E3S Web of Conferences **502**, 03008 (2024) https://doi.org/10.1051/e3sconf/202450203008
ICCR 2023

Diachronic Study of Coastal Vegetation Cover in Al Hoceima (Morocco): A Geospatial Analysis Using Remote Sensing and GIS

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Abstract. Coastal ecosystems are vital land-sea interfaces that are necessary to sustain environmental stability and biodiversity. In many places, the complex network of vegetation cover serves as an essential buffer, preventing erosion, sustaining a variety of habitats, and enhancing ecological resilience overall The study utilizes advanced technologies like GIS, remote sensing, and Landsat images to analyze vegetation changes in Sfiha and Swani's coastal regions over the past 18 years, aiming to understand the impact of land use, climate fluctuations, and human activities on the landscape, Sophisticated remote sensing technology, Landsat satellite images, and Geographic Information System (GIS) tools are among the materials employed. During the designated period, the proportions of changes in the plant cover in the research area are determined and interpreted with the help of these resources. The study reveals significant changes in vegetation cover in Sfiha and Swani, revealing patterns of 21% (2003), 25% (2010), 33% (2015), and 15% (2021), providing insight into the temporal evolution of the coastal ecosystem and influencing conservation strategies and sustainable management practices. This study underscores the broader relevance of employing advanced spatial technologies for the monitoring and management of coastal ecosystems.Introduction

1 Introduction

Morocco's diverse plant cover, including forests and desert plants, is vital for biodiversity and ecosystem services. However, it faces challenges from human activities like agriculture, urbanization, habitat fragmentation, and climate change[1]. Understanding Morocco's vegetation is crucial for sustainable land management techniques.

Coastal areas like Sfiha and Swani in Al Hoceima present dynamic ecological interfaces and natural borders, highlighting the global challenge of balancing environmental conservation with socio-economic development amid increasing anthropogenic pressures and environmental changes[2].

The study examines the metamorphosis of the Sfiha-Swani coastal region from 2003 to 2021 using advanced sensing and GIS technologies. It uses multi-temporal satellite imagery, Landsat ETM+ and OLI datasets, and aerial photographs from Google Earth. Digital image processing and radiometric corrections enhance the scientific strength and reliability of the results[3]

The study examines the changes in land cover and vegetation in the Sfiha-Swani coastal region of Al Hoceima, Morocco, over 18 years from 2003 to 2021. It aims to characterize the transformation, identify the causes, and quantify the proportions of vegetation changes. The research uses advanced remote sensing and GIS technologies to create detailed land cover maps, compute the Normalized Difference Vegetation Index, and identify degradation zones. The study aims to provide a deeper scientific understanding of coastal ecosystems and offer guidance for sustainable management and conservation strategies.

2 Methodology

2.1 Pre-treatment

Preprocessing functions, involving radiometric and geometric corrections, are essential before primary analysis and information extraction.

<u>Radiometric corrections</u>: are crucial for accurately delineating and visualizing images, accounting for illumination, visual geometry, climatic conditions, noise, and sensor reactions. These adjustments are influenced by the sensor, platform, and data collection circumstances. Two color compositions were created for satellite images: natural colors for ArcMap classification and fake colors to highlight vegetation cover[4]

<u>Geographical correction</u>: The goal of this step is to minimize geometric deformations in scene recording, including environmental deformations, measurement errors, and platform movements, by transforming data into real coordinates like latitude and

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 https://doi.org/10.1051/e3sconf/202450203008

longitude, which can then be superimposed on other information layers [5].

The images undergo geometric corrections for georeferencing in the UTM coordinate system and superimposition, enabling classification comparison and temporal variation detection, by transforming them to fit the required map projection.

Delimitation of the study area: The study area was delimited using a Shapefile after geometric and radiometric correction of Landsat images, allowing for the extraction of the desired portion of the satellite scene.

