

Amraoui, M., Bouabidi, L., El Amrani, M., Ouakhir, H., Dudic, B., Lukić, T., & Spalevic, V. (2024). Land use dynamics and soil conservation strategies in the El Kssiba Region, Atlas Mountains of Morocco. Agriculture and Forestry, 70(3), 7-27. <https://doi.org/10.17707/AgricultForest.70.3.01>

DOI: 10.17707/AgricultForest.70.3.01

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LAND USE DYNAMICS AND SOIL CONSERVATION STRATEGIES IN THE EL KSSIBA REGION, ATLAS MOUNTAINS OF MOROCCO

SUMMARY

This study investigates the dynamics of land use and land cover (LULC) changes in the El Kssiba region of the Middle Atlas Mountains, Morocco, with a focus on soil conservation and environmental sustainability. Through a comprehensive examination of historical archives, climatic data, geological characteristics, and land use patterns, this research assesses the impacts of environmental factors and socio-economic changes on land utilization over time. The study area, covering 576.57 km², has experienced significant transformations in land use driven by government policies, population growth, land tenure, and climatic conditions. Findings reveal a notable decline in agricultural and olive cultivation, alongside a substantial increase in bare land and forest cover, suggesting both degradation and potential recovery of land. These changes highlight the urgent need for sustainable land management and soil conservation strategies to mitigate degradation and enhance land productivity. The conducted SWOT analysis highlights the intricate relationship between the traditional strengths of pastoral systems and the pronounced contemporary challenges, especially regarding environmental degradation, climate change, and socio-economic pressures. This study offers key insights for policy development to promote balanced conservation and sustainable resource management, highlighting the need for long-term strategies to ensure sustainable land use in fragile ecosystems.

Keywords: Pastoralism; Land use dynamics; Soil conservation; Land cover change; Sustainability; El Kssiba region; Atlas Mountains; Morocco.

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Note: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Received: 23/07/2024

Accepted: 25/09/2024

INTRODUCTION

Land use changes, particularly in regions characterized by traditional subsistence practices, have profound impacts on soil conservation and environmental sustainability (Spalevic *et al.*, 2021; Palevic *et al.*, 2021; Kader *et al.*, 2022). In the Middle Atlas of Morocco, the transformation of land use and land cover (LULC) is shaped by both natural processes and human activities, including pastoralism, which has historically dominated the region. Leveraging Earth Observation Data (EO) and soil erosion modelling makes feasible the spatial and temporal monitoring of soil loss rates due to land cover change and implementation of mitigation strategies (Costea *et al.*, 2022; Sestras *et al.*, 2023; Stefanidis *et al.*, 2024a). As land degradation, shifting vegetation cover, and socio-economic shifts continue to influence the landscape, understanding the relationship between land use dynamics and environmental conservation becomes critical for sustainable development. Particularly important for stakeholders and policy makers is the quantification of ecosystem services related to soil conservation and provided by naturally vegetated areas (Stefanidis *et al.*, 2024b; Olivetti *et al.*, 2015; Lense *et al.*, 2020). This study explores the patterns and drivers of land use change in the El Kssiba region, assessing its implications for soil conservation and sustainable resource management.

Pastoralism is a form of agriculture or subsistence system where people primarily rely on the raising and herding of domesticated animals for their livelihood. It is often practiced in areas where crop farming is difficult due to harsh environmental conditions, such as deserts, mountains, or dry plains, where the climate or terrain makes large-scale agriculture unfeasible. Livestock such as cattle, sheep, goats, camels, yaks, or reindeer are the primary source of food, clothing, and materials. Pastoralists rely on these animals for meat, milk, hides, wool, and other resources. Some pastoralists are fully nomadic, moving with their herds in search of fresh pastures and water throughout the year. Others practice transhumance, a seasonal movement between fixed summer and winter pastures. Pastoralists adapt to their environment by moving their herds to find adequate food and water, often in response to seasonal changes or environmental factors like droughts. In pastoral societies, livestock often holds not just economic value but also social, cultural, and religious significance. Animals may serve as a form of wealth and status and play a role in social and ceremonial life.

According to Shikui *et al.* (2016), pastoralism is a production system and livelihood strategy based on extensive livestock grazing on rangelands or grasslands, often involving some form of herd mobility, and has been practiced in many regions of the world for centuries. Currently, extensive pastoralism occurs on about 25% of Earth's land area, mostly in the developing world, spanning from the drylands of Africa and the Arabian Peninsula to the highlands of Asia and Latin America, where intensive crop cultivation is physically not possible due to harsh environments and poor access (Freier *et al.*, 2014). Pastoralism is globally important for the human population it supports, the food and ecological services it provides, the economic contributions it makes to some of the world's poorest

regions, and the long-standing civilizations it helps to sustain (Fernández-Giménez et al., 2021; Milanovic et al., 2010).

Within the Atlas Mountains of Morocco, cold oases connected to rangelands and collective grazing areas have been created by the Amazigh people despite extreme climate conditions. Throughout centuries of isolation, they have maintained their cultural heritage, including agricultural, social, artisanal, and linguistic traditions (Gault & Saïdi, 2016; Bammouet et al., 2024a; Bammou et al., 2024b). Today, these people and their culture are recognized by the Moroccan Constitution as an integral part of the national identity.

Consequently, the nomadic populations of the Moroccan Middle Atlas have undergone major territorial, political, and economic transformations since the beginning of the twentieth century. These changes, deeply embedded in the collective memory of informants, reflect a transition from a fully nomadic society, prior to French colonization, to one increasingly aligned with the neoliberal principles of postmodern society.

As a result, pastoralism, traditionally characterized by extensive livestock grazing practices, has experienced substantial transformations globally due to factors such as climate change, socio-economic shifts, and policy interventions (Spalevic et al., 2020; Ljavić et al., 2023; Zhang et al., 2023; Lukovic et al., 2024). These changes have led to altered land use patterns, including shifts in vegetation cover, soil degradation, and changes in biodiversity (Mohammadi et al., 2021; Kader & Jaufer, 2022; Spalevic et al., 2024; Sabljic et al., 2024).

