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Oasis Expansion and its impacts on Ecosystem Services in Southern Tunisia

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Abstract

Many ecosystems face multiple pressures that affect their ability to provide ecosystem services. These services are commonly grouped into four categories: Provisioning, Regulating, Cultural and Supporting services. These services can lead to develop business opportunities for local communities. However, human activities and natural hazards may conduct to ecosystem degradation and loss of biodiversity and consequently, to business risks. In arid regions, oasis ecosystems have a crucial economic and social impact. However, natural and anthropogenic factors may affect oases ecosystems and their services. Therefore, the main objective of this research is to assess changes in oasis ecosystems in southern Tunisia using multi-temporal satellite images and NDVI analysis. The methodology is based on Landsat satellite data acquired between 1995 and 2025 and the calculation of NDVI. The results shows that the oasis areas in the study area increased by 42.36%. While this expansion reflects agricultural intensification, it may also lead to higher water consumption, soil degradation and biodiversity loss. This research can help local stakeholders better understand environmental risks and support the development of appropriate strategies to preserve oasis ecosystems.

1. INTRODUCTION

Ecosystem services are the benefits that humans obtain, directly or indirectly, from ecosystem functions (Costanza *et al.,* 1997). Moreover, ecosystem services are the benefits that people obtain from ecosystems. Ecosystem functions are defined as interactions between ecosystem structures and processes. In fact, The Millennium Ecosystem Assessment (MEA, 2005) identified four types of ecosystem services. These services include provisioning services such as food and water, regulating services as flood and disease control, cultural services such as spiritual and recreational benefits and supporting services such as nutrient cycling that sustains life on Earth.

Many people activities depend on natural resources which can conduct to degradation of the ecosystems due to improper use and management or overexploitation. In the future, an increasing number of people will face ecosystem services loss as the urban population and associated human activities increase exponentially (Bolund and Humhammar, 1999). For this reason, it is necessary to recognize the role of natural environment not only as provider but also as victim of pollution and overconsumption for the assessment of the ecosystem services (Cook and Spray, 2012).

Additionally, Changes in land use and land cover (LULC) are the result of human activities that have altered the land surface through various social and economic processes, influencing ecosystem stability and the conservation of biodiversity (Marino *et al*., 2021)

In Africa, natural resources support the livelihoods of many poor people directly. In fact, many African people depend on ecosystem services for the provisioning of wood for cooking, poles for fencing and wild animals for protein or water for drinking. For this reason, the loss and degradation of ecosystems may lead to affect

business activities for local people in particular (Egoh *et al.,* 2012).

In Tunisia, forest ecosystems provide a wide range of goods and services that are essential for environmental protection and human well-being. Forests play a key role in protecting water resources, supporting soil conservation by reducing erosion and sedimentation, and conserving biodiversity through habitat provision and carbon sequestration. They also contribute to climate regulation and the supply of non-wood forest products (forage, honey, aromatic plants) (DGF, 2011).

Moreover, in arid regions, oasis ecosystems have a crucial economic and social impact by supporting agricultural production, providing livelihoods for local communities and ensuring food security. In fact, these ecosystems create productive spaces in severe environments, generate employment, preserve traditional knowledge and strengthen social cohesion. It also contribute to stabilize populations and limit migration. Furthermore, these oases determine the use of limited natural resources to create areas rich in biodiversity that clearly differ from the surrounding desert and steppe landscapes. The most of oases are located in the four southern governorates (Gabes, Gafsa, Kebili, and Tozeur) (CDCGE, 2016).

In addition, oasis expansion caused by climate change and human activities has strongly affected ecosystem services in arid inland river basins. In this context, population growth is a major driver of urban expansion in the oasis and it can affect the loss of palm trees reduced agricultural productivity and weakened the agroecosystem (Han *et al.,* 2025)

In the face of climate change, water scarcity and increasing human pressure, the resilience of oasis systems and their capacity to cope with environmental and socio-economic stresses depend on the integration of traditional knowledge with modern water management practices, diversified farming systems and adaptive governance (Charieg *et al.,* 2025). Moreover, multi-temporal satellite imagery facilitates the detection of changes in palm tree cover and urban expansion. This allows the assessment of urban growth pressure on oasis agroecosystems (Salih *et al.,* 2025). In the economic and social context, this research aims to assess changes in oasis ecosystems in southern Tunisia and its impact on services. The results can provide a baseline for developing strategies to protect biodiversity and identify potential economic and business opportunities.

2. MATERIAL AND METHODS

In this study, we used multi-temporal satellite images to assess the impact of changes in oasis ecosystems on ecosystem services in the same area of Kebili Governorate.