2.2 Treatment

NDVI cards*:* NDVI, or Normalized Difference Vegetation Index, is a widely employed vegetation metric in remote sensing[6]. Calculated from red and near-infrared bands of satellite imagery using the equation (1)

$$NDVI = (PIR - R) / (PIR + R) \text{ [7]} \quad (1)$$

It produces an image portraying vegetation density across a landscape, with colors representing values between -1 (bare floor) and 1 (dense vegetation cover)[8]. This tool, essential for assessing vegetation health and distribution, finds applications in agriculture, forestry, and environmental monitoring.

Land Use Map: The study uses aerial photos from Google Earth to visually represent land types in a specific area, such as urban zones, forests, croplands, and water bodies. The method uses supervised classification to identify land cover classes, defining polygons for each pixel based on spectral, spatial, morphological, and textural characteristics, enabling pixel probabilities and assignment to the most probable class.

Statical study: Using ArcGIS, the study calculates vegetation cover area for NDVI maps and land use maps for selected years, allowing comparisons between years. Measurements are grouped in Excel and converted into diagrams for easier study and determination of vegetation loss and evolution.

Fieldwork: is crucial for studying land cover evolution, as it validates satellite images and provides photographs to understand ground occupation phenomena. It aids in identifying vegetation species, genus, status, and distribution, and provides insights into human activities causing vegetation damage, enhancing our understanding of land cover evolution.

3 Results

3.1 NDVI maps

In this study, the calculation of the Normalized Difference Vegetation Index (NDVI) resulted in five classes: very dense vegetation cover, sparse vegetation cover, agricultural systems, bare soil, and sea water. For detailed analysis, the focus is on the first four categories.

In 2003, the NDVI map revealed that 8% of the study area was covered by very dense vegetation (0.35-0.65), while sparse vegetation cover (0.20-0.35) occupied 6%. The majority of the zone was divided between agricultural systems and semi-bare areas (25%) and bare soil (25%).

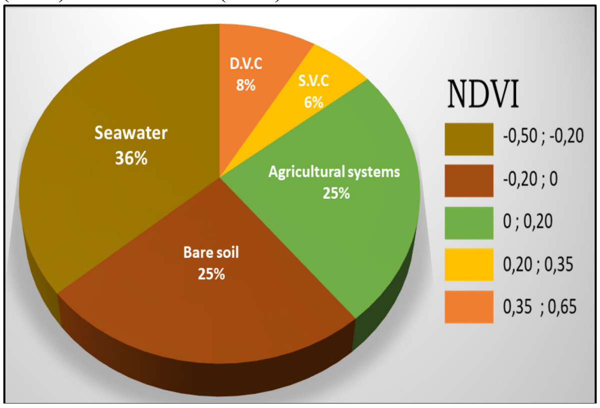

Fig. 1. Diagram of the proportions of NDVI classes according to the area (Sfiha-Swani,2003), (D.V.C: Dense vegetation cover, S.V.C: Sparse vegetation cover)

In 2010, agricultural systems and semi-bare soil (0.095-0.044) dominated 26% of the area, followed by sparse vegetation cover (0.23-0.095) at 17%, and dense vegetation (0.5-0.23) at 12%.

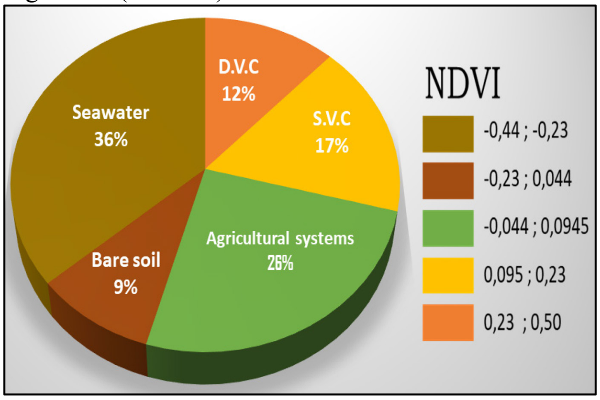

Fig. 2. Diagram of the proportions of NDVI classes according to the area (Sfiha-Swani2010)

In 2015, a large portion of the area was again occupied by agricultural systems and semi-bare soil (0.16-0.25), covering 17%, followed by sparse vegetation cover (0.25-0.35) at 17%, and dense vegetation (0.35-0.6) at 14%.