While some argue that these transformations have increased productivity and resilience among pastoral communities, others highlight negative implications such as land degradation, loss of biodiversity, and conflicts over land resources. Understanding the multifaceted impacts of pastoralism transformation on land use requires an interdisciplinary approach, drawing insights from ecology, geography, anthropology, and socio-economics.

Through empirical studies and theoretical frameworks, researchers aim to unravel the complexities of these dynamics and inform sustainable land management strategies (Fernández-Giménez et al., 2017; Galvin et al., 2008; Turner et al., 2016). In this context, the present study aims to assess the changes in land due to pastoral activities in the Middle Atlas of Morocco, particularly within the Ait Werra Tribe.

MATERIAL AND METHODS

Study area. The Ait Werra tribe historically extended over the Atlas Mountains of Morocco, covering both the Middle and parts of the High Atlas, within an area of 576.57 km². This area is bounded by the coordinates 6°6'12"W, 6°6'24"W and 33°32'34"N, 33°33'14"N (Figure 1). The tribal lands are situated between 1,600 and 2,100 meters above sea level, with all sites equally accessible by road (Figure 1).

The region experiences significant variation in annual rainfall, ranging from a maximum of 635 mm in the upstream areas to a minimum of 42 mm in the

downstream parts of the study area, with an average rainfall of 348 mm (Ouakhir *et al.*, 2020). Additionally, there are, on average, 25 days of snowfall per year at elevations exceeding 800 meters above sea level.

Temperature fluctuations in the area are notable, ranging from 2°C to 45°C. The average minimum temperature occurs in January at 3.7°C, while the average maximum temperature reaches 38°C in August (USAID, 2010; Ennaji *et al.*, 2024).

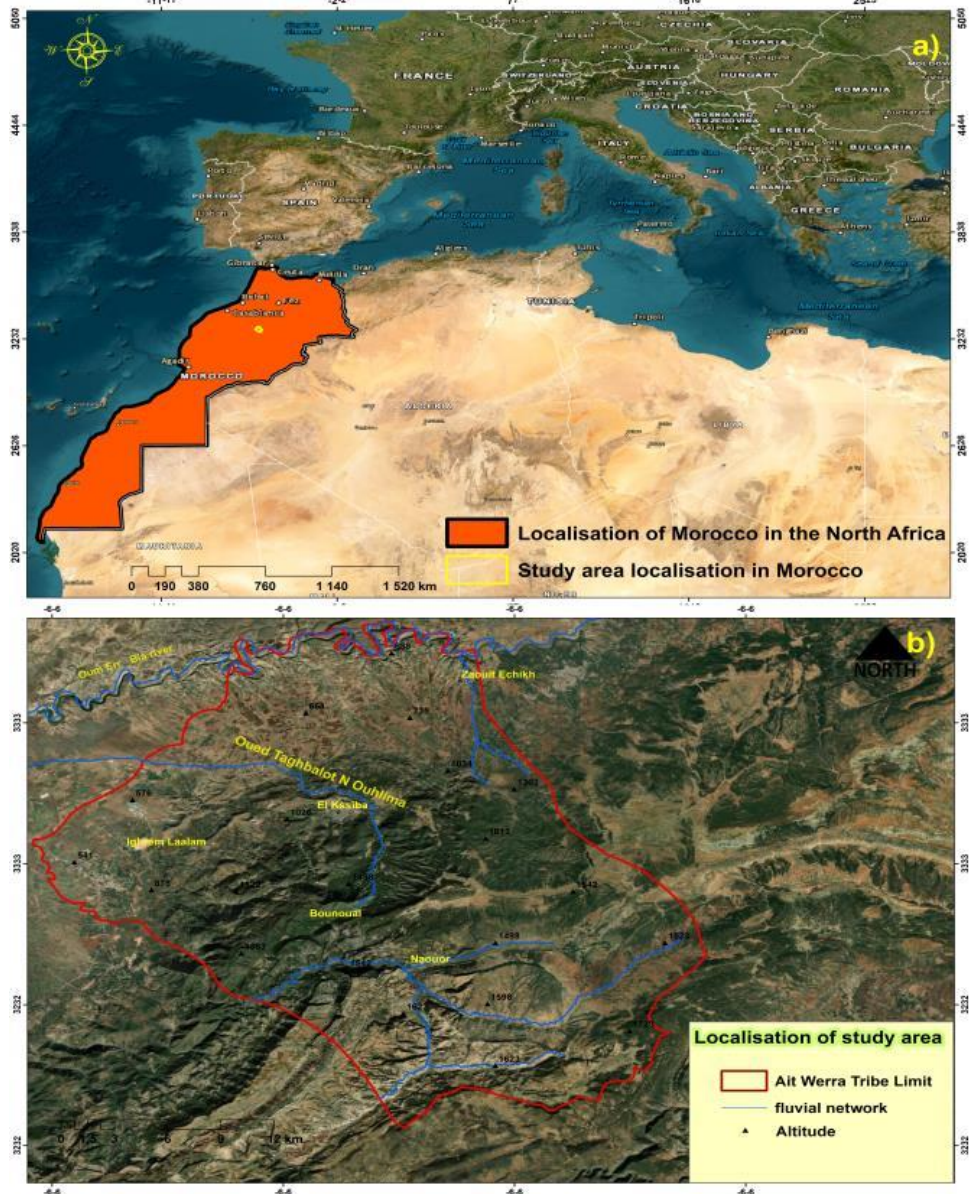


Figure 1: a) The geographical location of Morocco in North Africa, and b) the location of the study area within the Atlas Mountains of Morocco.

The study area is located within the Oum Err Bia Basin, which spans over 500 km in length, originating from the Middle Atlas at an elevation of 1,800 meters above sea level (Ouakhir & El Ghachi, 2023). The river traverses the Tadla plain and the coastal plateau before reaching the city of Azemmour, where it empties into the Atlantic Ocean (Barakat et al., 2016). The principal tributaries of the river, situated on the left bank, include the Derna, El Handek, Tessaout, Lakhdar, and El Abid rivers (Ennaji et al., 2022).

