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Spatial Patterns and Human Settlement Environmental Impacts of Land Degradation in Khubetsoana, Maseru, Lesotho

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ABSTRACT

Land degradation is a serious environmental problem affecting both developing and developed countries, with major effects on ecosystems and human well-being. In Lesotho, the problem is increasing in urban and peri-urban areas because of rapid population growth, weak land management and unplanned settlements. This research focuses on Khubetsoana in Maseru to examine the spatial patterns and socio-environmental effects of land degradation. The study is important because it improves understanding of local environmental challenges while reflecting global concerns about sustainable land use and urban development. A mixed-methods approach was applied by combining household surveys, interviews, field observations and basic spatial analysis. A total of 120 households were selected using stratified random sampling. Interviews gathered detailed information on land use practices, waste management and residents' experiences of environmental change. Field observations were conducted to identify visible signs of degradation, including soil erosion, vegetation loss and waste accumulation in different parts of the study area. These methods improved the reliability of findings through triangulation. Data were analysed using descriptive statistics and thematic analysis. Results show that land degradation is more severe in densely populated and poorly serviced areas. Contributing factors include poverty, low environmental awareness and weak urban planning. The study concludes that stronger land management policies, better infrastructure and increased community awareness are necessary to reduce environmental pressure and promote sustainable urban development. The

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findings also highlight the need for cooperation between government institutions, local communities and environmental organizations in protecting urban land resources for future generations.

Keywords: Spatial Distribution; Urban Environment; Khubetsoana; Sustainability; Land Degradation and Soil Erosion

1. Introduction

Land degradation is a serious ecological concern that affects the condition, productivity and sustainability of land resources [1]. It occurs when land loses its ecological, economic and social value because of both human activities and natural environmental processes. Land degradation includes soil erosion, vegetation decline, pollution, surface instability and the reduction of ecosystem services that support human livelihoods [2]. Globally, the problem has become one of the most pressing environmental challenges because it threatens food security, biodiversity conservation, water resources and sustainable urban development. Developing countries are particularly vulnerable because of limited financial resources, weak planning systems and rapid population growth [3]. In many urban areas, land degradation is closely connected to unplanned settlement expansion, poverty and inadequate environmental governance. Environmental governance refers to the systems, institutions and policies used to manage natural resources and guide sustainable land use. Where governance structures are weak, environmental problems often increase because regulations are poorly enforced and land use planning becomes ineffective [4].

Recent global studies on sustainable urban development argue that land degradation should not only be viewed as a physical environmental problem, but also as an issue of environmental justice and intergenerational equity [5]. Intergenerational equity refers to the responsibility of the present generation to manage land resources in ways that protect the needs and opportunities of future generations. This perspective is important in rapidly urbanizing areas where environmental damage accumulates over time and limits future development opportunities. The increasing expansion of informal settlements in developing countries demonstrates how unequal access to land, poor governance and socioeconomic inequality combine to create environmentally vulnerable communities. These issues are especially visible in Sub-Saharan African cities, where rapid urban growth often occurs faster than the development of infrastructure and planning systems [6].

In Lesotho, land degradation has historically been associated with rural areas because of overgrazing, soil erosion and unsustainable farming practices. However, urban and peri-urban areas are increasingly experiencing similar environmental pressures due to rapid urbanization and changing land use patterns. Maseru, the capital city of Lesotho, has experienced significant population growth over the past decades because of rural-to-urban migration, economic centralization and natural population increase [7]. This growth has created pressure on land resources, infrastructure and environmental management systems. Informal settlements continue to expand into environmentally sensitive areas such as steep slopes, riverbanks and poorly serviced land. As a result, land degradation has become a visible environmental and social challenge within urban communities.

Land tenure systems in Lesotho also contribute significantly to urban land degradation. Historically, land in Lesotho has been administered through a combination of customary and statutory systems. Chiefs traditionally allocated land under customary tenure arrangements, while modern urban administration introduced formal planning regulations and leasehold systems. However, the coexistence of these systems has often created conflicts, overlapping authority and weak enforcement of planning regulations. In peri-urban areas of Maseru, rapid population growth and informal settlement expansion have outpaced formal land administration systems. This has resulted in insecure land tenure, uncontrolled land subdivision and settlement development in environmentally unsuitable areas. Many planning interventions have failed because they did not adequately address the social realities of informal land access and the economic pressures facing low-income households. Understanding these historical and policy-related origins of land use patterns is essential for interpreting current spatial patterns of land degradation in Khubetsoana.

Urban political ecology provides an important theoretical framework for understanding why informal settlements are disproportionately affected by environmental degradation. Urban political ecology argues that environmental prob-

lems are shaped by political, economic and social power relations rather than natural processes alone [8]. According to this perspective, unequal access to land, infrastructure and environmental services creates uneven environmental conditions within cities. Informal settlements often receive limited investment in drainage systems, waste management and road infrastructure because of weak political representation and insecure land tenure arrangements. In Maseru, many peri-urban settlements developed outside formal planning systems, resulting in fragmented infrastructure provision and limited environmental regulation. Consequently, environmentally hazardous conditions become concentrated in poorer communities while wealthier areas benefit from better services and environmental protection.

The transition from the global problem of urban land degradation to the local context of Khubetsoana is important because it demonstrates how worldwide urbanization pressures are reproduced within smaller developing urban centres. Khubetsoana was selected as the study area because it represents a rapidly expanding peri-urban settlement characterized by high population density, informal housing development, inadequate infrastructure and increasing environmental stress. The area also reflects many of the common characteristics of lower-middle-income developing urban settlements in Sub-Saharan Africa, including unemployment, poverty, weak land administration and unequal access to public services [9]. Khubetsoana therefore provides an appropriate case study for understanding how urban expansion intersects with environmental stability in developing countries. Its location near the urban core of Maseru and its rapid settlement growth make it an important example of how environmental pressure emerges in peri-urban spaces undergoing urban transition.

Khubetsoana is one of the densely populated settlements where land is under constant pressure due to both anthropogenic and natural processes. Anthropogenic stressors include unplanned settlement expansion, waste accumulation, vegetation clearance, poor drainage systems and uncontrolled construction activities. These human-induced pressures accelerate land degradation by destabilizing soils, reducing vegetation cover and increasing surface runoff [10]. At the same time, natural or geogenic processes such as heavy rainfall, slope instability and natural soil susceptibility to erosion also contribute to environmental degradation. Differentiating between these natural and human-induced drivers is important because environmental management strategies must address both ecological vulnerability and unsustainable human activities. In Khubetsoana, anthropogenic pressures tend to intensify naturally occurring environmental processes, resulting in more severe degradation patterns.

The lack of proper planning and infrastructure has contributed to environmental problems such as soil erosion, waste accumulation and vegetation loss. These problems not only damage the physical environment but also affect the social and economic conditions of residents. Many people in Khubetsoana depend on land for shelter, informal trade and small-scale economic activities. This means that environmental degradation directly affects livelihoods, health conditions and daily survival strategies. Poor environmental conditions increase exposure to flooding, pollution and disease outbreaks, particularly among low-income households.

The relationship between socio-economic vulnerability and physical land degradation is more complex than simple correlation. Poor households often occupy environmentally fragile areas because safer and serviced land is economically inaccessible. Limited income reduces the ability of residents to invest in durable housing, proper waste disposal or soil protection measures. As a result, environmentally vulnerable populations become trapped in a cycle where poverty increases environmental degradation while degraded environments further reinforce poverty and social inequality [11]. In Khubetsoana, households living near eroded slopes, blocked drainage channels and waste disposal areas experience higher exposure to flooding, infrastructure damage and health risks. This demonstrates how environmental degradation disproportionately affects socially and economically marginalized communities.

The intersection between urban expansion and environmental stability requires both technical and socio-political analysis. Urban expansion in Khubetsoana has increased impermeable surfaces, reduced vegetation cover and intensified pressure on drainage systems. These processes contribute to runoff concentration, flooding and accelerated erosion [12]. Environmental stability is weakened when urban growth occurs without proper infrastructure planning, environmental regulation or land suitability assessment. Through spatial analysis, the study evaluates how settlement density, slope conditions, waste accumulation and infrastructure distribution interact

to influence environmental vulnerability. This integrated approach improves understanding of how urban growth patterns affect ecological sustainability in peri-urban settlements.