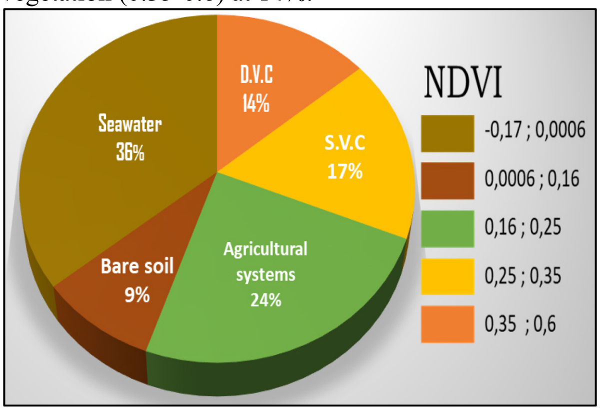

Fig. 3. Diagram of the proportions of NDVI classes according to the area (Sfiha-Swani,2015)

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By 2021, agricultural systems and semi-bare soil (0.098-0.15) and bare soil (0-0.098) dominated, covering 1.87 km^2 and 1.93 km^2, respectively. Sparse vegetation cover (0.22-0.15) occupied 15%, while dense vegetation (0.44-0.22) covered 8%.

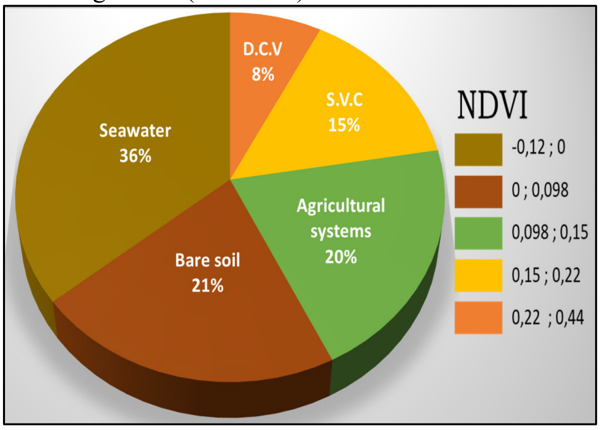

Fig. 4. Diagram of the proportions of NDVI classes according to the area (Sfiha-Swani,2021)

3.2 Land use maps

This study's diachronic analysis of land use maps from 2003 to 2021 reveals significant landscape changes. Six land use classes; dense forest cover, light forest cover, agricultural systems, buildings, bare soil, and water, were identified.

In 2003, the land use map indicates that 66% of the area is covered with bare land (approximately 2 km^2), with dense forest cover and agrosystems each occupying 12%, sparse forest cover at 9%, and buildings accounting for the remaining 1%.

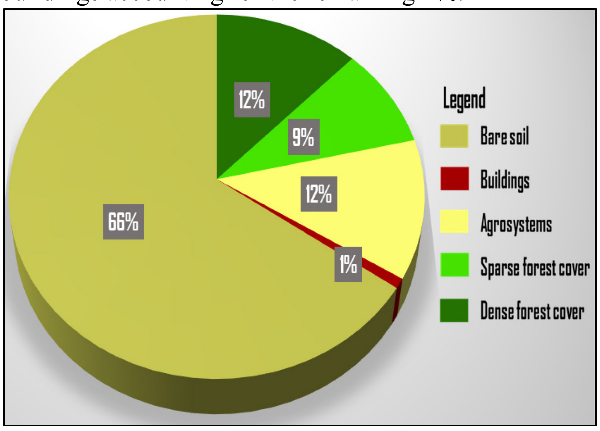

Fig. 5. Diagram of the proportions of the classes that occupy the ground (Sfiha-Swani,2003)

In 2010, bare land dominated the study area, covering 61% (1.82 km^2), followed by dense forest cover at 14%, while sparse forest cover and agrosystems have a smaller presence.