Numerous dams and reservoirs have been constructed along the Oum Er Rbia River to generate hydroelectric power, facilitate irrigation, and meet domestic and industrial water demands (Mosaid et al., 2022). The river and its tributaries pass through regions known for robust agricultural activities, featuring extensive irrigated areas and livestock farming, as well as industrial zones housing oil mills, phosphate extraction facilities, and sugar beet processing plants (Barakat et al., 2018).

The Aït Werra tribe is a significant and representative faction of the Aït Seri, located at the center of the Middle Atlas in Morocco, distant from major cities (Vaugien, 1950). Historically, the region's specific characteristics—such as its climate and location—made it ideal for livestock operations, with double transhumance being a traditional practice (Amraoui et al., 2023).

Fieldwork Methodology and Data Collection.

The main fieldwork, carried out in two phases December 2018 and in May-December of 2022, provided essential information on the impact of pastures in the field. Additionally, field surveys were conducted to gather comprehensive data on indigenous grazing practices, traditional pasture management, pastoral institutions, local perceptions, and responses to environmental changes. These surveys employed integrated methodologies such as participatory rural appraisal, open-ended questioning, and pretested questionnaires.

Supplementary data on challenges, opportunities, and changes in pastoral management systems, as well as external support and partnerships, were collected through group discussions and personal communications. The primary information gathered was documented through the transcription of audio or video recordings. Secondary information, including pasture management, pastoral development, and government policies, was collected and updated using various sources such as research publications, reports, newsletters, and yearbooks. Data quality was ensured through thorough investigation and cross-referencing with multiple sources. The analysis of all data was conducted using systematic qualitative techniques as recommended by Patton (1990) and Miles and Huberman (1994).

Hydrometeorological services provided rainfall and temperature data, allowing us to track the dynamics of the climatic situation in the study area during this period.

Data. The Table 1 presents the various types of data used and their sources, which include historical, environmental, and socio-cultural information, with a primary focus on El Kssiba. This includes rainfall data from the El Heri gauging station covering the period from 1975 to 2018, and French diplomatic archives

extending from 1934 to 1956. Livestock and grazing data, spanning from 1953 to 2024, were also included, along with municipal and tribunal archives covering 1924 to 1956. Furthermore, river characteristics data from 1948 to 1952, as well as oral histories on water distribution traditions within the tribe during the same period, were collected.

These sources provide a comprehensive perspective on the tribe's development, environmental changes, legal frameworks, and cultural practices. They offer invaluable insights into the interplay between human activities, natural systems, and socio-cultural dynamics over time in El Kssiba.

Table 1: Sources and periods of data utilized in the study

Data type	Date	Source of data
Rainfall data (El Heri gauging station)	1975-2018	HOBBER 2024/ www.abhoer.ma
French diplomatic archive in Nantes (C.A.D.N)	1934-1956	French Foreign Affairs https://www.diplomatie.gouv.fr
Livestock and grazing data	1953-2024	The water and forest agency of El Kssiba http://www.eauxetforets.gov.ma/
Archive of El Kssiba Municipality	1924-1956	El Kssiba Morocco
Archive of El Kssiba Tribunal	1929-1956	El Kssiba Morocco
River's characteristics	1948-1952	Municipality of El Kssiba
Water distribution traditions in the tribe	1948-1952	Testimonial evidence
Land Use and Land Cover	2024	Google Earth, OziExplorer, and Fieldwork
Geology map	2024	Geological Maps of Beni Mellal, El Kssiba, and Imilchil (1:100,000 scale)
Pastures map	1953-2024	Centre des Archives Diplomatiques de Nantes https://www.diplomatie.gouv.fr

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RESULTS AND DISCUSSION

Climate and Water Situation. In the studied region, there is significant variability in precipitation across the four seasons over the years. This seasonal rainfall variability is crucial for pastoralism, as it directly affects the availability of water and forage for livestock. While there are fluctuations from year to year, certain seasonal patterns emerge. For instance, winter and spring generally show higher precipitation levels compared to autumn and summer. These seasons may

provide more favorable conditions for pasture growth, thereby supporting pastoral activities.

However, some years exhibit exceptionally low precipitation levels across all seasons, indicating potential drought conditions. Droughts can severely impact pastoralism by reducing grazing land and water availability for livestock. Despite the overall lower precipitation in summer, some years show significant rainfall during this season (Figure 2). Summer rains are particularly important for replenishing water sources and sustaining pasture growth during the dry season, which directly influences the viability of pastoralism in the region.

The considerable variability in rainfall from year to year suggests that pastoralists in the Atlas Mountains must adapt their grazing strategies and herd management practices to cope with changing environmental conditions. While specific trends may fluctuate, analyzing the data over several decades could reveal long-term trends in precipitation patterns, offering valuable insights into the effects of climate change on pastoralism in the region.

The seasonal precipitation data highlights the importance of monitoring weather patterns and adapting pastoral practices to ensure sustainable livestock management in the study area (Figure 2).

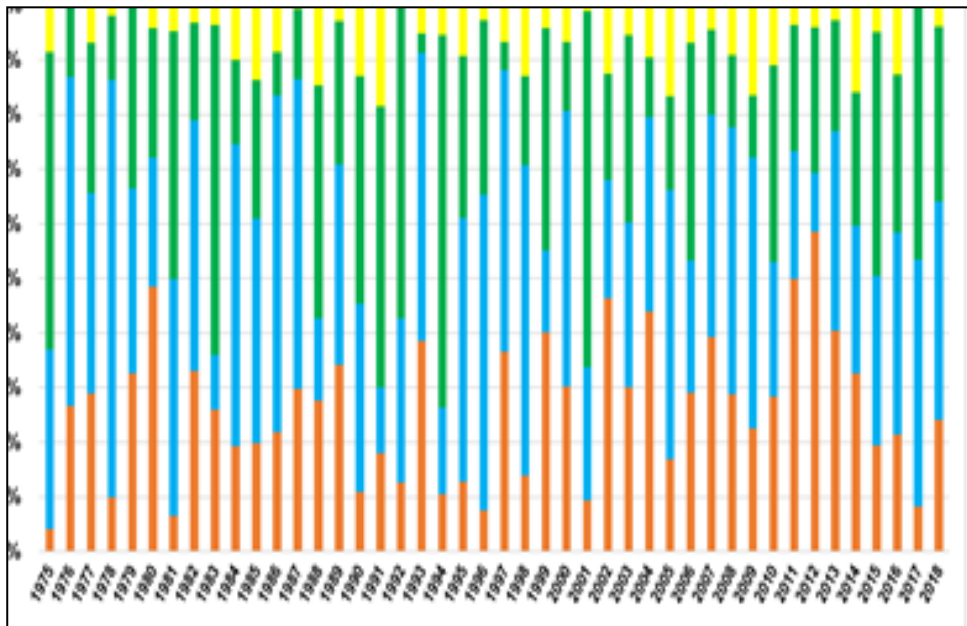


Figure 2: Seasonal rainfall distribution at the Tizi N'isli gauging station from 1975 to 2018.

