

Desertification on the Edge of the Namibe Desert: Causes and Socioenvironmental Consequences

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Abstract

Our society is changing at an unprecedented speed, due to a technological revolution unprecedented in our history. Consequently, there is an exponential growth in the availability of technology that will certainly continue to evolve in the coming decades. The impact of this technological transformation particularly affects financial institutions, with a view to changing the behavior of their customers, demanding excellence in the services provided, demanding expansion and variety in the provision of banking services, especially in aspects related to information technology. Desertification represents one of the most pressing environmental challenges in arid and semi-arid regions, with profound implications for biodiversity, land productivity, and human livelihoods. This paper examines the causes and socioenvironmental consequences of desertification on the edge of the Namib Desert, specifically in the municipalities of Moçâmedes and Tombwa in southern Angola. Using a qualitative methodology based on literature review, institutional reports, and field observations, the study identifies key drivers such as overgrazing, deforestation, climate variability, and unregulated urban expansion. The paper also highlights the impacts of land degradation on food security, migration patterns, and ecological stability. The findings underscore the urgent need for integrated land management strategies and participatory environmental governance to mitigate the effects of desertification in the region.

Keywords: Desertification, Namibe, Angola, Environmental degradation, Socioeconomic Impact, Land use

1. Introduction

Desertification is one of the most severe and complex environmental challenges of the 21st century, particularly in arid and semi-arid zones where ecological fragility intersects with socio-economic marginalization. According to the United Nations Convention to Combat Desertification desertification refers to land degradation in drylands caused by a combination of climatic variability and human activities [1]. Globally, more than 2 billion people are affected by the consequences of desertification, with significant impacts on agriculture, biodiversity, water resources, and human health [2,3]. The degradation of drylands is not a uniform process—it is shaped by regional ecological conditions, governance structures, and livelihood strategies. In Sub-Saharan Africa, where over 60% of the land is classified as dryland, desertification undermines

development efforts and exacerbates poverty, migration, and food insecurity [4,5]. In these regions, the combined pressures of climate change, population growth, and unsustainable land use have accelerated environmental deterioration. Scientific research has also shown that desertification can trigger feedback loops, leading to declining vegetation cover, soil erosion, reduced rainfall infiltration, and more frequent extreme weather events [6,7]. Within this global and regional context, southern Angola presents a critical case for understanding the dynamics of desertification at the fringes of the Namib Desert—one of the world's oldest and driest deserts [8]. The Namibe Province, particularly the municipalities of Moçâmedes and Tombwa, lies in a sensitive ecological transition zone between the hyper-arid Atlantic coastal desert and the semi-arid interior. These areas are characterized by

low and erratic rainfall (50–200 mm annually), sandy and erosion-prone soils, and sparse vegetation dominated by drought-resistant species. Despite these natural constraints, human activities have significantly intensified land degradation in the region. The demand for grazing land, charcoal, and space for informal urban expansion has accelerated environmental stress [9,10]. Moreover, weak land tenure systems and limited access to environmental education or alternative energy sources have compounded the vulnerability of local communities. With climate variability expected to worsen in the coming decades, understanding and addressing the socioenvironmental dimensions of desertification in Namibe is both urgent and necessary [11]. This paper aims to investigate the root causes of desertification and assess its socioenvironmental consequences in the municipalities of Moçâmedes and Tombwa. Through a combination of theoretical review, qualitative field insights, and institutional data, the study seeks to contribute to a more integrated understanding of land degradation in Angola's coastal drylands. It also aspires to inform sustainable land management strategies that bridge scientific knowledge and local practices—offering lessons applicable to other dryland regions facing similar ecological and governance challenges.

2. Theoretical Background

Desertification is a multifaceted environmental process that cannot be fully understood through a single disciplinary lens. It intersects ecology, climatology, geography, development studies, and environmental governance. Historically, desertification was framed as a result of prolonged drought and declining rainfall, particularly following the 1970s Sahel droughts. However, research over the past two decades has shifted toward more integrative explanations that emphasize the interplay between biophysical stress and human-induced pressures [12]. A key conceptual framework that facilitates this integrative understanding is the Pressure–State–Response (PSR) model, developed by the Organisation for Economic Co-operation and Development. The PSR model enables a systematic assessment of environmental degradation by categorizing:

- **Pressures:** such as overgrazing, deforestation, climate variability, and informal urban expansion;
- **State:** the current condition of ecosystems, including vegetation loss, soil fertility, and water availability;
- **Responses:** actions taken by individuals, communities, and governments, such as afforestation, conservation programs, or environmental regulation.