In 2015, a large portion (53%) was covered with bare land, with dense forest cover at 2.22%. Sparse forest cover and agrosystems each occupy 11%, and buildings have a low occupancy rate of 3%.

In 2021, bare soil becomes the dominant land cover, covering 53% (1.59 km2), followed by built-up areas at 25% (0.77 km^2). Dense vegetation covers 9% (0.27 km^2), surpassing sparse forest cover (0.17 km^2) and agrosystems (0.2 km^2). These changes highlight the dynamic evolution of the landscape over the analyzed period.

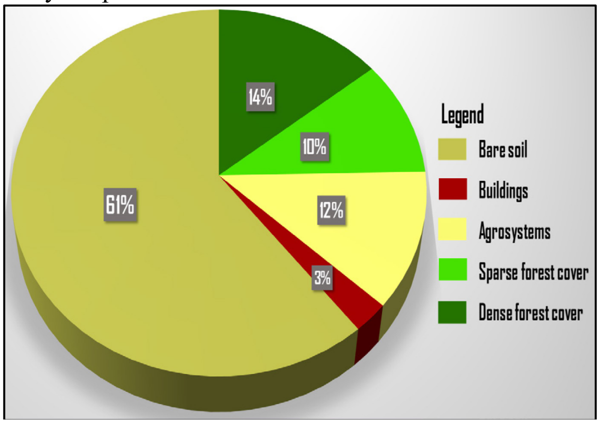

Fig. 6. Diagram of the proportions of the classes that occupy the ground (Sfiha-Swani,2010)

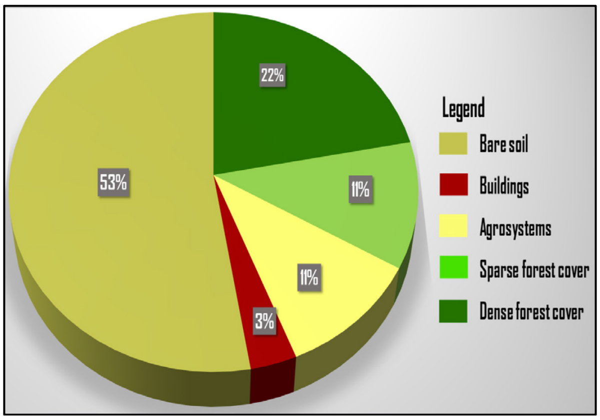

Fig. 7. Diagram of the **proportions** of the classes that occupy the ground (Sfiha-Swani,2015)

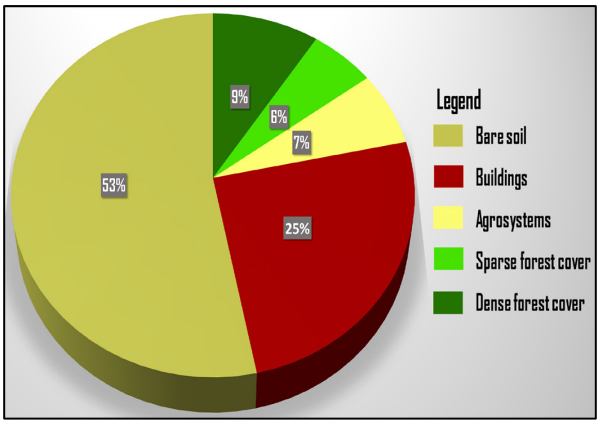

Fig. 8. Diagram of the proportions of the classes that occupy the ground (Sfiha-Swani,2021)

4 Discussion

From 2003 to 2015, vegetation changes occurred, notably an increase in forest cover from 21% to 33%. Land cover was dominated by bare soil, dense forest, agrosystems, and sparse forest, with urban areas in smaller proportions (Fig.9). This growth was influenced by increased precipitation, possibly due to declining Oued Ghis water levels and climate change effects.