The main objective of this study is to examine the spatial patterns of land degradation in Khubetsoana and evaluate its socio-environmental effects. Spatial patterns refer to the geographical distribution and concentration of degraded areas across the settlement. The study demonstrates these spatial patterns through cartographic representation (**Figure 1**), including the mapping of erosion hotspots, waste accumulation zones, vegetation loss areas, and densely populated vulnerable zones. Remote sensing data and quantitative spatial measurements provided supporting evidence by identifying the extent and distribution of degraded land, vegetation loss, settlement density, and environmental risk zones across the study area. Cartographic analysis allows the study to identify environmental risk clusters and spatial inequalities within the settlement[13]. This spatial perspective strengthens the analytical depth of the research by showing how environmental degradation is unevenly distributed across urban space.

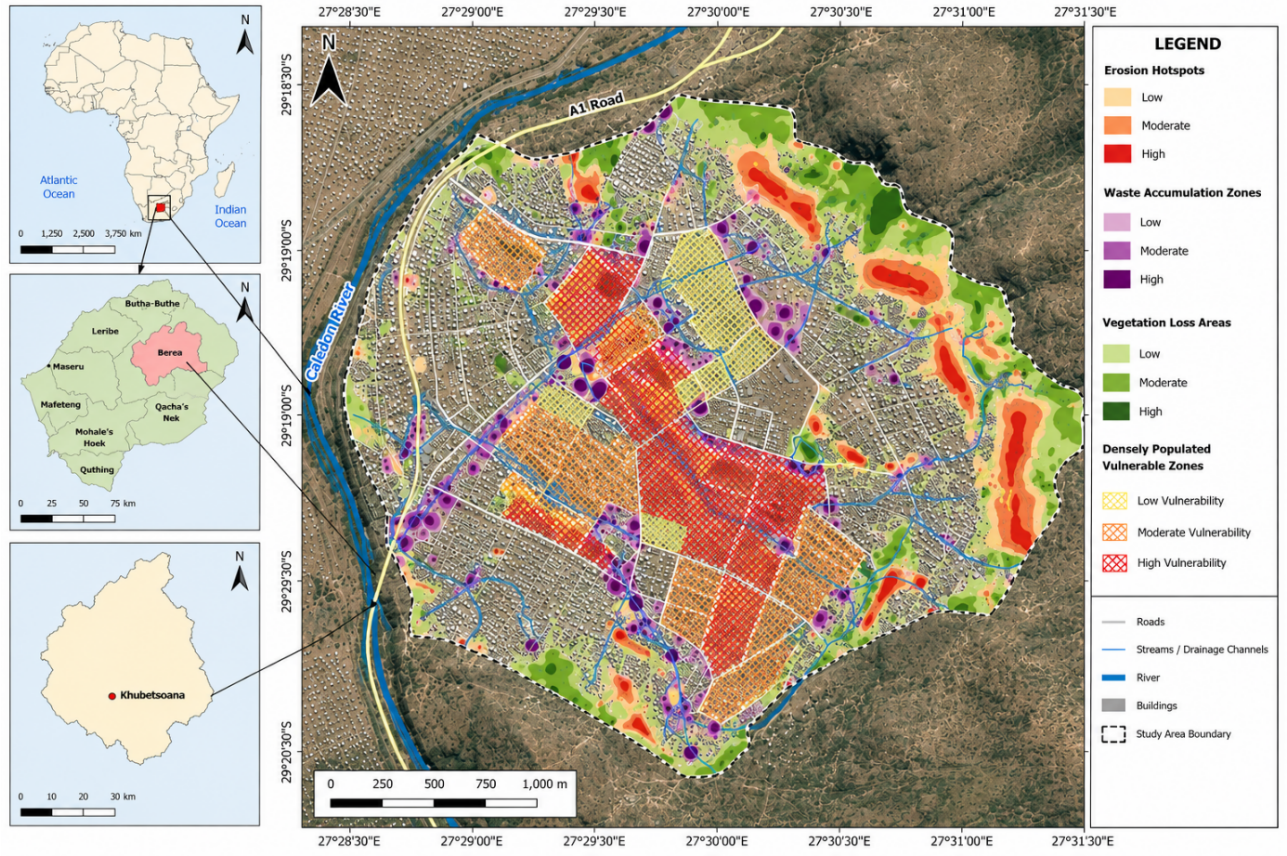

Figure 1. Spatial Distribution of Land Degradation in Khubetsoana, Berea District.

This study also addresses important research gaps. Although land degradation has been widely studied in Lesotho, most research has concentrated on rural agricultural landscapes rather than urban settlements. Existing studies in Lesotho commonly focus on rangeland degradation, overgrazing and rural soil erosion, while urban environmental degradation remains insufficiently explored. Similarly, studies from Sub-Saharan African cities such as Nairobi, Lusaka and Johannesburg demonstrate that rapid urbanization often leads to increased environmental vulnerability in informal settlements because of poor infrastructure and weak planning systems. These studies provide useful regional comparisons for understanding environmental pressures in Khubetsoana. However, there remains limited localized research examining how spatial patterns of urban land degradation interact with socio-economic vulnerability in smaller peri-urban settlements of Lesotho.

Khubetsoana serves as a representative case study be-

cause it reflects broader environmental and urbanization challenges experienced across peri-urban settlements in Lesotho. The area exhibits rapid population growth, limited waste management services, insecure land tenure, expanding informal housing and increasing environmental instability[14]. By focusing on Khubetsoana, the study provides baseline information that can support future comparative studies and urban environmental management strategies in other settlements facing similar challenges.

2. Materials and Methods

2.1. Literature Review

Land degradation is widely recognized as a major environmental problem because of its effects on ecosystems, livelihoods and urban sustainability. It refers to the reduction in land quality caused by both natural and human-induced processes[15]. In urban areas, land degradation is increasingly associated with rapid urban expansion, informal settlements, poor environmental governance and weak infrastructure development. Globally, studies show that soil erosion is one of the most widespread forms of land degradation. It removes nutrient-rich topsoil and reduces land productivity. In urban areas, erosion is often intensified by poor drainage systems, settlement construction and vegetation removal. Waste pollution further contributes to environmental decline by contaminating water sources and reducing environmental quality[16]. Climate variability also increases the vulnerability of degraded urban landscapes through extreme rainfall events and flooding.

The literature identifies four major pathways through which urban land degradation occurs. The first pathway is physical land disturbance caused by construction activities, settlement expansion and vegetation clearance. These activities expose soil surfaces and increase susceptibility to erosion and runoff[17]. The second pathway is waste-related degradation, which includes illegal dumping, poor sanitation and drainage blockage. Waste accumulation contaminates land and water resources while increasing flood risks[18]. The third pathway involves hydrological alteration caused by impermeable surfaces such as roads and buildings. Urban expansion changes natural drainage patterns and increases surface runoff, contributing to flooding and soil instability[19]. The fourth pathway is socio-economic pressure, where poverty, unemployment and insecure land tenure force vulnerable households to occupy environmentally fragile areas and adopt unsustainable land use practices.

The socio-environmental consequences of urban land degradation can also be grouped into several categories. First are ecological consequences, including vegetation loss, soil instability, biodiversity decline and reduced ecosystem services. Second are public health consequences resulting from pollution, poor sanitation and increased disease exposure. Third are socio-economic consequences such as property damage, reduced livelihood opportunities and increased household vulnerability. Fourth are governance-related consequences, where environmental degradation creates conflicts over land use, increases pressure on urban services and weakens sustainable planning efforts. These categories provide a clearer framework for understanding how environmental degradation affects both urban ecosystems and human well-being.

