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Vegetation health evolution and erosion impacts in the Upper Oueltana region (Morocco): An NDVI-based analysis

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KEYWORDS

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INTRODUCTION

The Upper Oueltana region, located in Morocco's Central High Atlas Mountains, represents a vulnerable semi-arid ecosystem where increasing pressures from both natural and human sources have accelerated environmental degradation. This area, covering the communes of Tifni, Sidi Boulkhalf, and Ait Blal, holds ecological and socioeconomic significance for local communities who depend heavily on subsistence agriculture and livestock. However, over the past few decades, intensive agricultural activities, deforestation, and overgrazing have disturbed the natural equilibrium of the region. Combined with irregular rainfall and complex terrain, these practices have led to extensive land degradation, notably reducing vegetation cover and accelerating soil erosion. This study aims to assess changes in vegetation health from 1984 to 2016, utilizing the Normalized Difference Vegetation Index (NDVI) as a quantitative indicator of vegetation dynamics. By tracking vegetation shifts over three decades, the study examines the relationship between human-induced pressures and ecological resilience in this mountainous semi-arid landscape. The findings contribute essential insights into the environmental challenges and adaptive strategies needed for sustainable land management in regions like Oueltana.

METHODOLOGY

The study's primary data source consists of satellite imagery from the NASA Landsat program, covering a time span from January 1984 to December 2016. Specific dates for image acquisition—such as January 1, 1984; March 15, 1990; June 5, 1996; September 20, 2002; December 10, 2008; and May 25, 2016—were selected to provide representative snapshots across the period studied. Each image underwent preprocessing using ERDAS IMAGINE software to correct atmospheric, geometric, and radiometric distortions, thereby ensuring high data reliability. The NDVI, a standard indicator of vegetation health, was calculated for each satellite image using the formula: NDVI=(NIR–RED)(NIR+RED)NDVI = \frac{(NIR - RED)}{(NIR + RED)}NDVI=(NIR+RED)(NIR–RED), where NIR and RED represent near-infrared and red reflectance bands, respectively. NDVI values range from -1 to +1, with higher values indicating healthier vegetation. These NDVI measurements were

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aggregated seasonally and annually to detect long-term trends and fluctuations. Further, spatial analysis allowed for the mapping of NDVI variations across the study area, while botanical field surveys validated the remote-sensing results. This methodology provided a comprehensive view of vegetation health evolution, land cover transformation, and the factors influencing these changes over time.

RESULTS

The analysis classified the region's land cover into six primary types: forests, matorral (shrubland), Euphorbia resinifera, fruit orchards, annual crops, and bare land. From 1984 to 2016, forest cover experienced a marked reduction, declining from approximately 5,635 hectares (representing 11.73% of the total area) in 1984 to around 3,250 hectares (3.58%) by 2016. This translates to an average annual loss of 74.55 hectares. Similar declines were observed in matorral and Euphorbia resinifera habitats, highlighting an overall trend of vegetative regression and ecosystem vulnerability. The most severe vegetation loss occurred from 1984 to 2000, with an average annual reduction of 319.54 hectares. However, from 2006 to 2016, some areas saw an increase in fruit orchards, which grew from 4,227 hectares in 2000 to 47,323 hectares by 2016, as local farmers shifted towards cultivating almond, olive, and carob trees. While these orchards provide benefits such as soil retention and supplemental income, they cannot fully counteract the broader ecological degradation.

DISCUSSION

The decline in vegetation cover has significant implications for soil erosion and water management, particularly in a region characterized by steep slopes and seasonal rainfall. Reduced vegetation decreases the soil's capacity to absorb water, leading to greater surface runoff and heightened erosion risks. This is especially evident on slopes with inclines exceeding 15 degrees, where soil loss is accelerated by gravity and rainfall. The predominant agricultural practices in the region—such as intensive plowing, overgrazing, and fallowing—further exacerbate erosion by exposing soil surfaces to the elements and disrupting natural hydrological cycles. Despite local efforts to mitigate these impacts through erosion control structures like terraces, these interventions face limitations. Terracing, which involves constructing soil-retaining walls along slopes, can reduce runoff velocity and soil loss, but maintaining these structures requires consistent labor and financial resources, both of which are scarce in this rural area.

The substitution of natural vegetation with fruit trees has provided some stabilization, particularly with trees like almond and olive that are well-suited to semi-arid conditions. However, this adaptation strategy faces limitations in terms of scalability and long-term sustainability. The labor-intensive nature of maintaining terraced orchards and the costs associated with fruit tree cultivation are prohibitive for many local farmers. Furthermore, replacing native vegetation with fruit orchards, while beneficial for soil retention, does not restore the ecosystem's original structure and functions, potentially limiting biodiversity and altering soil quality.

Since 2006, socio-economic shifts, including the increased use of gas for cooking, have alleviated some pressure on forest resources by reducing the reliance on wood for fuel. This change, although beneficial for forest preservation, underscores the complex socio-economic factors that influence environmental practices. The expansion of fruit orchards represents a form of adaptation to both environmental and economic pressures, yet the high costs and maintenance demands associated with these practices, combined with rural depopulation, hinder their effectiveness on a larger scale. As a result, without broader support for sustainable practices, these adaptive strategies may remain insufficient to address the full scope of environmental degradation in Oueltana.

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CONCLUSION

The findings of this study underscore the importance of sustainable land management practices for preserving the ecological health of the Upper Oueltana region. The NDVI analysis reveals a clear trend of vegetation decline over the past three decades, driven by unsustainable agricultural practices, deforestation, and climate variability. This degradation has led to increased erosion, reduced soil fertility, and decreased biodiversity, posing significant threats to the region's resilience. To address these issues, there is an urgent need for comprehensive conservation policies and community-based strategies that encourage sustainable agricultural practices.

Policy Implications and Recommendations

Several measures could help mitigate environmental degradation in Oueltana and support the region's ecological and socio-economic resilience:

- **Promote Agroforestry:** Integrating trees into agricultural landscapes could enhance soil stability, increase biodiversity, and offer farmers additional income streams.
- **Encourage Community Engagement:** Greater involvement of local communities in conservation initiatives could strengthen collective environmental protection efforts. Education and training programs on sustainable practices could build awareness and empower local populations.
- **Implement Sustainable Grazing Practices:** Regulating grazing pressure through strategies like rotational grazing could reduce overgrazing impacts and allow for vegetation recovery. Managing livestock distribution and grazing intensity would mitigate soil degradation while maintaining livestock productivity.
- **Establish Protected Areas:** Designating conservation zones could preserve critical habitats, prevent deforestation, and maintain ecosystem balance. Policies could be crafted to protect native flora and manage human activities sustainably within these zones.

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