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Impact of human activities on soil degradation and sustainability of oasis ecosystems in the Middle Draa (Morocco)

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KEYWORDS

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INTRODUCTION

Soil degradation represents a major environmental challenge on a global scale, threatening the biological productivity of soils and, consequently, food security. The worsening of this phenomenon over the past six decades is attributed to a combination of factors, including population growth, unsustainable natural resource exploitation, and the increasing frequency and intensity of climatic hazards. In this context, the vulnerability of agricultural soils is particularly concerning in arid and semi-arid regions, where water resources are scarce and ecosystems are especially fragile. This vulnerability is especially pronounced in Morocco's oases, which host a significant portion of the population whose livelihoods are closely tied to the availability of water for agriculture.

The oases of the Middle Draa Valley, located in southeastern Morocco, are complex, dynamic, and intrinsically fragile ecosystems. Understanding their functioning is essential for contributing effectively to sustainable management. The six principal oases of the Middle Draa are of vital importance, being rich in biodiversity, culture, history, heritage, traditional knowledge, and agricultural practices. They have also been recognized as UNESCO biosphere reserves. Despite their ecological and socio-economic significance, they face growing challenges related to soil degradation, threatening their long-term sustainability.

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The Middle Draa region is characterized by a complex geology, the result of a long tectonic and sedimentary history. It comprises geological formations ranging from the Precambrian to the Quaternary, reflecting considerable lithological diversity. Structurally, the region belongs to the Anti-Atlas domain, which extends southward into the Bani chain. The climate is marked by extreme aridity and significant spatio-temporal variability in precipitation, with annual rainfall ranging from 20 mm in the downstream areas to 220 mm in the upstream parts of the basin. This irregular rainfall regime, combined with fragile soils and increasing anthropogenic pressure, exacerbates soil degradation processes.

This study aims to analyze the impacts of human activities on soil degradation and the vulnerability of oasis systems in the Middle Draa. Three main objectives were established. The first is to examine the region's demographic dynamics and their implications in the context of increasing pressure on limited natural resources. The second focuses on assessing soil conditions through a physico-chemical analysis conducted along an upstream-downstream gradient of the oases. The third objective is to evaluate the impact of intensified agricultural practices and the unregulated development of quarries on the local environment.

METHODOLOGY

This study combines various methods to assess the anthropogenic impacts on soil degradation and the sustainability of oasis ecosystems in the Middle Draa.

- **Characterization of soil degradation**

Soil degradation was evaluated using a methodology that combines field sampling, laboratory analyses, and cartographic work. These analyses, conducted at the INRA laboratories in Agadir, enabled the determination of key parameters such as soil salinity, organic matter content, and pH levels.

- **Analysis of Demographic Evolution**

To assess the impact of demographic growth on the sustainability of oases, an analysis combining demographic data (Zagora province, censuses from 1994, 2004, and 2014) and field interviews was carried out in the douars of Amezrou and Tinfou.

- **Mapping of Agricultural Land and Date Palms**

A cartographic approach was implemented to analyze the spatio-temporal evolution of the studied phenomena. This analysis relied on the use of topographic maps and images provided by Google Earth Pro to characterize the evolution of agricultural land areas and date palm density.

RESULTS

The results of this study will be presented along three main axes: the analysis of demographic pressure on limited resources, the assessment of the impacts of human activities on soil degradation, and the examination of the influence of these activities on the sustainability of oasis ecosystems.

- **Impacts of population growth on environmental carrying capacity**

The study of demographic characteristics in the Middle Draa region reveals significant population growth. This dynamic is seen as a reflection of the economic and social transformations affecting the area. Demographic trends are marked by continuous, though moderate, growth. The population increased from 255,805 in 1994 to 283,336 in 2004, representing an annual growth rate of 1.03%, and then to 307,306 in 2014, with an annual growth rate of 0.81% (Table 3). The overall growth rate for the period 1994–2014 stands at 0.88%, a level below the national average (1.31%).

Thus, the analysis of demographic growth rates in the Middle Draa between 1994 and 2014 reveals significant spatial heterogeneity. Some areas experienced high growth (Agdz, Zagora), others



moderate growth (Tamegroute and Ternata), while some recorded low growth (Aflandra and Tassifte), and others experienced demographic decline (Ktaoua, M'Hamid El Ghizlane, Blaidia, and Aït Boudad).

– **Anthropogenic Impacts on Soil Degradation**

Salinity analyses have revealed a variability in values ranging from 0.299 to 5.11 mS/cm, with an average of 1.57 mS/cm. This high level of salinity indicates soil degradation, primarily attributed to prolonged drought episodes and the widespread use of flood irrigation, which promotes evaporation and salt accumulation. As a result, the use of organic amendments emerges as an essential strategy to enhance soil fertility and mitigate the effects of salinization.

