.309222	0.227	0.425	0.017857	0.2426077109
	L	0.311889	0.223	0.407	0.02061	
	M	0.260778	0.137	0.369	0.028256	
	H	0.251556	0.135	0.451	0.031551	
	VH	0.264111	0.193	0.367	0.020773	
Organic Carbon (OC)	VL	0.778222	0.569	1.067	0.044858	0.2119025519
	L	0.807222	0.559	1.021	0.056813	

	M	0.654333	0.343	0.927	0.071045	
	H	0.630967	0.339	1.132	0.079234	
	VH	0.692856	0.484	1.18	0.074115	
Electrical Conductivity (EC)	VL	3.757778	2.48	10.78	0.890822	**0.0023324300**
	L	8.075556	2.99	14.17	1.524884	
	M	9.927778	4.09	23.6	1.881734	
	H	46.06667	4.56	189.4	24.8326	
	VH	21.78667	7.91	110.7	11.15852	
pH	VL	8.311111	7.68	8.9	0.127175	**0.0006413541**
	L	8.093333	7.71	8.57	0.083832	
	M	8.661111	8.26	9.18	0.090852	
	H	8.477778	7.96	8.85	0.098245	
	VH	8.753333	8.6	9.08	0.047258	

Table 10: Descriptions of soil characteristics across all degradation categories in Otjimbundu village

Soil Property	**Category**	**Mean**	**Min**	**Max**	**SE**	**Kruskal-Wallis P-Value**
Clay	VL	16.39889	9.6	26.4	1.898735	**0.0000102174**
	L	14.06667	10.1	18.9	0.986999	
	M	12.47778	8.9	14.4	0.665369	
	H	8	5.4	11.5	0.678642	
	VH	7.344444	2.7	10.5	0.883665	
Silt	VL	22.04444	19.7	24.3	0.608758	**0.0482786007**
	L	22.24444	16.8	25.3	0.883036	
	M	19.05556	16	25.8	1.072265	
	H	20.95556	17	29	1.159515	
	VH	16.33333	6.1	25.4	2.181233	
Sand	VL	61.56667	51.9	70.4	1.866146	**0.0001203302**
	L	63.68889	58.6	69.9	1.369554	
	M	68.48889	59.8	73.7	1.325544	
	H	71.01111	59.4	77.5	1.737531	

	VH	76.3	64.1	91.1	2.925558	
Nitrogen	VL	0.216667	0.175	0.257	0.008038	0.4131894129
	L	0.226222	0.163	0.262	0.009724	
	M	0.196333	0.124	0.241	0.011645	
	H	0.238111	0.087	0.489	0.039978	
	VH	0.216222	0.135	0.38	0.02359	
Organic Carbon (OC)	VL	0.944889	0.763	1.119	0.034759	**0.0002823396**
	L	0.987667	0.71	1.144	0.042631	
	M	0.856111	0.541	1.052	0.05082	
	H	0.676556	0.381	1.226	0.086128	
	VH	0.542556	0.339	0.954	0.059267	
Electrical Conductivity (EC)	VL	7.188889	2.35	10.39	0.942343	0.6784261705
	L	6.767778	2.25	11.32	0.94849	
	M	9.665556	2.34	19.6	1.622335	
	H	7.906667	4.88	10.9	0.632231	
	VH	77.98333	3.56	401	48.47411	
pH	VL	8.122222	7.45	8.67	0.134276	**0.0004523444**
	L	7.944444	7.48	8.39	0.107524	
	M	8.152222	7.68	8.46	0.081731	
	H	8.454444	7.76	8.86	0.120889	
	VH	8.78	8.41	9.46	0.140208	

9.2. Ethical clearance

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ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0203 **Date: 18 APRIL 2024**

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

Title of Project:	ASSESSING LAND DEGRADATION THROUGH PARTICIPATORY MAPPING IN SELECTED VILLAGES OF THE KUNENE REGION, NAMIBIA: BRIDGING SCIENTIFIC AND LOCAL KNOWLEDGE BASES
Student:	NDAPANDA HASHOLO
Student Number:	218201890
Supervisor(s):	DR. EMILIA INMAN

Centre for Research Services

Take note of the following:

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

i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

EKwembeya

Prof. Ezekeil Gwinyai Kwembeya (Chairperson Ethics Committee)

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)