Precipitation and Water Availability. Precipitation, especially during autumn, winter, and spring, plays a direct role in replenishing surface water sources such as rivers, streams, and lakes (Ouakhir et al., 2023). Higher rainfall during these seasons generally leads to increased water availability in these bodies of

water, which is essential for both human consumption and supporting livestock during dry periods.

Geology and Lithology. According to the provided data, the lithology of the El Kssiba region is dominated by four main rock types: marl and limestone (31.74%), phosphate limestone (10.38%), marl and red clay (50.59%), and doleritic basalt (0.60%). Marl and limestone, as sedimentary rocks rich in calcium carbonate, tend to foster fertile soils by neutralizing acidity and improving soil structure. They also provide essential nutrients like magnesium, which benefit the overall soil fertility (Figure 3 and Table 2).

Table 2: Distribution of lithology percentage in the study area

Lithology type	Area (km ²)	Area (%)
Doleritic basalt	3.45	0.60
Marl and Limestone	182.83	31.74
Phosphate limestone	59.79	10.38
Marl and red clay	291.41	50.59
Deposit	38.55	6.69

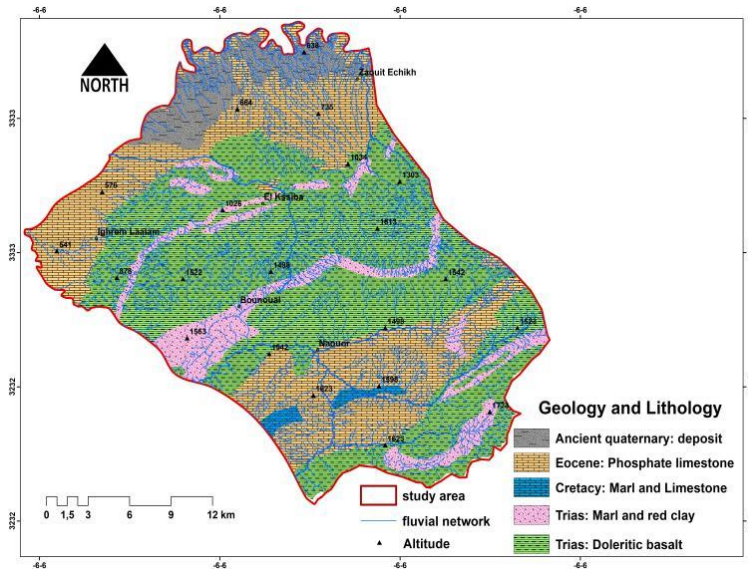


Figure 3: Geological and lithological characteristics of the study area.

Land Rights and Autonomy in the Ait Werra Region. The confederation of the Ait Werra settled in the Middle Atlas region between the seventeenth and nineteenth centuries, establishing their presence in territories such as El Kssiba and Ait Stri by the nineteenth century (Reifsteck, 1943). Over the centuries, they have accurately upheld their ancestral rights to the pastures within this critical area, rooted in age-old customs and traditions (El Bilali *et al.*, 2020). These rights,

established by historical precedent, granted them exclusive access to grazing lands through a system where precedence and defence were paramount.

Before the imposition of external governance in 1912, communities like the Ait Werra exercised autonomy, defining and enforcing their own imperatives. This autonomy was a testament to the sovereignty they once held over their territories (Tozy and Mahdi, 1990).



Figure 4: Partial view of the livestock fairground in Casablanca during the colonial period. Source: Velu, 1934.

Grazing Contracts During the Colonial Period. During the colonial period, grazing contracts replaced the pastoral systems that had characterized the region in the nineteenth century. Previously, most agreements were oral and based more on customs than on mutual understanding between the parties. Under these new contracts, shepherds were given the right to choose whether to receive their wages in cash or in kind. Additionally, they were able to obtain a share of the profits generated by the livestock. The contracts also specified the duration of the grazing (A.T.C.A.O, 1939).

For instance, in 1936, a grazing contract was agreed upon for a payment of 2,050 francs to a shepherd for grazing a flock of sheep for a year, without specifying the number of sheep. In the same year, another contract stipulated a payment of 1,042 francs for grazing twenty-five sheep annually. In the case of cattle, the shepherd's wage typically amounted to four hundred francs per head. When payment was made in kind, most contracts specified that the shepherd would receive a quarter of the profits as an annual wage in exchange for assuming all the responsibilities of caring for the livestock (A.T.C.A.O, 1936).

This shift can be attributed to the changes in the social system of the Ait Werra tribe. Grazing was no longer restricted to specific families but extended to various families that had lost their herds and lands due to the French invasion. The urgent need for cash to adapt to the developing economy, which integrated the local system into a capitalist framework, replaced traditional barter transactions with

monetary ones. As many tribe members settled in the El Kssiba region and other urban centers, job opportunities in grazing became more abundant, allowing shepherds to choose their employers (Figure 4).

Consequently, shepherds gained the ability to impose their conditions in the grazing contracts, choosing between cash or in-kind payment. They also acquired the right to terminate the contract if the livestock owner failed to fulfill their obligations, with compensation for the time they worked. The role of the tribal community, which previously regulated the grazing process, became limited to documenting agreements between the contracting parties. Traditional customs for grazing were gradually reduced, persisting only in some mountainous areas that remained less affected by the capitalist colonial system (Figure 5).

