Tourism Investment and Land Use Change in the Northern Piedmont of the Western High Atlas (1989-2022)

Hamza Ait Zamzami1*, Mohammed Elaanzouli1, Ayoub Zahrani1, Jamila Saidi1, Taieb Boumeaza1, Muhammad Musiyam2

1 Laboratory of Dynamics of Spaces and Societies (LADES), Department of Geography, Faculty of Arts and Humanities, HASSAN II University of Casablanca, Mohammedia, Casablanca 20000, Morocco
2 Faculty of Geography, Universitas Muhammadiyah Surakarta, Surakarta 57169, Indonesia

*Correspondence: hamza.aitzamzami-etu@etu.univh2c.ma

Abstract
This study aimed to investigate the profound influence of tourism investment on the northern piedmont of the western High Atlas over 34 years in response to the escalating global trend of tourism-driven land-use changes, particularly in the Marrakesh region. In this context, the driving forces behind the significant transformation of agricultural land and bare soils into tourism-driven investments were evaluated, and the critical role of accessibility was examined in shaping spatial shifts. The method used high-resolution (10 m) satellite images from Spot 1 (1989), Spot 5 (2003 & 2010), and Sentinel 2 (2022) through remote sensing methods to investigate the historical land-use changes over 34 years. The results showed significant transformations in land use based on the correlation between improved transportation infrastructure and the growth of tourism ventures, underscoring the role of roads and facilities as catalysts. The analysis suggested the need for reflection on the consequences of unregulated tourism growth, aiming to balance economic benefits with environmental and socio-cultural challenges in sensitive regions. Although tourism significantly contributed to economic development and employment opportunities, it also posed risks when not managed prudently. This underscored the need to strike a harmonious equilibrium between economic prosperity and the preservation of the region’s unique natural beauty and cultural heritage. The insights provided in this analysis had broader implications for responsible planning and management of tourism development in sensitive ecological and cultural regions. In conclusion, a thoughtful and sustainable approach was needed to safeguard the delicate balance between economic prosperity and environmental preservation.

Keywords: tourism investment; land-use dynamics; spatial remote sensing; accessibility and tourism; sustainable tourism development.

1. Introduction
Tourism is an important economic activity capable of stimulating economic growth, creating jobs, and fostering sustainable development (Raihan, 2024; Susila et al., 2024). Investment in this sector plays a crucial role in improving the quality of life among local populations, serving as a driver of regional and national development (Makkonen & Williams, 2024; Tong & Zhang, 2022). However, negative environmental and social impacts may occur in the absence of appropriate planning and management (Glyptou, 2022; Khusnani et al., 2023; Prayug et al., 2023). Tourism investment has a significant impact on land-use changes (Yasemin Sarıkaya Levent et al., 2024), leading to the conversion of agricultural and forest land into golf courses, leisure parks, or shopping malls, with negative consequences for local livelihoods and biodiversity (Mattah et al., 2024). The construction of tourism infrastructure potentially leads to habitat fragmentation and a loss of ecological connectivity, which may affect the survival of certain animal and plant species (Ma et al., 2024). However, tourism investment can also help to protect the environment and conserve natural landscapes, particularly in areas threatened by unregulated development or unsustainable economic activities. In response, natural areas are preserved, and more income is generated for local communities through activities such as birdwatching, wildlife tourism, and ecotourism (Higgins-Desbiolles et al., 2018; Pengfei Zhang et al., 2024).

Marrakech region is one of Morocco’s most popular tourist destinations, and it is known for its rich cultural heritage, bustling markets, and spectacular scenery. However, the rapid growth of tourism in recent years has also created social and environmental challenges that must be addressed to ensure the sustainability of the industry (Rafik, 2023). Existing scholarly literature pertaining to sustainable tourism in the Marrakech region of Morocco has extensively examined multiple facets of the business, encompassing regulatory interventions, social and environmental obstacles, and the imperative for adopting sustainable practices. Previous study conducted by Mohamed et al. (2019) and Gomih et al. (2021) have mainly examined sustainable tourism policy in the region. However, a significant research vacuum pertains to the spatial dimension of land use change and its influence on tourism investment.
In response to the gap, this study focuses on the northern piedmont of the Western High Atlas, an area witnessing a surge in tourism investment. This trend, driven by the region's popularity and government initiatives, significantly impacts land use and natural resources. To address the lack of data, spatial remote sensing methods and high-resolution satellite imagery (10 meters) from SPOT 1, SPOT 5, and Sentinel-2 satellites were used to analyse land-use changes over 34 years (1989-2022) in the western High Atlas Piedmont. By providing a "solid ground truth" on past developments, the results offer insights for stakeholders into the impact of legitimate tourism investment and the grouping patterns of illicit activities. The insights can help understand the crucial role of infrastructure, particularly network roads, in facilitating tourism investment, the dynamic relationship between these activities, and potential contribution to local enrichment. This entails contemplating investment in sustainable tourism, which aims to balance economic development with considerations for environmental and social well-being (Susila et al., 2024).