2.1. Study case description

The Governorate of Kebili, located in south-western Tunisia within the Nefzaoua region, is characterized by a hyper-arid Saharan climate and huge desert landscapes dominated by Chott El Jerid. Traditional oases are widely distributed in this region. Despite extremely low rainfall and high temperatures, these oases form highly productive agro-ecosystems that sustain local populations and protect against desertification. The oases of Kebili are irrigated using groundwater from the Continental Intercalaire and Complexe Terminal aquifers. The traditional oases as Rabta, Mansoura, Telmine are typically organized into a three-level system consisting of date palms at the top level, fruit trees such as pomegranate and fig in the middle and lower-layer fodder and market garden crops. This structure creates a favorable microclimate and supports rich plant and animal biodiversity, including numerous date palm cultivars, most particularly Deglet Nour. Furthermore, the oases are vital ecological, economic, and cultural systems. They are increasingly threatened by groundwater overexploitation, salinization and land degradation, making sustainable water and ecosystem management urgently needed (CDCGE, 2016).

For the analysis, we selected a representative area of the Kebili governorate, as shown in Fig. 1.

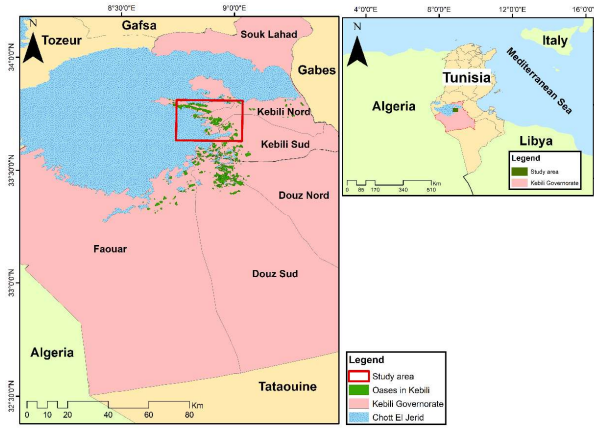

Fig. 1. Study area location

2.2. Data collection and processing

Multi-temporal medium-resolution Landsat imagery was used to analyze temporal changes in the Normalized Difference Vegetation Index (NDVI) across the study area. In this case study, satellite images acquired between 1995 and 2025 were employed to assess changes in the oasis ecosystem, as presented in Table 1. The Landsat data were obtained from the USGS Earth Explorer platform website (https ://earthexplorer.usgs.gov/). With a spatial resolution of 30 m, Landsat imagery is well suited for NDVI calculation using bands Red and Near-Infrared (NIR) and for examining long-term changes in palm tree cover over the 1995–2025 period. In fact, Normalized Difference Vegetation Index (NDVI) is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health (Campbell, 2007; USGS, 2025). Oasis locations were identified by calculating NDVI for the study area using equation (1) and appropriate Landsat bands (USGS, 2025). Moreover, the raster data developed to obtained NDVI had a resolution of 30 m and were georeferenced to Universal Transverse Mercator (UTM), zone 32N, WGS84.

$$NDVI = \frac{NIR-RED}{NIR+R} \quad \text{eq.1}$$

3. RESULTS AND DISCUSSION

3.1. Oases Evolution

Based on NDVI calculations, we assessed the expansion of oases. Between 1995 and 2025, the oasis area increased by 42.36%, with an average annual growth rate of 1.18% per year. Moreover, the spatial distribution of oasis growth reveals a clear expansion of modern oases compared to traditional oases (Fig. 2). These oases are characterized by intensive farming practices that have increased vegetable yields and market-oriented production. However, this intensification has also conducted to higher water use, soil degradation and the loss of traditional agro-ecological balance (Benaoun *et al.,* 2014).

Moreover, the analysis of oasis expansion over the past three decades reveals significant

Table 1. Landsat data acquisition in this study

N°	Path/Row	Data set	Cloud Cover (%)	Acquisation date	Band Used
1	191/37	Landsat 5 TM	1	15/11/1995	Band 3 : Red Band 4 : Near-Infrared (NIR)
2		Landsat 5 TM	1	10/11/2005	
3	191/37	Landsat 8 OLI	1.14	08/12/2015	Band 4 : Red Band 5 : Near-Infrared (NIR)
4		Landsat 9 OLI	0.14	09/11/2025	