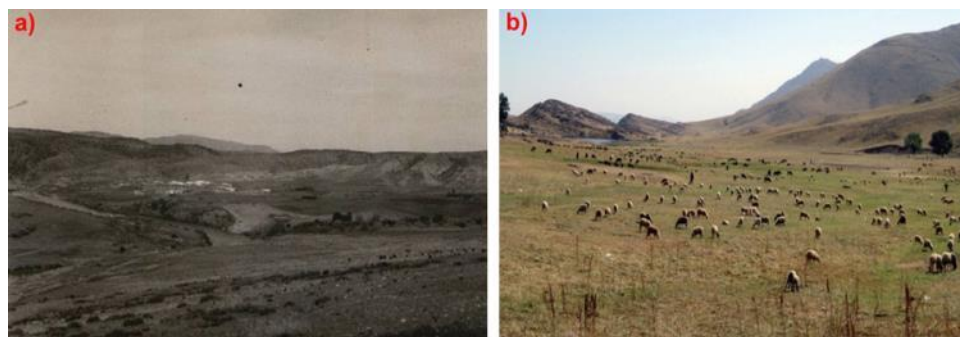


Figure 5: a) Examples of historical pastures (Velu, 1934.) and b) current pastures from the study area (Photo: Spalevic, 2018).

Distribution of Pasture Types in the Study Area. The need to adapt to evolving demands has led to a transition away from traditional nomadic lifestyles, necessitating a shift towards a more settled existence to maintain conventional livestock rearing practices. As a result, individuals who were once nomadic now establish fixed homes across different terrains within their tribal territories, adjusting their movements based on seasonal variations (Figure 6).

During the summer, they ascend to the mountainous regions, while in the winter and spring, they practice transhumance, moving towards lower, more hospitable pastures. As the seasons progress, they gradually migrate downstream, towards the banks of the Oum Err Bia River within the study area.

Changes in Land Use and Land Cover 1953 – 2024. The Atlas Mountains of Morocco have long supported transhumant pastoralism, a traditional practice characterized by the seasonal movement of livestock herds between lowland pastures in winter and highland pastures in summer. However, this age-old livelihood system has faced significant challenges due to changes in land use and land cover. Rapid urbanization, agricultural expansion, and infrastructure development have fragmented and degraded traditional grazing lands, reducing the availability of suitable pastures for transhumant herding (Figure 7).

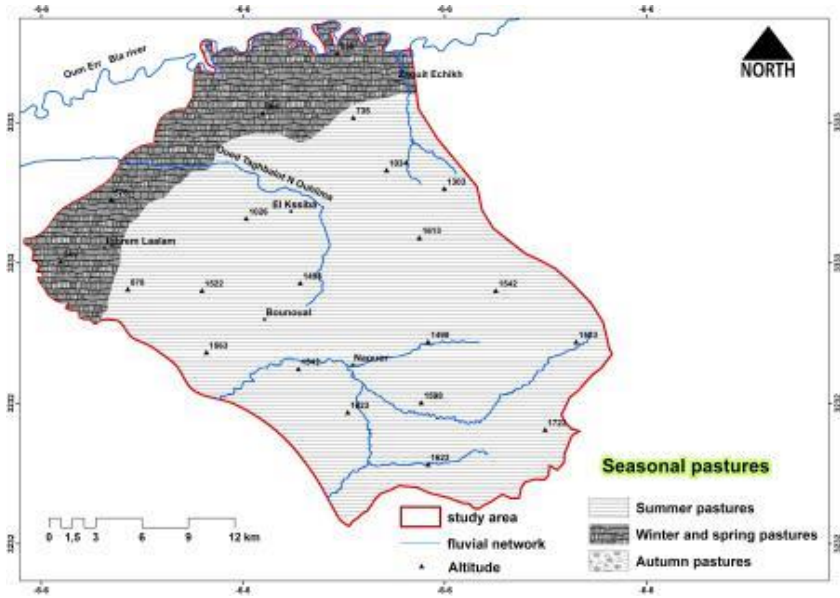


Figure 6: Distribution of seasonal pastures within the study area.

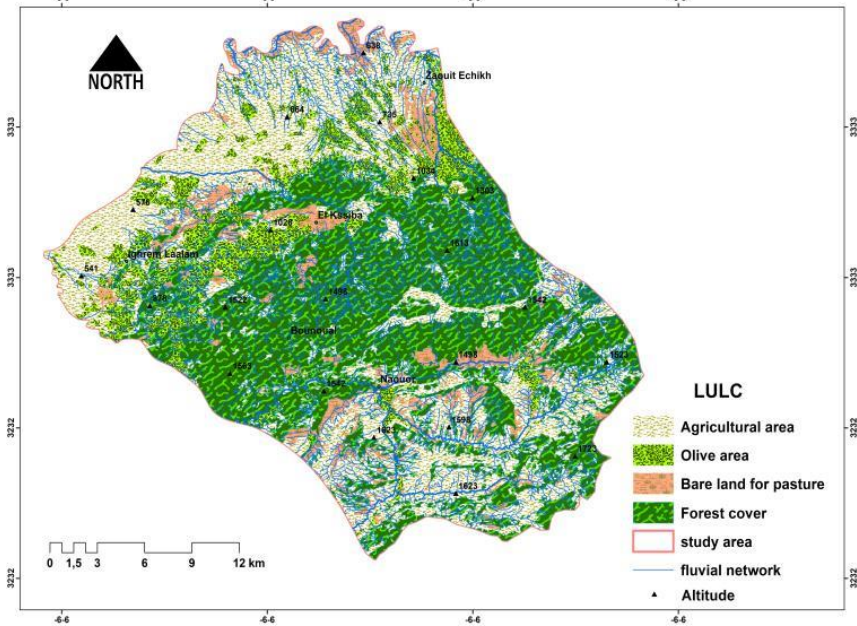


Figure 7: Land use and land cover in the study area.

Additionally, changes in land cover—such as deforestation and vegetation degradation—have diminished the quality and quantity of forage resources, further intensifying the difficulties faced by pastoralists. These pressures have forced many transhumant herders to adapt their traditional practices, including modifying

migration routes, intensifying herd management, and seeking alternative livelihoods.