To achieve the objective, this article is organised as follows: the next section will elaborate on the data analyses from satellites SPOT 1, SPOT 5, and Sentinel-2 to identify land use changes and environmental implications—results and discussion follow this section. Finally, it ends up with a conclusion section.

2. Research Methods

2.1 Study Area

The study area, located in the heart of the piedmont of the western High Atlas (Dir of Marrakech), extends over 1500 km², from Marrakech City in the north to the Atlas Mountains in the south, covering 12 territorial communes (Figure 1). These include Moulay Brahim, Ourika, Tameslohte, Aghouatim, Sidi Abdellah Ghiat, Ghmat, Tassoultante, Lalla Takarkoust, Ouazguita, Ait Faska, Tamazouzte, and Tahannaout. This area is characterised by lush green valleys, luxuriant palm groves, spectacular farmland, and low topography, creating a unique and attractive ecosystem for a livable space. The Atlas Mountains, which dominate landscape, play a crucial role in regulating the local climate and the distribution of rainfall. The region is also home to essential natural resources, such as fertile, agriculturally-suitable soils and groundwater sources (Abdelfadel et al., 2021; Roubil, et al., 2022).

Due to the unique attractions, the study area is a must-see tourist destination (Ali et al., 2021), with the picturesque landscapes attracting nature lovers and adventurers. The rich Berber culture is also on display, with authentic traditions and immersive cultural experiences.

![Figure 1. Geographic location of the study area.](image-url)
2.2 Data

The data used for this study were collected from a variety of sources (Table 1). For 1989, SPOT-1 images were used with 20 m and 10 m resolution (visible and panchromatic), while for 2003 and 2010, SPOT-5 images were used with 10 m resolution (Nosavan et al., 2020). Finally, for 2022, Sentinel 2-A images were used with 10 m resolution, supplied by the ESA (European Space Agency) platform on Table 1.

Table 1. Characteristics of satellite data used.

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch</th>
<th>Selected date</th>
<th>Spatial resolution</th>
<th>Spectral bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOT-1</td>
<td>1986</td>
<td>September 1989</td>
<td>Panchromatic band 10 m. Multispectral bands 20 m.</td>
<td>Green band (0.50 - 0.59 µm) Red band (0.61 - 0.68 µm) Near-infrared band (0.79 - 0.89 µm)</td>
</tr>
<tr>
<td>SPOT-5</td>
<td>2002</td>
<td>July 2003 and August 2010</td>
<td>Panchromatic band 2.5 m. Multispectral bands 10 m.</td>
<td>Green band: 0.50 - 0.59 µm Red band: 0.61 - 0.68 µm Near-infrared band: 0.79 - 0.89 µm</td>
</tr>
<tr>
<td>Sentinel 2</td>
<td>2015</td>
<td>July 2022</td>
<td>Bands 2, 3, 4, 8, 11, and 12: 10 meters, Bands 5, 6, 7, 8A, and 9: 20 meters, Bands 1 and 10: 60 meters.</td>
<td>Band 1 (Blue): 0.435 - 0.450 µm Band 2 (Green): 0.490 - 0.510 µm Band 3 (Red): 0.620 - 0.670 µm Band 4 (Bright Red): 0.665 - 0.680 µm Band 5 (Near-infrared): 0.690 - 0.710 µm Band 6 (Near-infrared): 0.740 - 0.760 µm Band 7 (Near-infrared): 0.770 - 0.790 µm Band 8 (Near-infrared): 0.835 - 0.865 µm Band 8A (Near-infrared): 0.860 - 0.880 µm Band 9 (Short-wave infrared): 0.935 - 0.955 µm Band 10 (Short-wave infrared): 1.360 - 1.390 µm Band 11 (Short-wave infrared): 1.560 - 1.660 µm Band 12 (Short-wave infrared): 2.100 - 2.300 µm</td>
</tr>
</tbody>
</table>