Research from Sub-Saharan Africa demonstrates that informal settlements are especially vulnerable to environmental degradation because they often develop in ecologically sensitive areas without proper infrastructure or environmental planning. For example, studies in Nairobi's informal settlements show that poor drainage and uncontrolled waste disposal increase flood risks and environmental health problems[20]. Similar findings from Lusaka and Johannesburg indicate that rapid urban growth, poverty and inadequate governance contribute to severe environmental instability in peri-urban communities. These studies provide direct empirical comparisons relevant to Khubetsoana because they illustrate how urban land degradation disproportionately affects marginalized urban populations in developing African contexts.

Urban political ecology theory provides a useful framework for understanding these issues because it explains how environmental conditions are shaped by unequal social and political relationships. The theory argues that environmental degradation is not distributed evenly but is influenced by access to power, services and resources[21]. Informal settlements often receive fewer public investments in infrastructure, drainage systems and environmental protection, increasing their exposure to environmental risks.

In Lesotho, most studies on land degradation focus on rural areas and agricultural systems. However, urban settlements increasingly experience environmental challenges associated with rapid urbanization. Available baseline data

indicate that Maseru has experienced continued peri-urban growth characterized by informal settlement expansion, inadequate infrastructure provision and increased pressure on land resources[22]. Despite this trend, there remains limited spatially focused research examining how urban land degradation affects socio-economic conditions within peri-urban settlements. This gap is particularly significant because peri-urban communities often experience the combined pressures of environmental vulnerability, weak governance and insecure land tenure.

Despite growing literature on urban environmental degradation, several gaps remain. There is still limited research integrating cartographic spatial analysis with socio-economic vulnerability assessment in smaller peri-urban settlements of Lesotho. Many studies focus either on physical environmental processes or social conditions separately without adequately connecting the two dimensions. This study contributes to existing knowledge by linking spatial patterns of land degradation with socio-environmental impacts in Khubetsoana. The study therefore strengthens understanding of how urban expansion, governance challenges and socio-economic inequality interact to influence environmental stability in peri-urban settlements.

2.2. Methodology

2.2.1. Study Area

Khubetsoana is an urban settlement located in Maseru, the capital city of Lesotho. It is situated at approximately latitude 29.31° South and longitude 27.48° East (**Figure 2**). The settlement developed as part of the broader urban expansion of Maseru and is surrounded by other rapidly growing urban fringe communities. Over time, Khubetsoana has experienced a transition from sparsely populated land into a densely built environment, characterized by a mixture of formal housing and expanding informal settlements. This spatial transformation revealed increased built-up land cover, reduced vegetation cover and higher settlement density associated with rapid urban growth. This spatial transformation reflects the broader pattern of unplanned urban growth in Maseru, where population pressure has outpaced infrastructure development.

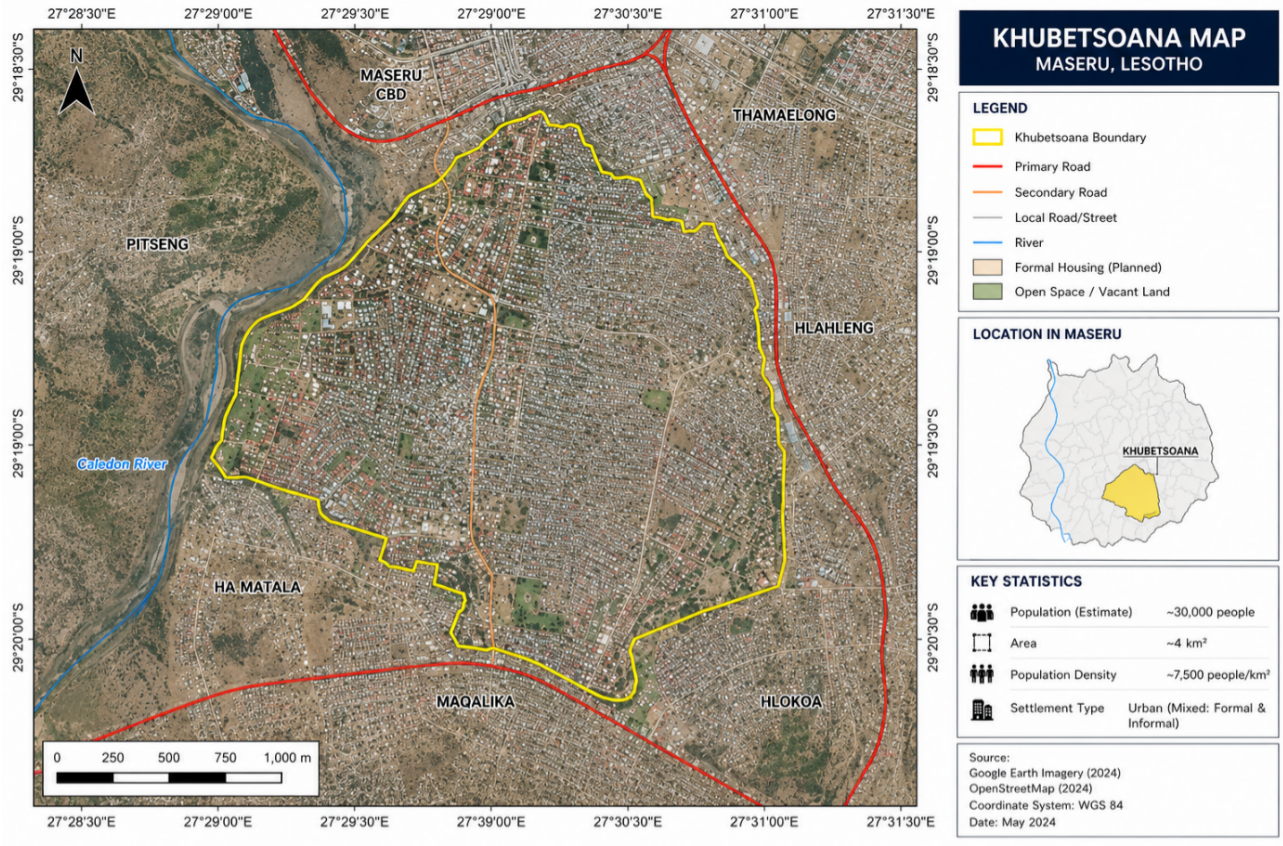

Figure 2. Location Map of Khubetsoana Settlement in Maseru, Lesotho.

The population of Khubetsoana is estimated at around 30,000 people, occupying an area of approximately 4 km^2. This high population density places continuous pressure on available land and essential services. As a result, the area experiences increasing demand for housing, water supply, sanitation services and waste management systems. However, infrastructure development has not expanded at the same rate as population growth. This imbalance has contributed to recurring environmental challenges such as overcrowding, inadequate drainage systems and inefficient waste disposal practices. These conditions collectively create a physically and socially vulnerable environment where land degradation processes can easily develop and intensify.

Within this context, Khubetsoana exhibits clear and observable signs of land degradation. These include active soil erosion on sloping surfaces, exposed soil patches, vegetation loss and the accumulation of solid waste in open spaces, road edges and drainage channels. Such environmental conditions not only reduce land quality but also increase risks to public health and safety through flooding, contamination and habitat deterioration. The persistence of these issues is partly linked to weak land management practices, limited enforcement of environmental regulations and insufficient investment in land restoration initiatives. In addition, low environmental awareness and constrained municipal capacity have further slowed effective intervention. These factors make Khubetsoana a relevant case for examining urban land degradation processes and identifying potential management responses.

The evolution of environmental challenges in Khubetsoana cannot be understood in isolation from broader governance and regional development dynamics. The area reflects local governance limitations, including weak enforcement of environmental by-laws, inadequate waste management services and limited urban planning capacity. These constraints are not unique to Khubetsoana but are consistent with wider trends observed across rapidly urbanizing settlements in Southern Africa[23]. In many such contexts, informal settlement growth, poverty and infrastructure deficits combine to intensify land degradation and environmental vulnerability. By situating Khubetsoana within this regional trajectory, the study highlights how local environmental conditions are shaped by both internal settlement dynamics and broader structural governance challenges affecting urban sustainability in developing regions.