Table 3: Dynamics of Land Use and Land Cover 1953 - 2024 in Area

LULC type	1953		2024	
	area (km ²)	area (%)	area (km ²)	area (%)
Agricultural area	212.10	36.79	85.60	14.85
Olive area	77.21	13.39	4.20	0.73
Bare land	45.16	7.83	102.10	17.71
Forest cover	242.10	41.99	384.60	17.71
Total	576.57	100.00	576.50	51.00
Max	242.10	41.99	384.60	17.71
Min	45.16	7.83	4.20	0.73
SD	82.96	14.39	120.24	6.01

Source: The water and forest agency of El Kssiba and LULC map

Addressing the impacts of land use and land cover changes on transhumant pastoralism requires integrated land management approaches that balance conservation efforts with the needs of local communities, ensuring sustainable resource use practices (FAO, 2017; De Leeuw *et al.*, 2020).

According to the inputs from table 3, significant changes in land use and land cover (LULC) have occurred in the study area between 1953 and 2024, reflecting both environmental and socio-economic dynamics. These transformations highlight key shifts in agricultural land, olive cultivation, bare land, and forest cover.

Agricultural Area. In 1953, agricultural land was a dominant feature, covering 212.10 km² or 36.79% of the total area. By 2024, this area had decreased sharply to 85.60 km², representing only 14.85% of the total. This reduction in agricultural land suggests a transition from farming to other land uses, in part related to industrial or urban development, but more likely a consequence of environmental changes such as land degradation and water scarcity. These factors may have made traditional farming practices unsustainable over time.

Olive Area. Olive cultivation also saw a dramatic decline. In 1953, olive groves covered 77.21 km² or 13.39% of the total area, but by 2024, this had dropped to only 4.20 km² or 0.73% of the total. The sharp reduction in olive cultivation could be due to several factors, including changing market demands, land degradation, and the repurposing of land for other uses such as residential or industrial zones. Additionally, challenges related to water availability and competition from other crops may have further contributed to this decline.

Bare Land. The area of bare land more than doubled between 1953 and 2024. In 1953, bare land accounted for 45.16 km² or 7.83% of the total area, but by 2024, it had expanded to 102.10 km² or 17.71%. This increase is indicative of environmental degradation, likely due to overgrazing, desertification, and land abandonment. The expansion of barren areas suggests a significant decline in land

productivity, making these areas more vulnerable to erosion and other environmental stresses.

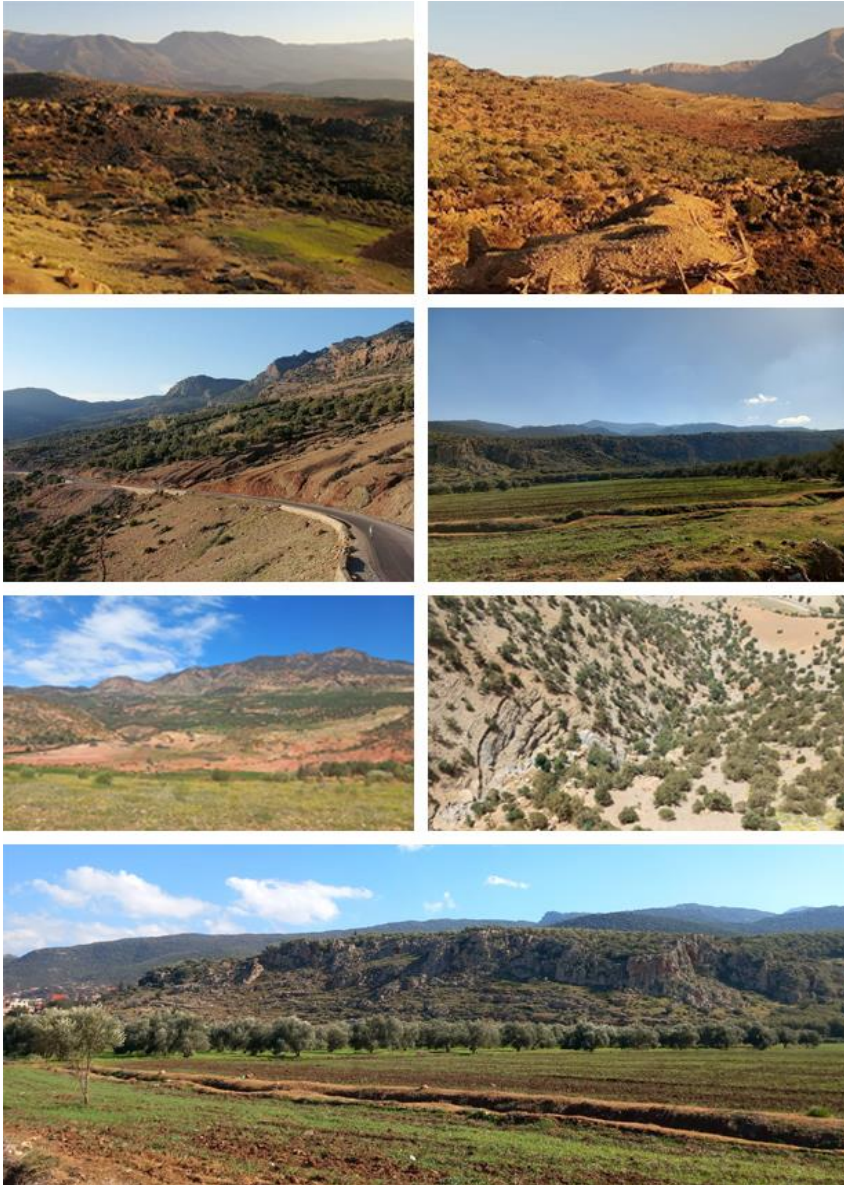


Figure 8: Landscape Dynamics in the El Kssiba Region: Pastoral and Agricultural Transformations (Photo: Spalevic, 2018; Amraoui 2024).

Forest Cover. While agricultural and olive areas have declined, forest cover has seen a positive trend. In 1953, forests covered 242.10 km² or 41.99% of the total area. By 2024, this had increased significantly to 384.60 km², accounting for

66.71% of the total land. The increase in forest cover could be attributed to the natural regeneration of vegetation as marginal agricultural land was abandoned. However, while this trend is encouraging, the quality of the forest, in terms of biodiversity and ecological health, requires further investigation to ensure the forests are thriving ecosystems and not just expanding in area.