Aside from satellite data, aerial imagery was used to obtain historical terrain samples. These samples were extracted using Google Earth Pro. Vector data were also used to delimit the study area and locate tourism investment, while satellite image processing and spatial analysis were carried out using QGIS and SNAP. The software packages were used for in-depth analyses of the images, extracting relevant information, and performing spatial manipulations to meet the objectives of the study.

2.3 Preprocessing

Several preprocessing processes were applied for the satellite and aerial data used to improve image quality and facilitate analysis.

- Atmospheric correction: Satellite images can be affected by atmospheric effects such as light scattering and absorption. Atmospheric correction reduces these effects and makes images more faithful to the earth's surface (Bégué et al., 2020; Sòria-Perpinyà et al., 2022).
- Georeferencing: Georeferencing entails associating images with precise geographic coordinates for consistency with a common spatial reference (Román et al., 2024). This enables images to be superimposed on other geospatial data and analysed together.
- Geometric rectification: Geometric rectification eliminates distortions caused by topographical variations, image projection, and sensor movements. This ensures that images are accurately and consistently matched.
- Image fusion: Fusion entails combining several images of the same scene, such as multispectral and panchromatic, taken at different spectral bands or resolutions, to obtain a single composite image with richer information. In the specific case of the SPOT-1 multispectral image from 1989, image fusion was used to improve spatial resolution to 10 meters. This was achieved by combining with a suitable panchromatic image. Data analysis and visualisation become more precise and detailed by increasing spatial resolution, enabling better interpretation of the information contained in the composite image (Xing et al., 2022).
- This preprocessing was carried out using specialised software such as QGIS, SNAP, or other image processing tools.

2.4 Data processing

2.4.1. NDVI
Once the satellite images had been preprocessed, including atmospheric correction, geo-referencing and geometric rectification, normalised difference vegetation index (NDVI) map was generated. The mathematical definition shows that NDVI of an area containing dense vegetation cover will tend towards positive values (0.3 to 0.8), while negative values characterise clouds and snowfields.

Other terrestrial targets visible from space include stagnant water (oceans, seas, lakes, and rivers), which has a rather low reflectance in both spectral bands (at least far from the shore), resulting in very low or even slightly negative NDVI values (Landsat Normalized Difference Vegetation, 2023).

The images covering Marrakech Piedmont area with a spatial resolution of 10 m were imported into SNAP image processing software to calculate NDVI. NDVI was calculated using the Equation 1 (Chen, 2008; Sharma et al., 2022). Where PIR represents the near-infrared band (0.835 - 0.865 µm) and R represents the red band (0.620 - 0.670 µm) (Sharma et al., 2022).

\[
\text{NDVI} = \frac{\text{PIR} - \text{R}}{\text{PIR} + \text{R}}
\] (1)

NDVI images were used to map land cover, due to the availability of high-resolution data for the years 1989, 2003, and 2010 (PIR, R bands). NDVI map obtained was used for land cover/land-use analyses, including classification, detection of changes in vegetation cover, and assessment of ecosystem health in the study area (Saha et al., 2024).

### 2.4.2. Land use

Land cover was mapped after obtaining NDVI images of the study area for 1989, 2003, 2010, and 2022. NDVI method offers several advantages for land cover mapping, including being more sensitive to vegetation (Patil et al., 2024; Li et al., 2024). Using this index, it becomes possible to differentiate areas with dense vegetation from those with sparse levels (Alexandre et al., 2024). This is because NDVI is derived by calculating the difference between the near-infrared (NIR) and red bands of a satellite image, as vegetation reflects NIR light more than red light. Furthermore, NDVI is relatively independent of atmospheric conditions (Peluzio & C., 2024), providing consistent estimates of vegetation even in the presence of clouds or other atmospheric phenomena (Lee et al., 2024; Musiyam et al., 2020; Hadibasyir et al., 2020). The method is not affected by atmospheric aerosols or water vapour, which can obscure the red and NIR bands of a satellite image. Finally, the ability to acquire NDVI images at different dates enables precise temporal monitoring of seasonal changes in vegetation and analysis of long-term trends. This ability is a major asset for land cover mapping. For example, NDVI can be used to track deforestation, monitor crop yields, and assess the impact of climate change on vegetation cover.