This structure is particularly useful in developing countries, where weak environmental monitoring systems often limit data availability and policy effectiveness. Another widely applied framework is the Human–Environment Interaction approach, which explores how humans shape and are shaped by the natural environment. This perspective recognizes that communities in drylands often rely directly on natural resources for survival and, in doing so, inadvertently contribute to ecological degradation. However, it also acknowledges that these same communities

possess deep ecological knowledge and adaptive practices, which can be leveraged in sustainable land management strategies. Closely related is the Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (DFID). This model helps to link environmental changes to socio-economic vulnerability by analyzing how land degradation affects access to key livelihood assets: natural, social, financial, physical, and human capital. In arid regions like Namibe, where communities depend heavily on rangeland and subsistence agriculture, the degradation of these assets leads to declining food security, increased rural–urban migration, and growing inequality. Furthermore, recent literature emphasizes the importance of socio-political and institutional factors in shaping environmental outcomes. For example, Stringer and Reed (2007) argue that the success of desertification mitigation depends less on the presence of technical solutions and more on the existence of inclusive institutions, land tenure security, and local participation in decision-making processes. In regions with limited environmental governance—such as many semi-arid zones in Sub-Saharan Africa—policy fragmentation, underfunding, and bureaucratic barriers often hinder the implementation of effective responses. In the Namibe region, desertification must be understood within this layered context: as the result of climatic variability interacting with socio-economic marginalization, weak land governance, and historically inadequate investment in dryland resilience. The existence of informal settlements, overdependence on biomass energy, and the lack of long-term land use planning are not merely environmental issues—they are reflections of deeper structural challenges. This study integrates the PSR model, Human–Environment Interaction, and Sustainable Livelihoods Framework to analyze the causes and consequences of desertification in Moçâmedes and Tombwa. These frameworks allow for a multi-dimensional diagnosis of degradation processes, while also guiding the formulation of integrated, community-based responses rooted in both scientific evidence and local knowledge.

3. Methodology

This study employs a qualitative, descriptive approach to investigate the causes and socioenvironmental consequences of desertification in the Namibe region of southern Angola. The research is grounded in three primary methodological components: a comprehensive literature review, analysis of secondary data, and contextual field observations.

4. Literature Review

A systematic review of academic literature, policy documents, and technical reports was conducted to consolidate existing knowledge on desertification processes in arid and semiarid regions. Sources were selected from reputable databases including Web of Science, Scopus, and Google Scholar. Key documents included reports by the United Nations Convention to Combat Desertification (UNCCD, 2022), the Food and Agriculture Organization (FAO, 2019), and the Intergovernmental Panel on Climate Change. The review aimed to identify prevailing theories, frameworks (such as the Pressure–State–Response model and the Sustainable Livelihoods Framework), and empirical findings relevant to

dryland degradation. This approach ensured that the study is informed by both global assessments (e.g., UNCCD & FAO, 2023) and region-specific research.

5. Secondary Data Analysis

In addition to the literature review, the study analyzed secondary data obtained from various institutional sources. Climatic records for the period 2000–2023 were sourced from national meteorological databases and corroborated with global datasets such as those provided by the World Bank (2021). Remote sensing data, including the MODIS NDVI dataset, were used to assess changes in vegetation cover over time, offering an objective measure of land degradation. This multi-source data triangulation allowed for the identification of temporal trends and the correlation between climatic variability and land degradation in the region.

6. Field Observations and Informal Interviews

To capture local perspectives, informal interviews were conducted with residents and community leaders in Moçâmedes and Tombwa. These discussions focused on perceptions of environmental change, changes in agricultural productivity, access to water, and adaptive strategies. Observational data were recorded regarding visible signs of desertification, such as soil erosion, reduced vegetation cover, and the expansion of informal settlements. Although not statistically representative, these qualitative insights provided a critical complement to the secondary data and helped ground the analysis in the lived experiences of local populations.

7. Data Integration and Analysis

The multiple data sources were integrated using a thematic analysis approach. Key themes emerged around the drivers of land degradation—both natural and anthropogenic—and the resulting socioenvironmental consequences. The analysis was guided by the Pressure–State–Response (PSR) framework (OECD, 1994; UNCCD, 2022) and the Human–Environment Interaction model which together provided a holistic lens to interpret the complex processes observed in Namibe.

8. Limitations

Despite the rigorous data triangulation, this study is subject to several limitations. First, the reliance on secondary data introduces a constraint due to the scarcity of updated and high-resolution land-use information. Second, the informal nature of the interviews may not fully capture the diversity of local perspectives. Finally, isolating the impacts of climatic variability from human-induced degradation remains challenging, necessitating further quantitative studies to complement the findings presented here.