2.2.2. Sampling Methods

The study adopted a mixed-methods research design that combined quantitative household surveys, qualitative interviews, field observations and spatial analysis. This approach was selected to ensure that both measurable environmental patterns and lived community experiences were captured in a single integrated framework. A stratified random sampling framework was then applied to improve representativeness and statistical reliability, ensuring that different environmental and socio-economic conditions within Khubetsoana were adequately captured.

The sampling process began with the division of the study area into four distinct strata based on settlement density, housing type, drainage conditions and visible levels of environmental degradation. These strata included high-density informal settlements, medium-density mixed settlements, planned residential areas and environmentally sensitive zones located near drainage channels and steep slopes. This stratification was necessary because Khubetsoana is not environmentally uniform, and land degradation patterns vary significantly across space. The sampling frame was developed using local administrative records and field mapping to identify all identifiable households within each stratum.

Once the strata were defined, proportional allocation was used to distribute the sample according to the relative size and population density of each stratum[24]. The final sample consisted of 40 households from high-density informal settlements, 30 households from medium-density mixed settlements, 25 households from planned residential areas and 25 households from environmentally sensitive zones. This proportional distribution ensured that no single settlement type was overrepresented, while still capturing the diversity of environmental conditions across the study area.

After allocation, households were randomly selected within each stratum. This random selection process reduced selection bias and improved the representativeness of the sample. It also ensured that households had an equal chance of being included within their respective zones, thereby strengthening the validity of comparisons across different environmental settings.

A total of 120 households were included in the study. This sample size was statistically justified based on population estimation principles. With an estimated population of approximately 30,000 people and an average household

size of five members, Khubetsoana was estimated to contain about 6,000 households. Using a 95% confidence level and a margin of error of approximately 9%, a sample of 120 households was considered sufficient to detect key environmental trends while remaining practical within available time and resource constraints. This sample size also allowed for meaningful spatial and socio-economic comparisons across different parts of the settlement.

Finally, the mixed-methods approach strengthened the overall analytical depth of the study by integrating quantitative and qualitative evidence. Quantitative data provided structured and measurable indicators of environmental degradation, while qualitative data explained the underlying social and governance dynamics influencing these patterns. The combination of these methods improved the reliability, validity and interpretative strength of the findings, allowing for a more comprehensive understanding of land degradation processes in Khubetsoana [25].

2.2.3. Population Study

The demographic size of Khubetsoana is an important factor in understanding the extent of environmental degradation in the area. Located within Maseru, Khubetsoana has an estimated population of about 30,000 inhabitants. This relatively large number of people living within a limited space places considerable pressure on land and other environmental resources. As population density increases, demand for housing, infrastructure and basic services also rises, often exceeding the capacity of existing systems. This imbalance contributes directly to environmental challenges such as soil erosion, waste accumulation and the degradation of natural surfaces [26].

Within this context, the study adopted households as the main unit of analysis rather than individuals. This decision was made because households represent the primary decision-making unit in relation to land use practices, including waste disposal, housing construction and local environmental management. Using households therefore provided a more accurate and practical understanding of how human activities interact with land resources on a daily basis. It also allowed the study to capture environmental behaviour patterns in a structured and comparable way across different parts of Khubetsoana.

Focusing on households also improved the efficiency and consistency of data collection. It enabled the researcher to gather uniform information from each selected unit and to compare results across spatially different zones within the settlement. This approach is widely used in social and environmental studies because it links household-level decisions to broader environmental outcomes, thereby strengthening the explanatory power of the findings [27]. A clear understanding of the demographic structure of Khubetsoana is therefore essential for explaining both the causes and impacts of land degradation. It also provides a foundation for designing targeted environmental and social interventions that respond to local conditions.

To further describe the surveyed population, basic descriptive statistics were generated from the 120 sampled households. The gender distribution showed that approximately 55% of households were female-headed, while 45% were male-headed. In terms of age distribution, the majority of respondents (48%) were between 30 and 49 years old, followed by 27% aged 18 to 29 years, 19% aged 50 to 64 years, and 6% aged above 65 years. Educational attainment varied across the settlement, with 18% of respondents having primary education, 52% secondary education and 30% possessing tertiary or vocational qualifications.

The employment structure revealed that unemployment and informal employment were dominant within the study area. Approximately 38% of respondents were unemployed, 29% engaged in informal trading or casual labour, 21% were formally employed, and 12% operated small businesses. Household income levels were generally low, with nearly half of respondents earning below the national urban average income level. These demographic characteristics are important because they directly influence household vulnerability, land-use decisions and the capacity of residents to engage in environmental management practices.

2.2.4. Data Collection Methods

Data for this study were collected using a combination of household surveys, interviews, field observations and basic spatial analysis. These methods were selected in a sequential and complementary manner to ensure that both quantitative and qualitative dimensions of land degradation were adequately captured. The mixed-methods design allowed the study to build a comprehensive understanding of environmental conditions in Khubetsoana by integrating numerical data, lived experiences and spatial evidence.

The data collection process began with household sur-

veys, which were used to gather structured quantitative data from 120 selected households. The questionnaires included both closed and open-ended questions focusing on land use practices, waste management behaviours and perceived environmental conditions. This approach enabled the collection of standardized responses that could be statistically analysed while still allowing limited qualitative insights from respondents.

Following the surveys, semi-structured interviews were conducted to obtain more detailed qualitative information [28]. These interviews allowed respondents to explain their experiences, perceptions and observations in their own words. Key informant discussions were also included to provide deeper insights into environmental governance challenges and community-level land management practices. This stage helped to capture contextual information that could not be fully obtained through structured questionnaires alone.

Before the main data collection phase, a pilot study involving 10 households was conducted. The purpose of the pilot study was to test the clarity, relevance and structure of the survey and interview instruments. Feedback from participants revealed that several questions were too technical and difficult to understand. As a result, environmental management questions were simplified, repetitive items were removed and additional response options were added, particularly for waste disposal practices and perceptions of local governance. The pilot study also highlighted the need for practical examples when discussing land degradation concepts, which were subsequently incorporated into the final data collection tools. The actual fieldwork was conducted over a period of one month, allowing sufficient time for systematic data collection across all selected households.

In addition to survey and interview data, field observations were carried out to directly assess physical environmental conditions across Khubetsoana. These observations included identifying signs of soil erosion, vegetation loss, waste accumulation and general land-use patterns. Field observations played an important role in validating household responses by providing direct visual confirmation of reported environmental conditions.

Spatial analysis was then conducted using Geographic Information Systems (GIS), specifically ArcGIS and Quantum Geographic Information System (QGIS). Global Positioning System (GPS) coordinates collected during fieldwork were used to map key environmental degradation features, including erosion hotspots, illegal dumping sites and areas of vegetation loss. Several spatial indicators were calculated, including land-use intensity, vegetation cover loss, drainage density, proximity to waste sites and slope-related erosion susceptibility. Analytical techniques such as kernel density mapping, hotspot analysis and spatial overlay analysis were used to identify areas of concentrated environmental stress and to examine relationships between settlement density, infrastructure distribution and degradation patterns.

To ensure methodological coherence, a structured triangulation process was applied during analysis [29]. Instead of analysing each dataset separately, findings from surveys, interviews, field observations and spatial analysis were systematically compared. Quantitative results were first summarized statistically, followed by comparison with qualitative themes to identify consistencies and contradictions. These findings were then cross-checked against spatial outputs and field observations to confirm whether reported conditions aligned with observed environmental patterns. This integrated approach strengthened the reliability and validity of the study by ensuring that conclusions were supported by multiple independent sources of evidence.

Finally, a step-by-step data integration process was used to ensure transparency and reproducibility. Quantitative survey data were coded and entered into spreadsheets for statistical analysis. Interview transcripts were transcribed and organized into thematic categories. Field observation notes and GPS coordinates were digitized into GIS software for spatial mapping, as shown in **Figure 3**. This figure identifies erosion hotspots, vegetation loss areas, exposed surfaces and waste accumulation zones across Khubetsoana. These datasets were then systematically compared to identify recurring patterns related to land degradation and governance challenges. The final stage involved integrating all datasets to produce a unified interpretation of environmental degradation processes in Khubetsoana, thereby enhancing the analytical depth and scientific robustness of the study.