Shift from Agriculture to Forests and Bare Land. The most prominent trend between 1953 and 2024 is the significant shift from agricultural and olive cultivation to forests and bare land. The decrease in agricultural land, along with the increase in bare land, suggests that large portions of land have been abandoned or degraded, likely due to unsustainable land management practices and environmental pressures. However, the increase in forest cover provides a sign of recovery and potential reforestation in the region, offering some optimism for the future of the landscape.

Environmental Concerns. The rise in bare land is concerning, as it signals ongoing environmental degradation driven by unsustainable land use practices, including overgrazing. This trend highlights the urgent need for sustainable land management strategies aimed at restoring degraded areas and preventing further environmental deterioration. The degradation of land is a critical issue that affects not only the environment but also the livelihoods of pastoralists and local communities.

Socio-Economic Shifts. The reduction in agricultural and olive cultivation could also reflect broader socio-economic changes. Urbanization, shifts in land ownership, and changing economic priorities have likely reduced the emphasis on traditional farming practices. As areas are repurposed for urban and industrial development, rural communities may be experiencing significant economic and lifestyle transformations. These socio-economic shifts are further evidenced by the changes in land use patterns over time.

Statistical Overview. Statistical analysis reveals increased variability in land use patterns between 1953 and 2024. The standard deviation values indicate greater fluctuations, particularly in forest cover and bare land. Maximum values suggest that forest cover became the dominant land use type in 2024, while bare land experienced the greatest increase in both area and percentage, highlighting major transitions in land cover and use.

The data reveal substantial changes in land use and cover between 1953 and 2024, reflecting both environmental and socio-economic shifts. The decline in agricultural areas and olive groves, coupled with the rise in forest cover and bare land, underscores the complex interaction between land degradation, reforestation efforts, and economic factors. These trends emphasize the importance of implementing integrated land management practices that balance conservation efforts with sustainable agricultural and socio-economic development in the region.

Overall, pastoralism has played a significant role in shaping the LULC dynamics in the Ait Werra tribe area. This traditional practice has influenced both

landscape and resource utilization patterns over the years, contributing to the transformations observed in the region.

Exploitation of Resources and Colonial Impact. During the French colonial period, exploitation of the region's resources—particularly the wood industry, firewood, and charcoal for export to Casablanca—had a significant impact on the local landscape. Despite efforts by the Water and Forest Service to protect and replant pine forests, the Ait Werra tribe continued to view the forest as communal property, exploiting it for their needs and resisting colonial authority over their lands.

While foreign exploiters dominated during the colonial period, the local population primarily used the forest for firewood and heating during the winter. The colonial authorities acknowledged the difficulty of strictly enforcing forest protection laws, especially given the Ait Werra tribe's dependence on the forest for survival (C.A.D.N, 1953). This dynamic reflects the ongoing tension between resource conservation efforts and the livelihood needs of local communities, a challenge that persists even today.

SWOT Analysis of the transformation of Land Use in the Ait Werra Tribe. The following Table 4 summarizes the key strengths, weaknesses, opportunities, and threats related to the transformation of land use within the Ait Werra Tribe.

The SWOT analysis (Table 4) reveals a complex interplay between the historical strengths of pastoral systems in the Ait Werra tribe and the modern challenges they face, particularly in terms of environmental degradation, climate change, and socio-economic pressures. While significant opportunities exist for sustainable land management and climate adaptation, addressing weaknesses like bare land expansion and declining agricultural productivity will require coordinated efforts involving both government policies and local community engagement. Sustainable practices, such as reforestation and improved grazing management, are essential for balancing conservation efforts with pastoral and agricultural livelihoods.

Recommendations to transform Threats into Opportunities. Implementing innovative water conservation techniques, such as rainwater harvesting and advanced irrigation systems, can help mitigate the effects of drought. Introducing more resilient crop varieties and livestock breeds can also support pastoral communities in adapting to changing climate conditions.

Enforcing stricter regulations on urban and industrial development can help preserve traditional grazing lands. Creating protected grazing areas and developing infrastructure solutions that minimize land fragmentation can ensure long-term resource availability for pastoralism.

Providing education and training for pastoral communities on sustainable practices and resource management can help them better integrate into modern economic systems, reducing reliance on unstable traditional methods. Developing alternative income sources through eco-tourism and geo-tourism or creating markets for pastoral products (such as organic meat or dairy) can reduce economic pressure on these communities.