9. Study Area Overview

The Namibe Province is located in the southwestern region of Angola, bordering the Atlantic Ocean and forming part of the country's coastal desert belt. Covering approximately 57,000 square kilometers, Namibe is one of Angola's most ecologically fragile regions due to its location on the fringe of the Namib Desert, which extends from southern Angola through Namibia into South Africa. The province consists of five municipalities, among

which Moçâmedes and Tombwa are the most directly affected by desertification processes due to their proximity to the desert and demographic pressures. The region is characterized by an arid to semi-arid climate, with mean annual rainfall ranging from as low as 50 mm in the coastal zones to about 200 mm in the more inland areas (Angola Ministry of Environment, 2020). Rainfall is highly variable both temporally and spatially, and the region experiences frequent dry spells. Temperatures are generally high year-round, with average annual temperatures ranging from 20°C to 28°C. The Benguela Current, a cold oceanic current that flows along the coast, plays a significant role in the climatic conditions of the region, contributing to low humidity and sparse precipitation. Topographically, the area features extensive sand dunes, rocky outcrops, and ephemeral riverbeds. The soils are predominantly sandy and nutrient-poor, making them highly susceptible to erosion and degradation. Vegetation is sparse and primarily composed of xerophytic plant species such as *Welwitschia mirabilis*, which are well-adapted to extreme aridity but highly sensitive to disturbance. These ecosystems are vital not only for biodiversity conservation but also for maintaining ecological stability. Moçâmedes, the provincial capital, and Tombwa, a coastal municipality further south, are the region's main urban centers. Both cities have witnessed moderate population growth driven by rural–urban migration, economic activity in the fishing and salt industries, and limited development in agriculture and infrastructure. However, the growth has also led to the expansion of informal settlements, particularly in peri-urban areas, where access to basic services such as potable water, sanitation, and electricity remains inadequate. The socio-economic context is marked by low income levels, high dependency on natural resources, and weak institutional capacity to regulate land use and environmental protection. Land tenure systems remain largely informal, which discourages long-term investment in land conservation. These factors combine to create a scenario in which both natural and anthropogenic forces interact to accelerate land degradation, especially in vulnerable zones around human settlements.

10. Drivers of Desertification

Desertification in the Namibe region is the result of a complex interplay between natural forces and anthropogenic pressures. While the region's biophysical characteristics—low rainfall, high evaporation rates, and fragile soils—create a natural predisposition for land degradation, it is the intensification of human activities without adequate environmental management that has accelerated the phenomenon.

10.1. Climatic Factors

The region's arid and semi-arid climate, heavily influenced by the Benguela Current, leads to limited and erratic rainfall patterns, concentrated within a short rainy season. This variability creates cycles of prolonged drought, reducing soil moisture and inhibiting vegetation regrowth. Studies have shown that rising temperatures due to global climate change have further intensified evapotranspiration rates in southern Angola, contributing to declining vegetation cover and increasing aridity (Maestre et al., 2022; Middleton & Sternberg, 2013).

10.2. Overgrazing and Livestock Pressure

Overgrazing is one of the most prominent direct drivers of desertification in Namibe. The growth of livestock herds—particularly goats and cattle—has exceeded the carrying capacity of local rangelands. Goats, which are more resilient to drought, are increasingly preferred by herders but contribute significantly to soil compaction and the destruction of vegetation. Without rotational grazing systems or regulated access to communal pastures, overgrazing leads to barren landscapes, soil crusting, and reduced infiltration capacity.

10.3. Deforestation and Biomass Dependence

The reliance on wood-based fuels remains high in both urban and rural households in Moçâmedes and Tombwa. Charcoal production and fuelwood collection are major contributors to the removal of native vegetation, particularly in areas surrounding informal settlements. This process not only depletes vegetative cover but also exposes the soil to erosion and reduces biodiversity. Unlike sustainable forestry practices, most of the harvesting in the region occurs without replanting, aggravating the degradation of ecosystem services.

10.4. Unregulated Urban Expansion

The expansion of informal settlements in peri-urban zones has significant environmental impacts. As population density increases in Moçâmedes and Tombwa, land is often cleared without environmental impact assessments, infrastructure planning, or soil stabilization efforts. Construction on marginal lands further weakens soil structures and reduces vegetation buffers, intensifying runoff and erosion during rainfall events.