2.2.5. Data Analysis and Methodological Transparency

Data analysis in this study was carried out using Microsoft Excel (version 2019) as the primary tool for organizing and analysing quantitative data. This software was selected because it allows efficient data entry, cleaning and

basic statistical computation in a structured format. After data collection, quantitative responses from household surveys and structured interview sections were systematically coded and entered into spreadsheets for analysis. Descriptive statistics, including frequencies and percentages, were then generated to summarize key variables and identify broad patterns in land degradation across Khubetsoana [30]. These results were presented using tables and charts, which facilitated comparison between different environmental and socio-economic categories.

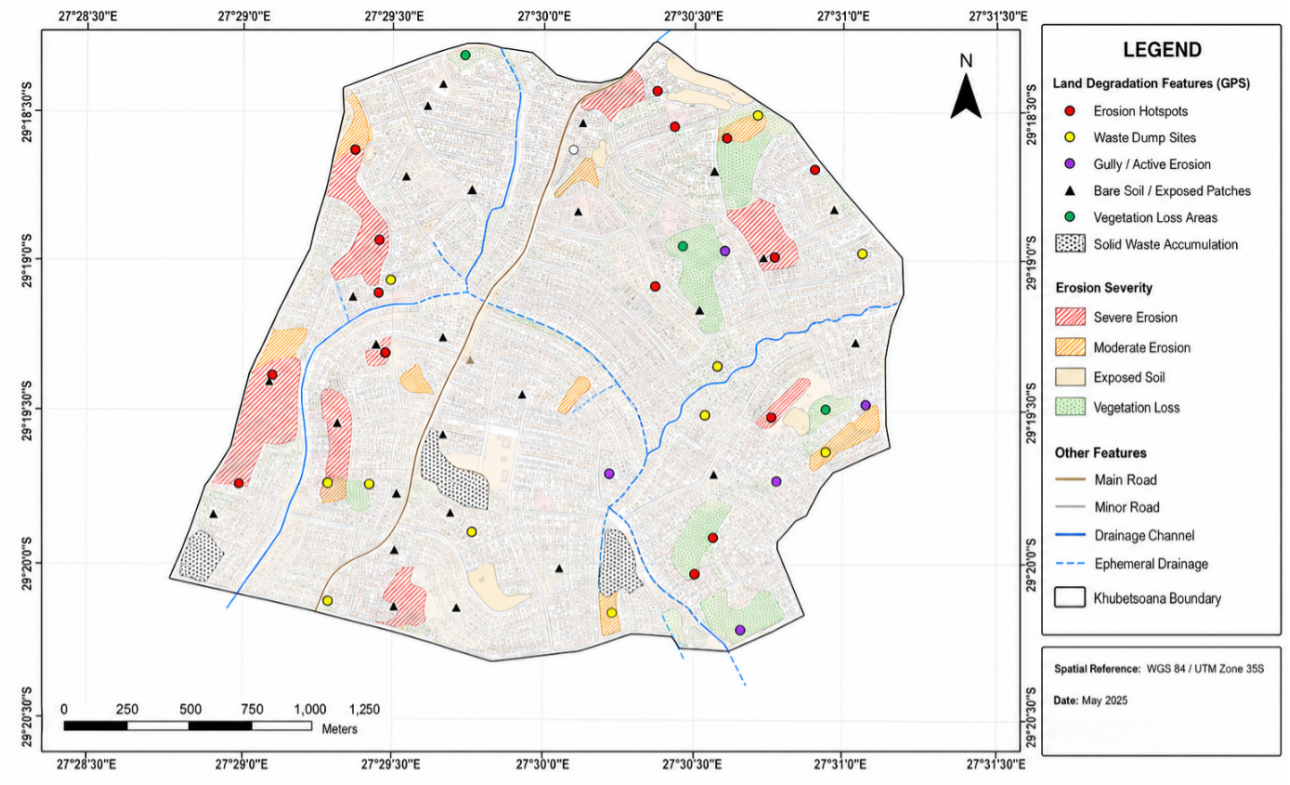

Figure 3. GIS-Based Map of Land Degradation in Khubetsoana, Maseru.

Once the quantitative analysis was completed, qualitative data from interviews and field observations were analysed using thematic analysis. This process involved systematically reviewing transcripts and observation notes to identify recurring ideas, perceptions and experiences related to land degradation. Similar responses were grouped into categories and then refined into broader themes that explained key environmental issues such as waste accumulation, governance challenges and land-use practices. This sequential approach ensured that qualitative insights complemented and explained the statistical trends observed in the quantitative dataset.

To strengthen the reliability and consistency of the findings, methodological transparency was maintained throughout the analytical process. All steps of data handling, coding and interpretation were documented in detail to ensure traceability. Reliability was enhanced by applying consistent procedures during data collection and analysis, including the use of the same interview guide across all participants. Validity was further strengthened through triangulation, where survey results, interview findings and field observations were systematically compared to confirm consistency and reduce analytical bias [31]. This process ensured that findings were not based on a single source of evidence but were supported by multiple datasets.

To improve scientific rigor and reproducibility, Geographic Information Systems (GIS) were integrated into the analytical framework to support spatial analysis. Spatial datasets collected during fieldwork were processed and analyzed to generate maps illustrating patterns of environmental degradation across Khubetsoana. Raster and vector layers were developed to represent key environmental variables, including settlement density, erosion-prone zones, waste ac-

cumulation areas, and vegetation cover conditions (**Figure 4**). The GIS analysis was further supported by remote sensing data and quantitative measurements, including vegetation cover indices, settlement density patterns, slope gradients, erosion-prone zones, and proximity analysis, providing objective evidence of environmental degradation across the study area. **Figure 4** presents the GIS-based spatial analysis of environmental degradation in the study area. The map integrates multiple spatial datasets to visualize the distribution and interaction of environmental and human-induced factors contributing to degradation. In addition to the mapped variables, spatial techniques such as slope classification and proximity analysis were applied to examine the relationships between topography, settlement patterns, and the intensity of environmental degradation. The results reveal areas that are particularly vulnerable to degradation due to steep slopes, high settlement concentrations, and close proximity to erosion-prone zones. By combining these spatial indicators, the analysis provides a more objective and comprehensive understanding of environmental degradation patterns across Khubetsoana, thereby strengthening the interpretation of field-based observations.