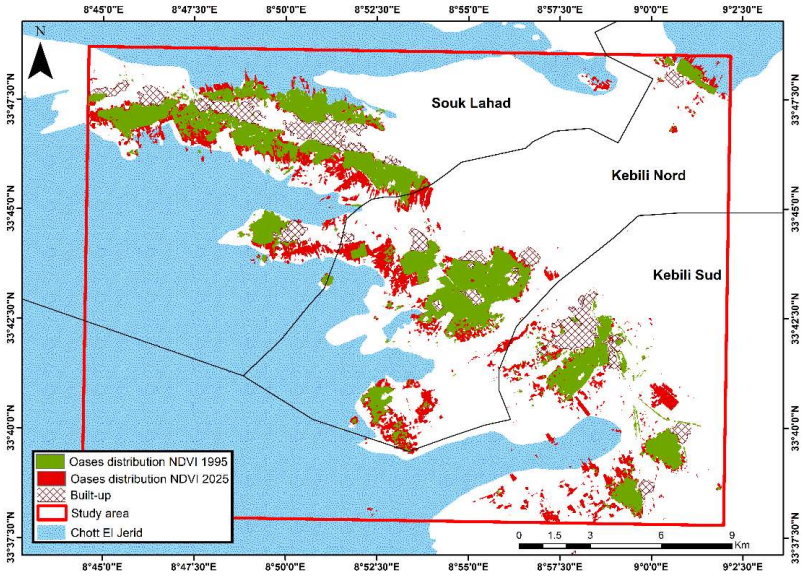

Fig. 2. Spatial distribution in oasis in the study area

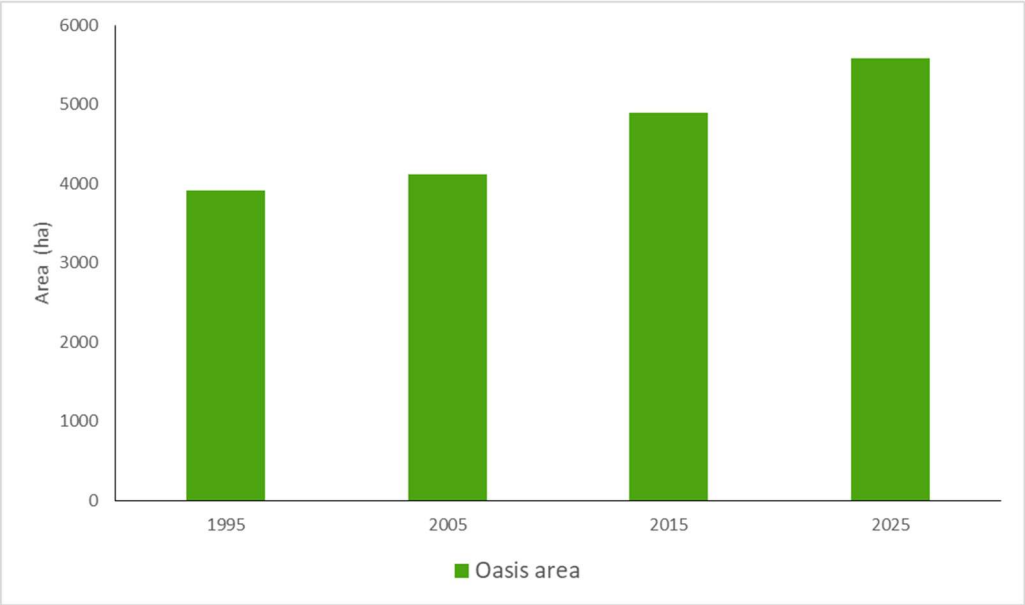

Fig. 3. Temporal variation in total oases area

spatial and temporal variability in growth rates as it was presented in Fig. 3. This variability can be explained by several factors. Between 1995 and 2005, a moderate growth rate of 4.93% was observed mainly due to traditional farming practices and limited use of technology. However, between 2005 and 2015, oasis expansion increased rapidly (18.95%) which can be driven by modern irrigation techniques, appropriate policy and higher demand for agricultural products. During the period between 2015 and 2025, oasis expansion continued at a slightly slower rate (14.05%) compared to the previous decade. It can be due to constraints related to water resources and land availability.

3.2. Link Between Oasis Growth and Ecosystem Services and trade-offs

Ecosystem services are the benefits people get from ecosystems, including provisioning, regulating, supporting and cultural services. Moreover, the economic value of these services are important for sustainable strategies (Karmaoui et al., 2015). In fact, oasis expansion affects these services in several ways:

(i) Provisioning Services (Agricultural product): The expansion of oasis increases the production of dates, fruits, vegetables and fodder, improving local food security.

(ii) Regulating Services (Microclimate regulation) : More vegetation helps lower soil temperatures, reduce wind erosion, and increase local humidity.

(iii) Supporting Services (Biodiversity): Oases provide habitats for plants, insects, birds, and small mammals, supporting ecological balance and resilience

(iv) Cultural Services (Recreation and heritage): Oases maintain traditional landscapes and lifestyles, which are important for tourism and community identity.

While oasis expansion can enhance many ecosystem services, it can also create trade-offs. In fact, increased water use for irrigation can lead to water stress (Sharafatmandrad and Mashizi, 2026). Expansion into marginal lands may cause soil salinization and erosion, while intensification focused on monocultures can reduce native species and put pressure on biodiversity.

4. CONCLUSION

Oasis ecosystems make an important economic and social contribution by supporting agricultural production, providing livelihoods for local communities and ensuring food security. However, oasis communities are increasingly affected by environmental degradation, water scarcity and socio-economic changes. In this study, oasis expansion was assessed using multi-temporal satellite imagery and NDVI monitoring, which provides useful information for sustainable resource management. The results show that oasis expansion has significantly increased agricultural capacity and socio-economic benefits over the past 30 years. Nevertheless, continued growth must be carefully managed to ensure environmental sustainability

and long-term resource availability. This analysis can be considered a preliminary step toward identifying risks and opportunities related to biodiversity and ecosystem services in oases. Future work could be strengthened by applying specific tools for managing biodiversity and ecosystem service risks and supporting market development. Finally, this type of research can be helpful to increase stakeholders' awareness of the risk of environmental problem in oasis and to encourage them to implement appropriate strategies to preserve the ecosystem.

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