![Diagram of data processing](image)

**Figure 2.** Method assessing the impact of tourism investment on land-use through satellite data.
Training samples were collected, and NDVI thresholds were determined to differentiate between different land-use classes. The five main classes identified include bare soil, pasture, and fallow land or Bour (non-irrigated crops), irrigated vegetation, trees and forests, and water bodies. These classes facilitated the analysis of trends and variations in the distribution of land-use types over time (Foody et al., 2002). Understanding land use dynamics is crucial to identify ecological processes and environmental changes occurring in the study area (Herold et al., 2008; Turner et al., 2007).

3. Results and Discussion

The examination of 1037 samples shed light on the impact of tourism investment on land-use change and vocation. The land-use mapping results for the years 1989, 2003, 2010, and 2022, depicted in Figure 3, provided a foundational understanding of the temporal shifts in land utilization. Figure 4 further delved into the historical preoccupations with land use, highlighting the significant transformations experienced. Specifically, agricultural lands, comprising 407 samples of irrigated and tree crops, historically dedicated to farming activities, have undergone a transformation into tourist resorts. Similarly, areas categorized under weeds/grazing, which included 67 samples and were once used as natural pastures or for rain-fed cultivation, have become fallow following the advent of tourism projects. This transition suggests that the introduction of tourism infrastructure precipitated the abandonment of agricultural practices in these areas, making way for tourism-related developments. In contrast, bare soil, which accounted for 558 samples, did not witness substantial change in land use. However, these lands have been earmarked for tourism investments, notably for the construction of villas complemented by vegetated areas such as gardens and green spaces, indicating a nuanced approach to integrating tourism within the natural landscape.

Figure 3. Evolution of land cover in the Western High Atlas Piedmont across decades. Panel (a) presents the land cover map for the year 1989, utilizing data from SPOT 1 satellite imagery. (a) Time series of land cover maps for 1989 (SPOT 1), (b) time series of land cover maps for 2003, (c) time series of land cover maps for 2010 (SPOT 5), and (d) time series of land cover maps for 2022 (Sentinel 2).
3.1. Spatial Distribution of Tourism Investments by Origin

The maps produced show the uneven distribution of investment. Figure 5 shows a high concentration of tourism investment near the urban perimeter of Marrakech located in the communes of Tassoultante and Aghouatim. This concentration is explained in part by the lack of availability of undeveloped land in Marrakech, which has led to a strong demand for land and opened up investment opportunities in the tourism sector (Kurniawansyah et al., 2023; Stapane et al., 2023).

In the eastern part of the study area, a more even spread of tourism investment was observed, originating from land previously used for agricultural purposes (Basuki et al., 2022). The abundance of this category was attributed to the flourishing agricultural activity in the communes of Ghmate, Ourika, and Tamazoutte, where water resources, such as Oued Ourika and Issyl and the tributaries, favour development. However, a new investment trend was observed associated with the road infrastructure (Mamirkulova et al., 2020). Figure 6 explains this concentration, which
has affected farmland. Provincial road N° P2017 links Marrakech to the natural tourist landscape of Ourika and Sti Fadma.

![Figure 6. Example of land-use change and tourism investment implementation in the Northern Piedmont of the Western High Atlas.](image)

### 3.2. Infrastructure Impact On Tourism Investment Implementation

The west zone was characterised by a concentration of tourism investments on land that was initially unfit for agricultural use. This zone covering the communes of Tameslouht and Agafay has limestone soil not very suitable for agriculture but possesses great potential for tourism (Piotr Migoń, 2024; Carvalhinho et al., 2024). The Agafay region of Marrakech attracts visitors with a diversity of activities including hiking in desert landscapes, quad biking for adrenaline seekers, and camel riding for an authentic experience. Starry evenings fascinate astronomy enthusiasts and desert camps offer sumptuous moments of relaxation. Agafay is a photographer's paradise due to the presence of breathtaking landscapes.