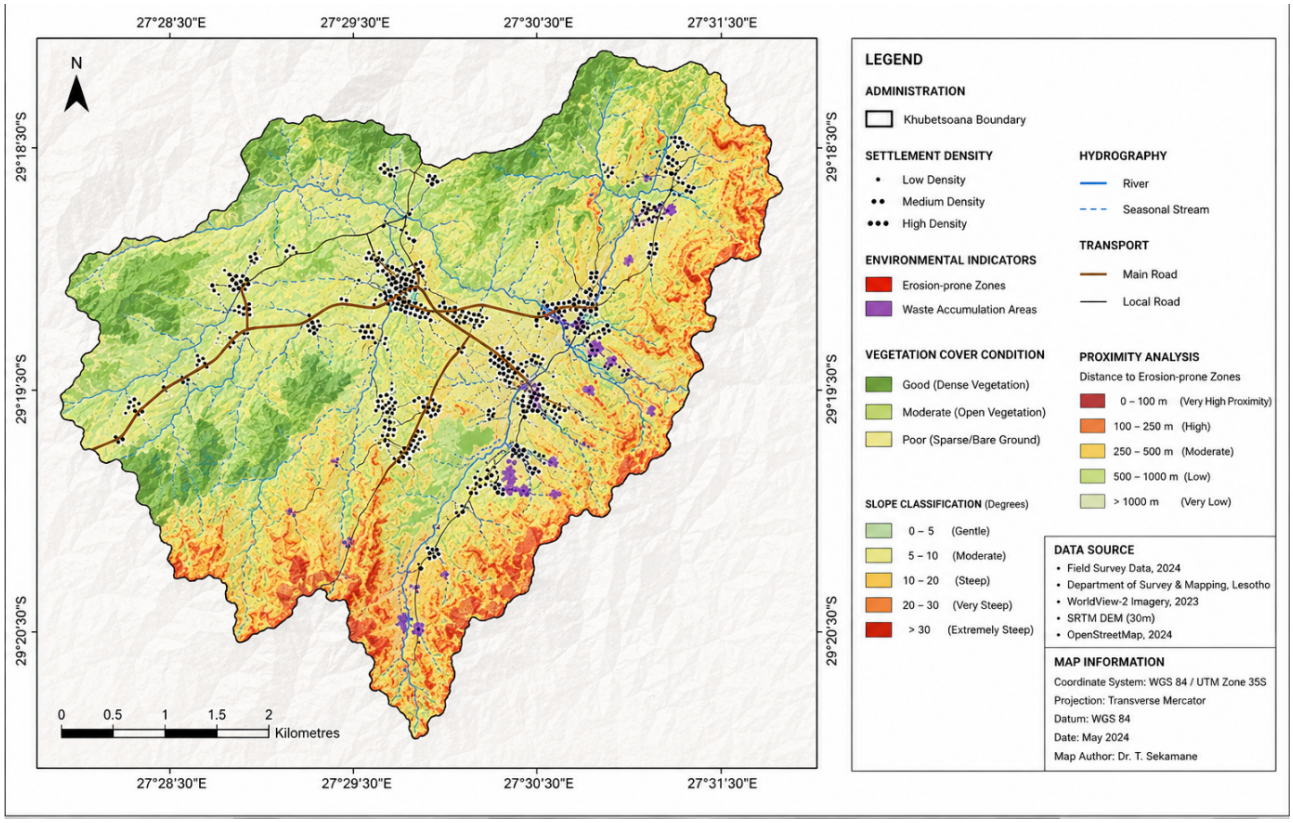

Figure 4. Khubetsoana Environmental Degradation Patterns.

The qualitative coding process was also structured to minimize researcher bias and enhance transparency. Interview transcripts were transcribed verbatim and analysed using an inductive coding approach. Initial open coding identified recurring concepts related to environmental awareness, waste management behaviour, governance inefficiencies and land-use practices. These codes were then refined into broader analytical themes through repeated review and comparison with field observation notes. Reflexive documentation was maintained throughout the process to ensure that interpretations remained grounded in participant responses rather than subjective assumptions.

Finally, the methodological framework was refined through an integrated approach to data interpretation. Instead of analysing quantitative, qualitative and spatial data separately, the study combined all datasets during the final stage of analysis to generate unified conclusions. This integration demonstrated how different forms of evidence reinforced each other in explaining land degradation patterns. By consolidating multiple analytical techniques into a single

interpretive framework, the study moved beyond descriptive analysis toward a more robust and scientifically grounded contribution to understanding urban environmental degradation and supporting sustainable planning interventions [32].

2.2.6. Ethical Considerations

Ethical considerations formed an integral part of the research design to ensure that all participants were treated with respect, dignity and fairness throughout the study. Before any data collection began, participants were first informed about the purpose of the study, the type of information required and how their responses would be used. This initial stage was important in ensuring transparency and building trust between the researcher and the community. After receiving this information, participants were asked to provide informed consent, confirming that they voluntarily agreed to take part in the study with a full understanding of its objectives and procedures [33].

Following consent, participation remained entirely voluntary throughout the research process. Participants were clearly informed that they had the right to refuse participation or withdraw from the study at any stage without facing any negative consequences. This approach ensured respect for individual autonomy and helped to create a non-coercive research environment. At the same time, careful measures were taken to protect participant identity. No personal identifiers such as names, identification numbers or exact residential addresses were recorded. Instead, each participant was assigned a unique code, ensuring that all responses remained anonymous and could not be traced back to specific individuals. This anonymity encouraged participants to provide more open and honest responses, particularly when discussing sensitive environmental and socio-economic issues.

Once data collection commenced, strict confidentiality measures were implemented to safeguard all collected information. Data obtained from household surveys, interviews and field observations were securely stored in password-protected digital files accessible only to the researcher. No data were shared with unauthorized third parties, and all information was used strictly for academic purposes. These procedures were designed to ensure compliance with core ethical principles, including confidentiality, privacy protection and the principle of "do no harm." Care was taken to ensure that participants were not exposed to any form of physical, emotional or psychological harm during the study. Questions were designed to be respectful, non-invasive and culturally appropriate, and participants were treated with dignity at all times.

Ethical compliance also contributed to the quality and reliability of the data collected. Because participants felt safe, respected and protected, they were more willing to provide accurate and detailed information about their experiences and environmental conditions. This strengthened the overall credibility of the findings. Finally, after the completion of data analysis, ethical practice was extended beyond data collection through community feedback. The findings of the study were communicated back to the Khubetsoana community through organized feedback sessions. These meetings presented key results related to land degradation, waste management challenges and environmental risks. Participants were given the opportunity to reflect on the findings and discuss possible community-based solutions for improving environmental management. This feedback process strengthened accountability, promoted community participation and ensured that the research contributed meaningfully to local environmental awareness and action beyond academic objectives alone.

2.2.7. Data Validation and Transparency

Data validation and transparency were essential components of this study to ensure that the findings were accurate, consistent and scientifically trustworthy. The validation process began during the planning stage by identifying appropriate strategies that could be used to check data quality and strengthen the reliability of the research process. This early emphasis on validation ensured that both data collection and analysis were guided by clear quality-control principles.

The first and most important validation strategy applied was triangulation. This method involved using multiple sources of data to investigate the same phenomenon in order to cross-check and confirm findings. In this study, data obtained from household surveys were systematically compared with information gathered from interviews and field observations. This step-by-step comparison made it possible to identify consistencies and discrepancies across datasets, thereby improving the accuracy of interpretations and reducing the likelihood of measurement or reporting errors [34]. Triangulation therefore served as a core mechanism for strengthening internal validity.

After triangulation, qualitative data were subjected to

a structured coding process. This stage involved carefully reviewing interview transcripts and field observation notes to identify recurring ideas and patterns. Responses were then grouped into meaningful categories, which were further refined into broader themes related to land degradation, waste management and environmental governance. This systematic coding process improved the clarity and organization of qualitative data while ensuring that interpretation remained grounded in participant responses rather than subjective assumptions. It also enhanced transparency by making the analytical steps traceable and replicable.

To further strengthen transparency, all stages of data handling were carefully documented throughout the research process. The researcher maintained detailed records of how data were collected, processed and analysed, ensuring that each stage of the study could be traced and verified if necessary. In addition, cross-checking procedures were continuously applied by comparing results across different data sources. For example, observed environmental conditions in the field were compared with respondents' descriptions during interviews to assess consistency and accuracy.

Both quantitative and qualitative validation techniques were applied to improve overall reliability. Quantitative data were checked during entry and analysis to detect and correct possible errors, while qualitative data were repeatedly reviewed to ensure accurate interpretation of participant meanings. This combination of validation techniques reduced bias and strengthened confidence in the results.

Ultimately, the integration of triangulation, systematic coding and continuous cross-checking ensured that the findings were not only consistent across different datasets but also clearly supported by multiple lines of evidence. This structured validation process significantly enhanced the credibility, reliability and scientific robustness of the study outcomes.

3. Results

The results of this study show that land degradation in Khubetsoana is uneven across the settlement. This means that some areas are more affected than others. The differences are linked to factors such as population density, land use practices and the level of infrastructure development. The data collected from households, interviews and field observations clearly show that environmental conditions vary from one section of the area to another.

The spatial analysis revealed that 72 out of the 120 surveyed households (60%) were located in high-density settlement zones, while 48 households (40%) were situated in lower-density residential areas. Among households located in high-density areas, 81% reported serious environmental problems compared to 37% in low-density areas. GIS-based mapping further showed that densely populated areas recorded the highest concentration of waste accumulation sites and erosion hotspots. **Table 1** presents the spatial distribution of land degradation severity across Khubetsoana, while **Table 2** summarizes household responses according to settlement density.