10.5. Unsustainable Agricultural Practices

Although agriculture is limited due to water scarcity, some subsistence farming takes place in inland valleys and dry riverbeds. Traditional techniques such as slash-and-burn and monocropping remain common, while the use of conservation agriculture techniques (e.g., mulching, terracing, crop rotation) is minimal. Combined with poor soil quality and the absence of irrigation infrastructure, these practices accelerate nutrient depletion and land exhaustion.

10.6. Institutional and Policy Gaps

Land degradation is further compounded by weak institutional frameworks and limited enforcement of environmental regulations. Land tenure insecurity discourages investment in land conservation, and provincial environmental authorities often lack the technical capacity and financial resources to monitor or mitigate degradation processes. Moreover, the absence of integrated land use planning has allowed fragmented and competing land claims to emerge, especially in zones experiencing population influx.

11. Socioenvironmental Consequences

The impacts of desertification in the Namibe region are wide-ranging, affecting not only ecological systems but also the livelihoods, health, and social stability of local populations. These consequences are particularly acute in municipalities

such as Moçâmedes and Tombwa, where the interplay between environmental degradation and socio-economic vulnerability is most pronounced.

11.1. Decline in Agricultural Productivity

One of the most immediate and visible consequences of desertification is the reduction in agricultural productivity. As soils become depleted of nutrients, lose structure due to erosion, and suffer from reduced moisture retention, crop yields decline significantly. In Namibe, subsistence farmers often operate on marginal lands with poor soil quality, relying on rainfall for irrigation. The increasing unpredictability of rainfall patterns, coupled with land degradation, undermines food security and exacerbates poverty, especially in rural areas where alternative livelihoods are scarce.

11.2. Loss of Livestock and Rangeland Degradation

Pastoralist communities, which are common in the region, face diminishing grazing lands due to overuse and the encroachment of desert conditions. The degradation of rangelands leads to increased livestock mortality and reduced reproductive rates, directly affecting household incomes and food access. As animals are central to the local economy and cultural identity, their decline contributes to deeper social and psychological distress among affected populations.

11.3. Biodiversity Loss and Habitat Fragmentation

Desertification also leads to a reduction in biological diversity, particularly of endemic plant and animal species adapted to arid environments. The removal of native vegetation and the fragmentation of natural habitats compromise essential ecological functions such as seed dispersal, nutrient cycling, and groundwater recharge. Iconic species such as *Welwitschia mirabilis* face increasing pressure as their habitat is degraded, posing long-term risks to the region's ecological heritage.

11.4. Human Health Risks

Environmental degradation in drylands is closely linked to public health challenges. In Namibe, the increasing frequency of dust storms and reduced air quality have been associated with respiratory diseases such as asthma and chronic bronchitis. Furthermore, degraded land and poor water management contribute to the contamination of water sources, facilitating the spread of waterborne diseases. The lack of basic sanitation in many informal settlements further increases vulnerability to illness.

11.5. Migration and Social Tensions

As agricultural productivity and livestock capacity decline, many households are forced to migrate in search of better opportunities. Internal displacement toward urban centers such as Moçâmedes creates pressure on already limited infrastructure and public services. In turn, this may lead to increased social tensions, competition over housing and jobs, and the proliferation of informal settlements. The resulting demographic shifts also disrupt traditional land-use practices and weaken local community cohesion.

11.6. Increased Vulnerability to Climate Shocks

Desertification reduces the resilience of both ecosystems and human communities to climate variability and extreme weather events. Degraded soils are less able to absorb water during storms, increasing the risk of flash floods, while droughts become more devastating in the absence of healthy vegetation cover. These dynamics create a vicious cycle in which degradation and vulnerability reinforce each other.

12. Discussion

The results of this study highlight the intricate and dynamic nature of desertification in the Namibe region. Desertification is not merely an ecological process but a socioecological syndrome—driven by environmental, institutional, cultural, and economic factors that act simultaneously and interactively. The implications of this are significant: to address desertification effectively, interventions must extend beyond technical solutions and address the root causes embedded in governance systems, social inequality, and climate vulnerability.

12.1. Weak Governance and Fragmented Institutional Capacity

One of the clearest conclusions of this study is that weak governance is a core enabler of desertification in Namibe. While Angola has ratified international frameworks like the United Nations Convention to Combat Desertification (UNCCD), the translation of these commitments into localized, enforceable policies has been limited. Provincial institutions in Namibe often operate with constrained budgets, insufficient technical capacity, and limited coordination between environmental and urban planning departments. Land tenure insecurity further compounds the problem. In many parts of Moçâmedes and Tombwa, land is held informally or communally, creating ambiguity over rights and responsibilities. As a result, land degradation often goes unregulated, and land users have little incentive to invest in long-term soil restoration or conservation techniques. This aligns with global findings showing that insecure land tenure is consistently associated with unsustainable land management in drylands.