Between 2015 and 2021, significant disruptions led to vegetation degradation (Fig.9), resulting in an 18% reduction in forest cover from 33% to 15%. Urban areas surged by 22%, dominating the study area over arid lands and structures, surpassing forest cover (Fig.10).

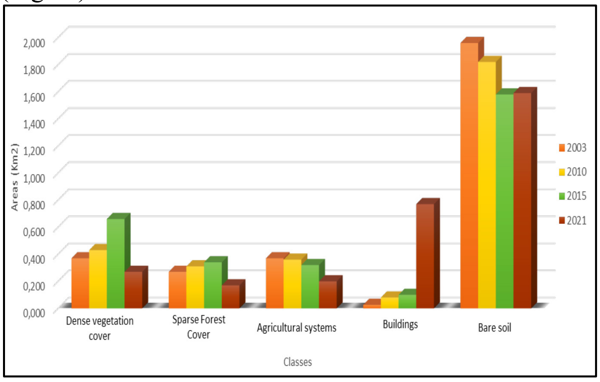

Fig. 9. Histogram of the evolution of the areas by class

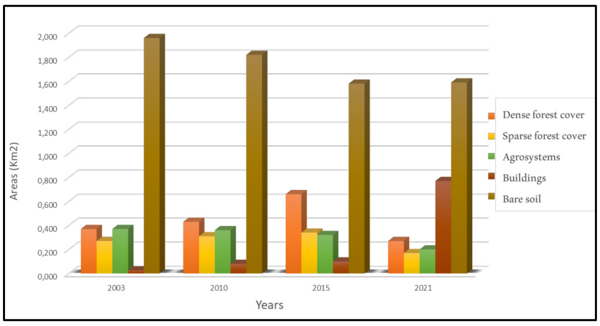

Fig. 10. Histogram Analysis: Evolution of Class Areas Over the Years

In general, The Sfiha-Swani region experienced a notable 20% reduction in plant growth between 2003 and 2021, equating to a loss of 0.2 km² of forest cover, particularly around Sfiha beach This decline is attributed to human activities like fires, grazing, deforestation, and parasitic attacks on pines, as well as variations in dry spells and marine intrusion.

5 Conclusion

The Sfiha-Swani coastal region experienced a significant increase in forest cover from 21% to 33% between 2003 and 2015, indicating its resilience to environmental factors like precipitation and climate change. However, this has been reduced to 15% by 2021, highlighting the ecosystem's vulnerability. The notable increase in urban areas within the region in 2021 highlights the intricate interplay between conservation imperatives and socio-economic developmental dynamics.

In summary, the Sfiha-Swani region serves as a microcosm of global challenges in balancing environmental conservation and development. This study contributes valuable insights into the spatio-temporal dynamics of coastal ecosystems, fostering a deeper scientific understanding crucial for informed decision-making and sustainable environmental stewardship.

6 Recommendation

In light of our findings, recommendations for sustainable management of the Sfiha-Swani coastal region include implementing land-use planning strategies to mitigate urban sprawl and protect critical ecosystems. Robust conservation measures for the remaining forest cover are essential, addressing factors like fire prevention, controlled grazing, and reforestation efforts. Community engagement and awareness programs can foster local participation in conservation initiatives. Additionally, monitoring and early detection systems for parasitic attacks on vegetation are crucial. Finally, fostering interdisciplinary research collaborations can enhance our understanding of complex coastal dynamics, guiding evidence-based policies for long-term environmental health.

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