Table 1. Relationship between Population Density and Land Degradation.

Settlement Type	Number of Households	Average Population Density (Person/km^2)	Average Soil Loss (t/ha/Year)	Average Waste Volume (kg/Week)
High-density areas	72	8,500	18.4	42
Low-density areas	48	3,200	7.1	18

Table 2. Environmental Problems Reported by Households.

Environmental Issue	Number of Households	Percentage (%)
Soil erosion	78	65
Waste accumulation	92	77
Blocked drainage systems	84	70
Vegetation loss	69	58

Areas with high population density were found to experience more severe land degradation. In these areas, there is greater pressure on land due to the high number of people living in a small space. This often leads to overcrowding,

increased waste generation and limited open space. As a result, land becomes degraded more quickly. Many respondents from these areas reported problems such as poor waste disposal, blocked drainage systems and lack of proper sanitation. These findings are supported by field observations, which showed visible signs of environmental stress, including littered spaces and degraded land surfaces.

The results provide supporting evidence that land degradation is more severe in densely populated and poorly serviced areas. High-density zones showed significantly greater levels of soil erosion, blocked drainage systems and waste accumulation. Field measurements estimated that soil loss in densely populated sections reached approximately 18.4 t per hectare per year compared to 7.1 t in lower-density areas. Waste accumulation was also higher in overcrowded settlements due to insufficient municipal collection services and the absence of proper disposal infrastructure.

The study also found that soil erosion is a common problem in sloped areas of Khubetsoana. These areas are more vulnerable because water flows quickly downhill during rainfall, washing away the topsoil. Field observations showed gullies and exposed soil surfaces in these locations. Respondents living in these areas reported that erosion has affected their homes and reduced the stability of the land. In some cases, it has made it difficult to build or maintain houses. These findings are consistent with other studies that show that sloped land is more prone to erosion, especially when vegetation cover is low.

Quantitative survey results showed that 78 households (65%) experienced noticeable soil erosion around their homes or nearby areas. In addition, 84 households (70%) reported blocked drainage systems, while 69 households (58%) identified visible vegetation loss within their surroundings (see **Table 2**). These findings confirm that environmental degradation affects multiple components of the urban environment simultaneously.

Waste accumulation was found to be a major issue in poorly serviced areas where waste collection services were limited or unavailable. As a result, residents often disposed of waste in open spaces, along roads or inside drainage channels. This contributed to environmental pollution, unpleasant smells, pest infestations and increased disease risks. Quantitative findings showed that 92 households (77%) reported severe waste accumulation problems, particularly within informal settlement zones lacking proper waste collection services.

The spatial distribution of land degradation was also influenced by differences in infrastructure. Areas with better infrastructure, such as proper roads and waste collection services, showed lower levels of degradation. In contrast, areas with limited infrastructure were more affected. This shows that access to services plays an important role in reducing environmental problems. The findings suggest that improving infrastructure can help reduce land degradation and improve living conditions.

Remote sensing analysis using the Normalized Difference Vegetation Index (NDVI) further confirmed environmental degradation patterns in the study area (**Figure 5**). The remote sensing data provided quantitative evidence of environmental degradation, showing a decline in average NDVI values from 0.42 in 2015 to 0.26 in 2025. This decrease indicates a substantial reduction in vegetation cover within the settlement. Areas experiencing the greatest vegetation loss corresponded closely with densely populated informal settlements and erosion-prone slopes. The reduction in vegetation cover increased exposure to surface runoff, soil instability, and erosion, thereby exacerbating land degradation conditions. These findings support the spatial analysis results and demonstrate the effectiveness of remote sensing techniques in monitoring environmental change over time.

The data also revealed that land degradation affects different groups of people in different ways. Female-headed households reported slightly higher exposure to environmental degradation than male-headed households, mainly because women were more involved in household waste management and water collection activities. Younger respondents between 18 and 35 years showed higher environmental awareness levels than older age groups, mainly due to greater exposure to environmental education and media campaigns. Low-income households experienced the greatest environmental challenges because they were concentrated in poorly serviced and overcrowded sections of the settlement. Approximately 74% of households earning below the urban average income level lived in areas classified as environmentally high-risk zones.

Another important finding is that community awareness of land degradation varies across the settlement. Some respondents showed a good understanding of environmental issues and the importance of proper land management.

However, others had limited knowledge and continued to practice unsustainable activities. Areas where residents were more aware of environmental issues generally showed better environmental conditions.

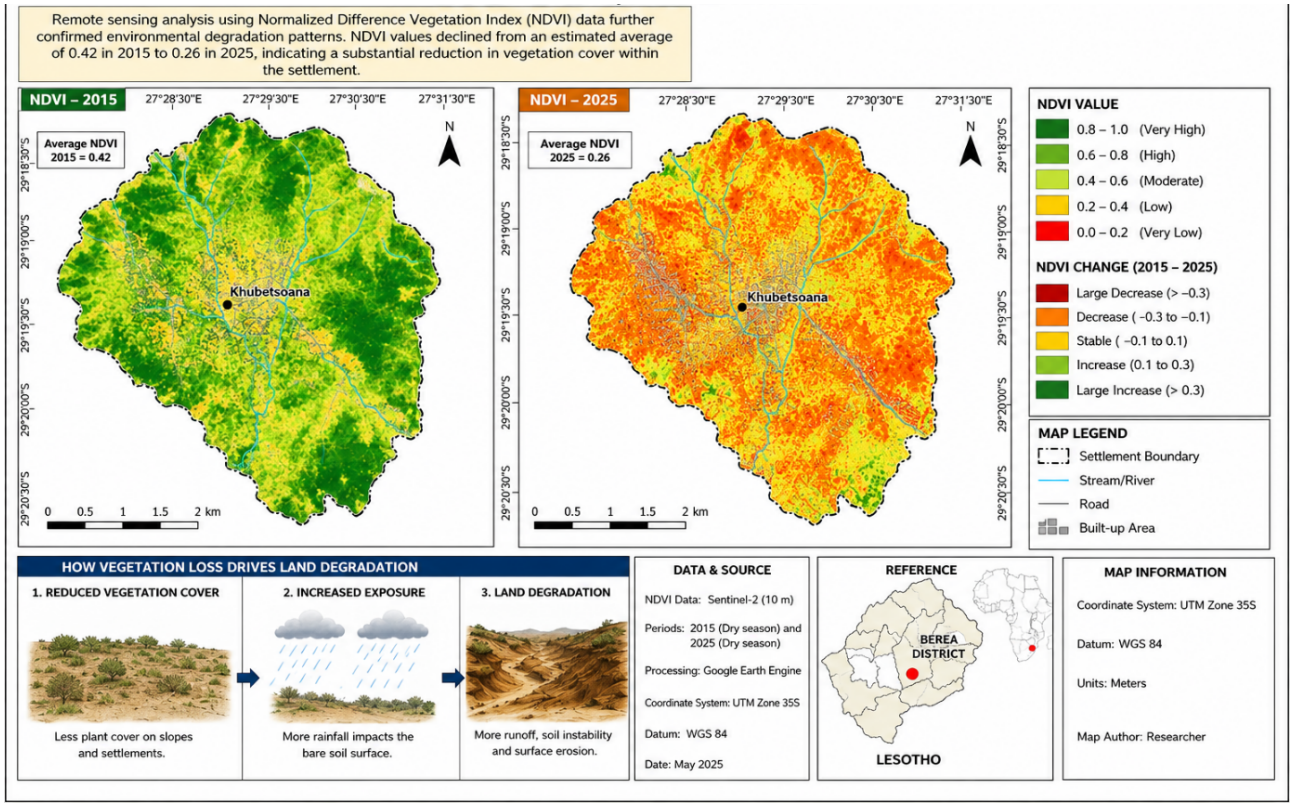

Figure 5. NDVI-Based Environmental Degradation and Vegetation Cover Change in Khubetsoana, Berea District (2015–2025).