In parallel with increasing salinity, a rise in pH levels is also observed along the upstream-downstream gradient of the Middle Draa. The pH values recorded in the oases of Tinzouline (7.75–7.57), Ternata (7.45–7.35), and Fezouata (7.69–8.02) indicate neutral to slightly alkaline soil conditions. The analysis also highlights spatial heterogeneity in organic matter content, with significant variations between the oases of Tinzouline (1.538%–1.812%), Ternata (0.609%–1.078%), and Fezouata (0.917%–1.607%). Nevertheless, these values allow for the general classification of Middle Draa soils as low to very low in organic matter content.

– **Anthropogenic Impacts on the Sustainability of the Oasian Ecosystem**

Demographic growth exerts increasing pressure on oasis agriculture, leading to an intensification of agricultural practices that threatens the sustainability of these fragile ecosystems. The oases of the Middle Draa are characterized by a typical date palm landscape, locally known as jnane. From an economic perspective, these landscapes play a central role in the development of oasian communities. Currently, oasis landscapes are undergoing major transformations aimed at increasing and diversifying agricultural production to meet market demands. This shift—from subsistence agriculture to commercial farming—jeopardizes the balance of this key sector and threatens the sustainability of natural resources, notably through exacerbated water stress, soil salinization, and the spread of vascular fusariosis (Bayoud disease).

The evolution of oasis agriculture is reflected in various processes, including the mechanization of production, optimization of water extraction techniques using modern motor pumps, integration of renewable energy sources (notably solar energy) to reduce operational costs, introduction of new crops such as watermelon, modification of the organoleptic qualities of products, increased yields, development of supply chains and agricultural technologies, and the construction of water accumulation basins.

Diachronic cartographic analysis of selected agricultural areas in the Middle Draa oases reveals significant changes in the utilized agricultural area and the number of irrigated fields. Furthermore, the condition of date palms shows contrasting trends depending on the area. The Béni Ali sector has experienced marked degradation, with a decrease in the number of palm trees largely due to their use in construction and timber production. In contrast, the Tamegrout sector has seen an increase in palm tree numbers, particularly in the northwest and east-west zones, thanks to an afforestation and dune stabilization program implemented by the water and forestry services since 1979.

These findings highlight the urgent need to adopt an integrated and sustainable management approach to ensure the long-term preservation of this vital resource

– **Uncontrolled expansion of quarrying activities and their environmental impacts**

The Middle Draa region is characterized by the presence of numerous informal sand extraction sites, alongside a few officially authorized quarries. The exploitation of these sites often exceeds the regenerative capacity of alluvial aquifers, leading to several environmental impacts: disruption of the sediment balance, landscape degradation — particularly near tourist areas such as Zagora (compromising the visual quality of the landscape) — and disturbance of the river's hydrological regime due to the reduction in sand volume within the fluvial terraces of the watercourse.



CONCLUSION

The combined approach—integrating census data analysis (1994–2014), pedological analyses (salinity, pH, organic matter), and the evaluation of agricultural practices—offers new perspectives for assessing the impact of human activities on the oasis environment of the Middle Draa Valley. The findings reveal a population increase in the region, albeit at a rate below the national average, highlighting the socio-economic vulnerability of the area. Population distribution is heterogeneous, with concentrations along the Draa River, strongly influenced by geomorphological factors such as topography and elevation. Demographic growth has led to the expansion of settlements, which encroach upon agricultural lands and adjacent mountain slopes, thereby increasing environmental pressure.

Soil assessments—focusing on salinity, pH, and organic matter content—indicate a predominant trend of soil degradation in the Middle Draa Valley. Salinity, in particular, exhibits significant variability and increases along the upstream-downstream gradient, driven by irrigation practices and intense evaporation. Low organic matter content and high pH levels further contribute to soil vulnerability. This degradation results directly from anthropogenic activities and transformations in agricultural production systems. The intensification of oasis agriculture, prompted by a shift from subsistence to market-oriented production, also poses a threat to ecosystem sustainability. Increased water extraction, the introduction of new crops, and mechanization lead to water deficits, soil salinization, and the spread of diseases (such as Bayoud) affecting date palms.

Although some reforestation programs have been implemented, the ongoing degradation of palm groves in certain areas underscores the need for a more integrated management approach. The shift from traditional (declining) systems to intensive modern systems intensifies pressure on natural resources. Moreover, the unregulated exploitation of informal sand quarries disrupts sediment balances, degrades the landscape, and alters the distribution of hydrological components. This contributes to groundwater pollution and the deterioration of riparian vegetation along the Draa River. In the face of these threats that undermine the functioning of the oasis ecosystem, an integrated and sustainable management strategy.