![Figure 7. Map of tourist axis according to the distribution of tourist investment.](image)
This type of tourism investment remains closely associated with basic infrastructure, particularly the road network. Figure 7 summarises the main roads that concentrate tourism investment, specifically those leading from Marrakech to:

- Ourika and Sti Fadma and high Atlas Mountains on provincial road N° P2017.
- Tahannouate and Toubkal National Park (PNT) on national road N°7.
- Towards Lalla Takerkoust dam and Amizmiz centre on provincial road N°P2009.

Road infrastructure has a significant impact on the implementation of tourism investment and accessibility to areas with great potential (Adhuze et al., 2023; Valeriani et al., 2020). Figure 8 shows the distribution of tourism investment by distance to roads and accessibility.

![Figure 8](image)

**Figure 8.** Trend of tourism investment classified by distance to the nearest road in the Northern Piedmont of the Western High Atlas.

This study found a highly compelling and statistically significant relationship in the analysis of tourism investment in relation to road distance (Chavan & Bhola, 2013). The strong correlation between the presence of road infrastructure and tourism investment was indicated by the significant R-squared value (R²) of 0.9671 (Figure 9).

![Figure 9](image)

**Figure 9.** Relationship between road distance and tourism investment in the Northern Piedmont of the Western High Atlas.

This R² value signifies that approximately 96.71% of the variability in tourism investment in the Northern Piedmont of the Western High Atlas could be explained by road distance in the regression model. In simpler terms, the proximity to road infrastructure is an exceptionally powerful...
predictor of tourism investment in this specific geographic region. The convenience and accessibility provided by road infrastructure play a significant role in influencing the distribution of tourism investment (Maziliauske, 2024).

3.2. Discussion

The analysis underscores the crucial role of road infrastructure as a driving force behind tourism investment, emphasising the need for decision-makers, investors, and regional planners to consider road accessibility in guiding the strategic development of tourist destinations (Shen, 2024). A well-developed road network is shown to attract higher tourism investment, ultimately enhancing the region's overall appeal and economic potential. Moreover, the practical implications of spatial analysis were significant, enabling the identification of spatial concentrations of tourism investment and offering insights into basic infrastructure as well as local land suitability (Mo Fan et al., 2024; G. Dong et al., 2021). This information can be used to better target resources and efforts to address land-use change issues (Statopoulos et al., 2023). Furthermore, spatial analysis provides a solid foundation for future studies aimed at understanding the underlying causes of spatial distributions in tourism investment (Robinson, 2018).

This spatial analysis has certain limitations, for example, the spatial land data were sourced from satellite imagery and field visits, which might contain measurement errors or biases. In addition, the method used was based on specific assumptions, capable of influencing the results. Due to data constraints, this study did not take into account certain important variables related to the type of land in Morocco. It is essential to take the limitations into account when interpreting the results of the analysis.

4. Conclusion

This comprehensive analysis showed the significant impact of tourism investment on the evolving landscape of the Northern Piedmont of the Western High Atlas. As fertile farmland experiences a transformative shift into tourist destinations, concerns arise regarding environmental sustainability and the welfare of local communities. This study underscored the critical importance of a nuanced method to tourism development, with a particular focus on the intricate interplay of land-use and cover.

A dedicated examination of road accessibility and statistical correlation with tourism investment showed a compelling relationship. The significant R-squared value of 0.9671 underlined the indispensable role of well-connected road infrastructure in shaping the distribution of tourism investment in the region. This statistical significance demonstrates the symbiotic relationship between tourism development and a well-developed road network.

Considering the future trajectory for the Northern Piedmont of the Western High Atlas, this study underscored the importance of integrating sustainable practices into tourism planning. The benefits of tourism development must coincide harmoniously with environmental preservation as well as the socio-economic well-being of local communities. Moreover, the statistical insights into the correlation between road accessibility and tourism investments offer a strategic foundation for future decision-making. This study advocates for continued investigations to deepen the current understanding of intricate dynamics. Collaborative efforts between stakeholders and additional investigation attempts are needed to make tourism become a force for positive transformation. In this vision, economic prosperity coexists with ecological health while preserving the region's unique cultural heritage.

References