12.2. Socioenvironmental Feedback Loops

The degradation observed in Namibe is not simply an outcome of human action, but part of a reinforcing feedback loop between environmental stress and socio-economic vulnerability. For example, declining soil fertility reduces food production, which drives migration, which in turn results in new land clearance and informal settlement in ecologically fragile zones. Each element reinforces the next in a self-perpetuating cycle. This pattern is consistent with the vulnerability–exposure–sensitivity framework proposed by Adger (2006), which identifies how social groups exposed to environmental change respond based on their adaptive capacity and institutional context. In Namibe, low adaptive capacity—due to poverty, limited access to education, and marginalization—translates into coping strategies that may intensify degradation, such as shifting cultivation or overgrazing.

12.3. The Role of Climate Change as a Threat Multiplier

Although desertification is not new in Namibe, climate change has intensified the process. The region is already prone to climatic extremes due to the cold, upwelling Benguela Current, which reduces rainfall and increases evapotranspiration. However, climate models project even more erratic precipitation and higher mean temperatures for southwestern Angola in the coming decades. This creates a threat multiplier effect: areas already experiencing degradation become more vulnerable to extreme events such as prolonged droughts, sudden floods, or coastal salt intrusion. Importantly, climate stress disproportionately affects those with the fewest resources to adapt—rural women, elderly farmers, and informal settlers—thereby deepening social inequality.

12.4. Opportunities for Community-Based and Nature-Based Solutions

Despite the challenges, there is growing evidence that community-based adaptation and nature-based solutions can offer pathways out of desertification traps. Community reforestation efforts using indigenous species, for example, have shown strong results in restoring vegetation and improving soil structure in regions such as the Sahel and the Horn of Africa. Similar pilot initiatives in southern Angola, though small-scale, demonstrate promising outcomes when local knowledge is respected and supported with training and material inputs. Furthermore, agroecological approaches—such as mixed cropping, conservation tillage, and composting—can enhance soil fertility without reliance on external chemical inputs. These methods are low-cost, scalable, and well-suited to semi-arid environments. In areas like Namibe, where financial and technological barriers exist, such methods may offer a more feasible route to land rehabilitation than large infrastructure projects. However, these interventions must be embedded within broader policy reforms. Without land rights, climate information systems, or access to markets, community efforts may stall or be reversed [13-16].

12.5. Importance of Multiscalar and Interdisciplinary Interventions

The cross-cutting nature of desertification necessitates multi-scalar responses. Local-level actions must be supported by national policy coherence, regional cooperation, and international financing. Institutions at all levels should be aligned to avoid fragmented mandates and overlapping responsibilities. Moreover, addressing desertification requires interdisciplinary approaches. For instance, technical soil monitoring is only useful when coupled with socio-economic data about land users, power dynamics, and community priorities. Without this, even the best scientific plans may fail in practice.

13. Conclusion

Desertification on the edge of the Namib Desert, particularly in the municipalities of Moçâmedes and Tombwa, represents a critical environmental and socio-economic challenge in southern Angola. This study has demonstrated that desertification in this region is not solely the result of natural aridity or climate variability, but a multifactorial phenomenon driven by the intersection of ecological

fragility, unsustainable land use practices, weak governance, and socio-economic vulnerability. The degradation of soils, loss of vegetation, and decline in water availability have direct consequences for local food systems, pastoralism, biodiversity, and public health. The discussion has highlighted how desertification in Namibe shares characteristics with other dryland regions across Africa, while also presenting unique features due to its proximity to the Benguela Current and the historical marginalization of the southern coastal provinces. The Namibe case thus offers valuable insights into the broader dynamics of land degradation in semi-arid transition zones — areas where human development aspirations and ecological limits are in constant tension. While the study did not seek to provide exhaustive policy prescriptions, it underscores the need for integrated, interdisciplinary, and inclusive approaches to land and environmental governance. It also reveals critical data gaps — especially regarding land use mapping, local climate records, and socio-economic trends — which must be addressed to improve planning and decision-making. In conclusion, desertification in Namibe is both a local and global concern. Its causes and consequences reflect broader patterns of unsustainable development in fragile environments. Yet, it also offers an opportunity: by studying, understanding, and responding to the desertification process in this region, scholars, policymakers, and communities can co-produce knowledge and strategies that foster resilience.

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