Table 4: SWOT Analysis of the transformation of Land Use in the Tribe

Strengths:	Weaknesses:
<p>Historical Heritage and Knowledge: The Ait Werra tribe's rich history and cultural heritage in pastoralism have provided sustainable land-use practices that have helped manage the region's resources over centuries. Their knowledge of seasonal migration and pasture management ensures the efficient use of the land.</p> <p>Natural Resource Regeneration: The increase in forest cover since 1953, attributed to natural regeneration and possible reforestation efforts, shows a positive environmental trend that could enhance biodiversity and improve ecosystem services.</p> <p>Adaptability of Pastoral Communities: The ability of pastoralists to adapt their transhumance routes and grazing practices in response to environmental and socio-economic changes highlights resilience in managing their livelihoods amid external pressures such as climate change and policy changes.</p>	<p>Environmental Degradation: The significant increase in bare land, indicating environmental degradation, desertification, and deforestation, poses a major threat to the sustainability of pastoralism and agricultural practices. Overgrazing, land abandonment, and soil erosion are critical issues that have not been adequately managed.</p> <p>Decline in Agricultural and Olive Areas: The reduction in agricultural and olive cultivation areas is a sign of declining land productivity and could indicate socio-economic struggles for communities dependent on farming as part of their livelihood mix. The shrinking olive cultivation area, in particular, is alarming given its importance for both local economies and ecosystems.</p> <p>Lack of Sustainable Land Management: Historical and ongoing challenges in implementing effective sustainable land management practices have led to over-exploitation of resources, as evident in the colonial and post-colonial periods. Resource management struggles continue to exacerbate the vulnerability of ecosystems and communities.</p>
Opportunities:	Threats:
<p>Sustainable Land Management Initiatives: There is potential for implementing integrated land management strategies, which would balance conservation efforts with sustainable land use. This includes improving forest management, promoting sustainable agriculture, and addressing land degradation issues through reforestation and soil restoration programs.</p> <p>Policy Reforms and Community Involvement: Strengthening government policies that prioritize the restoration of degraded lands, alongside community-driven initiatives, could foster more sustainable resource management. Recognizing indigenous knowledge and giving local communities greater authority over land-use decisions can empower better stewardship of the environment.</p> <p>Climate Adaptation Strategies: The ongoing climate variability presents an opportunity to introduce climate-resilient agricultural practices and innovative water management techniques that could mitigate the effects of droughts and improve pastoralists' livelihoods.</p>	<p>Climate Change: Increasing climate variability, including unpredictable rainfall patterns and extended droughts, threatens the delicate balance required for pastoralism and agriculture. This exacerbates water scarcity and reduces forage availability, making it difficult for traditional systems to thrive.</p> <p>Land Fragmentation and Urbanization: Rapid urbanization, infrastructure development, and agricultural expansion have led to the fragmentation of grazing lands, which could result in the further degradation of the pastoral system. Reduced pasture availability may force pastoralists to either abandon their traditional practices or overexploit remaining lands.</p> <p>Socio-Economic Pressures: Economic shifts, including increased reliance on cash-based economies and the decline in traditional barter systems, are putting pressure on pastoral communities. The move away from traditional pastoral livelihoods could result in the erosion of cultural heritage and the loss of land-use knowledge.</p>

Recommendations to Transform Weaknesses to Strengths.

Implementing programs for land conservation through agroforestry, reforestation, and soil conservation techniques can help reduce erosion and restore land fertility. These practices would increase the availability of grazing land and improve sustainable food production in the long run.

Developing irrigation infrastructure, including technologies for efficient water use, can help revitalize agricultural and olive-growing areas. Promoting organic and sustainable farming can increase the market value of these products, improving the economic sustainability of communities that rely on agriculture.

Strengthening the capacity of local communities to manage natural resources through training and policy support can establish effective practices that balance ecosystem conservation and agriculture. In this way, traditional knowledge and practices, which were once seen as weaknesses due to lack of modernization, can be transformed into strengths for preserving local resources.

In the long term, these steps can help transform threats into opportunities and weaknesses into strengths, enabling communities to pursue sustainable development and resilience against future challenges.

CONCLUSIONS

The study highlights significant transformations in land use and land cover (LULC) within the Ait Werra Tribe's region in the Middle Atlas of Morocco, driven by both environmental and socio-economic changes. The transition from agricultural and olive-growing lands toward more bare land and forest cover reflects broader issues of land abandonment, environmental stress, and socio-economic shifts. However, this transition also provides a window for potential recovery through reforestation and land rehabilitation. This underscores the need for concerted efforts from farmers, local communities, and policymakers to secure the future of pastoralism and land use in the region.

Recommendations for Farmers and Local Communities are to develop and adopt in communication with national services Sustainable Grazing Practices. Farmers and pastoralists should transition to more sustainable grazing techniques to prevent further land degradation. Rotational grazing and controlled stocking rates can help restore vegetation and reduce soil erosion, ensuring long-term productivity of the grazing lands. Given the vulnerability of pastoralism to climate change and land degradation, local communities should explore alternative income sources such as eco-tourism, organic farming, and value-added agricultural products (e.g., dairy and wool). This diversification would provide economic resilience and reduce pressure on land resources. With the increasing scarcity of water due to fluctuating rainfall, it is essential for local farmers to adopt water conservation methods. Techniques such as rainwater harvesting, the use of efficient irrigation systems, and drought-resistant crops should be encouraged to sustain agricultural activities during dry periods.

Community-based reforestation projects can help rehabilitate degraded lands and increase forest cover. By planting native tree species and restoring

ecosystems, farmers can not only protect their land but also contribute to mitigating the effects of climate change.

Local Authorities and Decision Makers should strive towards implementation of Integrated Land Management Policies. Decision-makers should establish comprehensive land management frameworks that integrate sustainable agriculture, conservation, and pastoralism. This includes setting aside protected grazing areas, encouraging reforestation programs, and providing incentives for sustainable land use practices. Local authorities should invest in infrastructure that supports sustainable farming, such as improving irrigation systems and offering training programs for farmers on organic and regenerative agriculture. Providing access to markets for sustainably produced goods will help farmers make the transition to greener practices.

Strengthen Climate Adaptation Strategies is of crucial importance. Policymakers should prioritize climate adaptation initiatives by promoting research and development of resilient agricultural technologies, including the introduction of drought-tolerant crop varieties and the creation of early warning systems for extreme weather events. Financial support, such as grants or subsidies, should be made available to farmers adopting these strategies.

Traditional knowledge and practices of pastoralists, such as transhumance, should be documented and integrated into modern resource management frameworks. Decision-makers should work with local communities to preserve these practices and incorporate them into policies aimed at sustainable land use and environmental conservation. Urban expansion and infrastructure projects must be carefully regulated to prevent further fragmentation of grazing lands and agricultural areas. Zoning laws and land-use planning should take into account the needs of pastoralists and farmers, ensuring that development does not compromise the sustainability of rural livelihoods.

Local communities, particularly pastoralists and farmers, should have a seat at the table in discussions about land use policy. Establishing participatory governance structures where local stakeholders can voice their concerns and contribute to decision-making will lead to more effective and equitable outcomes.

The challenges faced by pastoralism and land use in the Ait Werra region reflect larger global issues concerning the sustainability of traditional livelihoods in the face of climate change and socio-economic development. However, these challenges also present opportunities for transformation. By fostering collaboration between local communities and policymakers, it is possible to create sustainable solutions that ensure both the conservation of the environment and the long-term viability of pastoralism and agriculture.

Sustainable development in the Middle Atlas region will require balancing conservation efforts with the economic needs of local populations. With the right strategies and commitment from all stakeholders—farmers, local communities, and decision-makers alike—it is possible to achieve a future where the environment is preserved and livelihoods are secure.

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