Community awareness was measured using an environmental awareness index based on respondents' understanding of waste management, soil conservation, environmental regulations and sustainable land-use practices. Respondents were grouped into three categories: low awareness, moderate awareness and high awareness (**Table 3**). Results showed that 28% of respondents had low awareness levels, 46% moderate awareness and 26% high awareness. However, although awareness levels varied, awareness alone did not always translate into improved environmental practices because many residents lacked access to waste management services and financial resources.

Table 3. Relationship between Income Levels and Environmental Awareness.

Income Group	Low Awareness (%)	Moderate Awareness (%)	High Awareness (%)
Low-income households	41	44	15
Middle-income households	22	51	27
Higher-income households	11	43	46

The cross-tabulated data show that environmental awareness generally increased with income levels. Higher-income households demonstrated greater knowledge of environmental management practices and were more likely to participate in waste disposal and land conservation activities. However, the findings also indicate that structural challenges such as inadequate infrastructure and weak municipal services remained major contributors to environmental degradation regardless of awareness levels.

Moreover, the results demonstrate that land degradation in Khubetsoana is influenced by a combination of physical and human factors. Population density, land slope, waste

management, vegetation loss and infrastructure conditions all play important roles. The findings highlight the need for targeted interventions that address specific environmental challenges in different parts of the settlement. Understanding these spatial patterns is important for developing effective solutions and improving environmental conditions.

4. Discussion

The findings of this study demonstrate that land degradation in Khubetsoana is strongly associated with rapid urban expansion, population pressure, weak environmental governance and inadequate infrastructure provision. Areas with high population density experienced the most severe environmental degradation, including soil erosion, waste accumulation and vegetation loss. Similar findings have been reported in urban studies conducted in South Africa, Zimbabwe and Botswana, where informal settlement growth and poor service delivery were identified as major drivers of urban environmental decline. However, the case of Khubetsoana reflects unique local characteristics, particularly the combined influence of steep topography, weak municipal waste systems and increasing socio-economic vulnerability within densely populated settlements.

The study findings support existing literature arguing that weak urban governance and insecure land management systems intensify environmental degradation in developing urban settlements. In many parts of Southern Africa, poor land-use planning and ineffective environmental regulation contribute to unregulated settlement expansion, blocked drainage systems and uncontrolled waste disposal. Similar studies conducted in informal settlements in Johannesburg, Harare and Gaborone found that environmental degradation is closely linked to governance failures and limited municipal capacity. In Khubetsoana, these problems are further complicated by steep slopes and fragile land surfaces that accelerate erosion processes during heavy rainfall events.

By situating the findings within this broader regional context, the study offers more than just local observations; it provides a blueprint for policy shifts aimed at improving urban environmental governance in rapidly growing settlements. The findings demonstrate that land degradation is not simply a physical environmental problem, but rather a multidimensional challenge linked to governance systems, poverty, unemployment and unequal access to urban services. The results therefore move beyond descriptive observations into an interpretative and analytical understanding of the deeper structural causes of environmental vulnerability in Khubetsoana.

The discussion also highlights the importance of environmental governance, land tenure and intergenerational equity. Poor households often settle in environmentally sensitive areas because they lack access to secure and affordable land. As environmental degradation increases, land productivity declines and living conditions worsen. This creates a cyclical relationship between poverty, unemployment and environmental vulnerability. Residents with limited income are unable to invest in proper housing, drainage systems or waste management practices, while degraded environmental conditions reduce economic opportunities and increase public health risks. Consequently, communities become trapped in a feedback loop of declining adaptive capacity and increasing socio-economic vulnerability.

The relationship between waste accumulation and public health identified in this study further demonstrates the need for integrated urban governance frameworks. Accumulated waste blocks drainage channels, contaminates water sources and creates breeding sites for disease vectors. Effective urban planning should therefore integrate sustainable environmental governance with public health infrastructure to improve long-term community resilience. Similar urban studies in Southern Africa have shown that settlements with improved waste management systems and better drainage infrastructure experience lower levels of environmental degradation and reduced exposure to waterborne diseases.

The study also recommends more innovative and sustainable mitigation strategies that move beyond conventional waste collection approaches. Community-led waste management initiatives and circular economy practices could significantly reduce environmental pressure within Khubetsoana. Organic waste could be transformed into compost for urban gardening, while recyclable materials such as plastics and metals could be converted into reusable products or sold through local recycling cooperatives. Integrated waste management systems would reduce urban pollution, improve drainage conditions and protect local water sources from contamination.

In erosion-prone areas, bio-engineering solutions

should be introduced to stabilize slopes and reduce soil loss. The planting of local vegetation species such as vetiver grass, shrubs and indigenous trees could strengthen soil structure and reduce surface runoff. These approaches should be combined with improved drainage channels, terracing and controlled settlement expansion in vulnerable zones. Such technically grounded recommendations provide practical guidance for urban planners, environmental organizations and local authorities in Maseru seeking to strengthen environmental sustainability and urban resilience.

Although the study provides important insights into spatial patterns and environmental impacts of land degradation in Khubetsoana, several limitations should be acknowledged. The study relied on a relatively small sample size of 120 households, which may not fully capture all environmental variations across the settlement. In addition, some environmental indicators were based on self-reported household experiences, which may be influenced by perception bias. Limited availability of long-term remote sensing data also restricted the ability to conduct extended historical environmental analysis. Despite these limitations, the use of mixed methods, GIS analysis and triangulation strengthened the reliability and scientific validity of the findings.

5. Conclusions

The study demonstrated that land degradation in Khubetsoana is unevenly distributed and strongly influenced by population density, poor infrastructure, weak waste management systems and environmental governance challenges. Spatial analysis confirmed that environmental degradation is closely associated with settlement patterns, inadequate drainage systems and limited access to municipal services. Densely populated and poorly serviced areas experienced more severe environmental problems, including soil erosion, waste accumulation and vegetation loss. The findings also showed that socio-economic factors such as poverty, unemployment and low environmental awareness contribute significantly to environmental vulnerability within the settlement.

The study further highlights the importance of cooperation between government institutions, local authorities and community members in addressing environmental degradation. Sustainable environmental management in Khubetsoana will require stronger institutional accountability, inclusive governance systems and long-term partnerships between government agencies and local communities. However, several barriers continue to limit effective collaboration. These include limited financial resources, weak institutional capacity, low public trust in municipal authorities and inadequate community participation in environmental decision-making processes. In addition, power imbalances and institutional gaps often prevent the consistent enforcement of existing land management policies, particularly in informal settlements where unregulated land occupation and weak governance structures are common.

The conclusion of this study emphasizes that effective environmental interventions must be integrated into existing legal and institutional frameworks in Lesotho in order to bridge the gap between academic research and practical environmental policy implementation. Policies such as urban land-use planning regulations, waste management by-laws and environmental protection frameworks should be strengthened through improved enforcement mechanisms and coordinated institutional action. Integrating sustainable urban planning, community-based waste management and slope stabilization programs into municipal development strategies would improve environmental resilience and reduce future land degradation risks in Khubetsoana.

Without addressing these governance and institutional challenges, recommendations for stronger environmental policies and increased community awareness may remain difficult to implement effectively. Therefore, future environmental management strategies should focus not only on physical land restoration but also on strengthening governance capacity, improving public participation and increasing institutional coordination. Such integrated approaches would help create more sustainable and resilient urban settlements capable of responding effectively to long-term environmental pressures.

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Institutional Review Board Statement

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Before collecting data, the researcher asked for permission from the village.

Approval processes were granted. The study followed ethical standards by explaining the purpose of the research, ensuring confidentiality and obtaining consent from participants. Formal ethical clearance from an Institutional Review Board or Ethics Committee was not required for this study because it involved voluntary community participation and did not include medical or clinical procedures.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The data will be available on request from the writer.

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Conflicts of Interest

The author declares no conflict of interest.

Al Use Statement

I confirm that, during the preparation of this work, I, Thabang Sekamane, have used Toolsmart in order to paraphrase, and I did not generate the content using it. After using this tool, I reviewed and edited the content as needed, and I take full responsibility for the content of the published article.

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