

# Assessing Land Degradation Neutrality (LDN) in Southeastern Tunisia Based on Earth Observation Data and Open Source Applications



Olfa Terwayet Bayouli, Bouajila Essifi, and Mohamed Ouessar

**Abstract** Land Degradation Neutrality (LDN) is a new approach, which is receiving considerable interest worldwide, in assessing current land condition. An LDN assessment was undertaken for the Dhahar-Jeffara transect in southeastern Tunisia. The assessment was performed following the United Nations Convention to Combat Desertification (UNCCD) method in terms of three indicators: land cover, land productivity and soil organic carbon. Over a 20-year period (1999–2018), satellite data, Geographic Information Systems (GIS), and Open Source applications were used to assess the changes in these indicators. As a result, the LDN baseline status was evaluated across the region to better understand its distribution, to evaluate trends as well as drivers of land degradation, and eventually identify “hot-spots”, targeted for restoration options and used to achieve the Sustainable Development Goal (SDG15.3) by 2030 in the studied area. The Trends.Earth tool under the QGIS software has been explored to support UNCCD-LDN indicators. Based on the three derived indicators, the majority of the study area (89%) showed clear stability toward the land degradation process. Only 3% (7330 ha) of the Dhahar-Jeffara transect were identified as degraded land areas; however, 8% (17860 ha) are identified as improved (not degraded) land. This study recommends the implementation of an LDN target setting at a regional level, in addition to targeting land degradation drivers behind the land degradation process by implementing different sustainable land practices to tackle this phenomenon.

**Keywords** Land Degradation Neutrality (LDN) · UNCCD indicators · Remote sensing · QGIS Trends.Earth · Southeastern Tunisia

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## 1 Introduction

Land degradation is one of the major environmental problems in Tunisia, since up to 75% of its territory is threatened by this phenomenon [1]. The south of Tunisia is the most vulnerable zone to desertification, as about 38% of lands are degraded in the Medenine Governorate [1]. Degradations were featured by a reduction and disappearance of vegetation cover, soil degradation, and a decline in biological diversity. Land degradation is, then, a national concern for sustainable development, biodiversity conservation and climate change (CC) mitigation and adaptation. The urgency of this matter mobilized the national government to adopt immediate and assertive actions and policies to combat this anthropogenic and natural phenomenon.

In 2015, the United Nations Convention on Combating Desertification (UNCCD) has adopted a goal related to land degradation, and the accompanying targets are developed among the 17 SDGs aiming to achieve a land degradation-neutral world by 2030. Specifically, goal 15.3 of the SDGs states “By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world” [2]. The land degradation neutrality (LDN) is a new concept of SDGs under the UN 2030 Agenda for Sustainable Development. LDN creates a target for land degradation management, promoting a dual-pronged approach of measures to avoid or reduce the degradation of land, combined with measures to reverse past degradation. The objective is that losses are balanced by gains, in order to achieve a position of no net loss, of a healthy and productive land [3].

## 2 Materials and Methods

The current research was applied at a local scale in the Dhahar-Jeffara transect (Southeastern Tunisia, Fig. 1), where land degradation is highly active, in order to take a leading role in this matter and ensure a fundamental requisite for LDN target setting. On that account, approaches based on earth observation data (Table 1) and open source applications, and following the provided guidance of [4], have been developed in this study to estimate the state of land resources, trends of land degradation, and define a national voluntary target and measures to achieve LDN by 2030.

This study explores the innovative *Trends.Earth* tool, which is a platform supporting the three indicators for monitoring achievement of LDN. It offers many options allowing to plot time series of land change key indicators (including degradation and improvement), to produce maps, graphics and statistics that can support monitoring and reporting, and to track the impact of sustainable land management.

The main objectives of this study are

- LDN assessment through mapping of land cover change, land productivity change and soil organic carbon stock indicators using Landsat (ETM+ and OLI\_TIRS)



**Fig. 1** Location map of the Dhahar-Jeffara transect in southeastern Tunisia, governorate of Medenine

**Table 1** Characteristics of the Acquired Landsat OLI and ETM+ Images over the Dahar-Jeffara Transect, southeastern Tunisia

Image	Acquisition date	Satellite	Sensor	Cloud cover	WRS path	WRS row
1	22/07/1999	Landsat	ETM+	0.00	190	37
2	18/07/2018	Landsat	OLI_TIRS	0.06	190	37

Source <http://glovis.usgs.gov/>

and MODIS data (MOD13Q1 products from 2002 to 2017) under TIMESAT environment and Trends.Earth plugin under QGIS environment, over the period 1999–2015–2018.

- Analyzing land cover evolution, land productivity dynamics and soil organic carbon change.
- Identifying trends and drivers of land degradation, as well as LDN hot spots and progress toward achieving it.

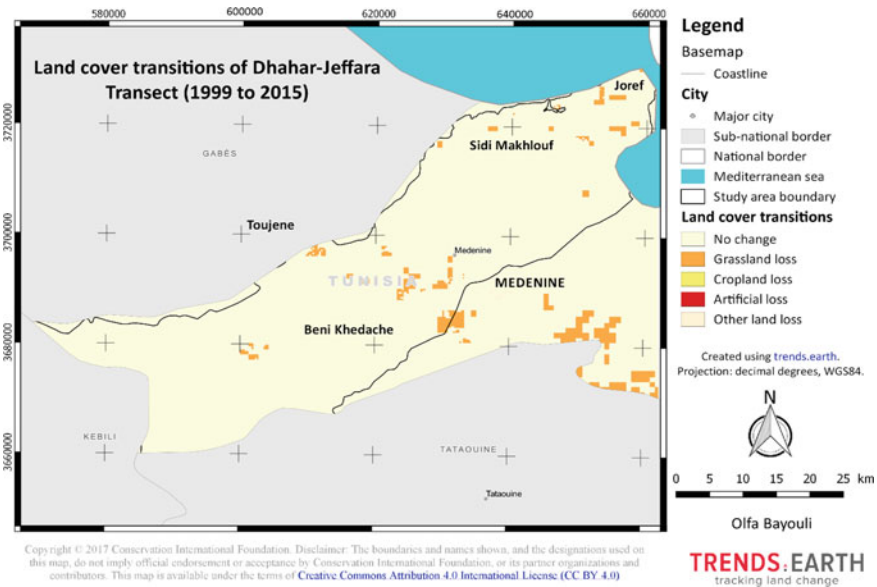
### 3 Results

#### 3.1 Land Cover and Change Detection Mapping

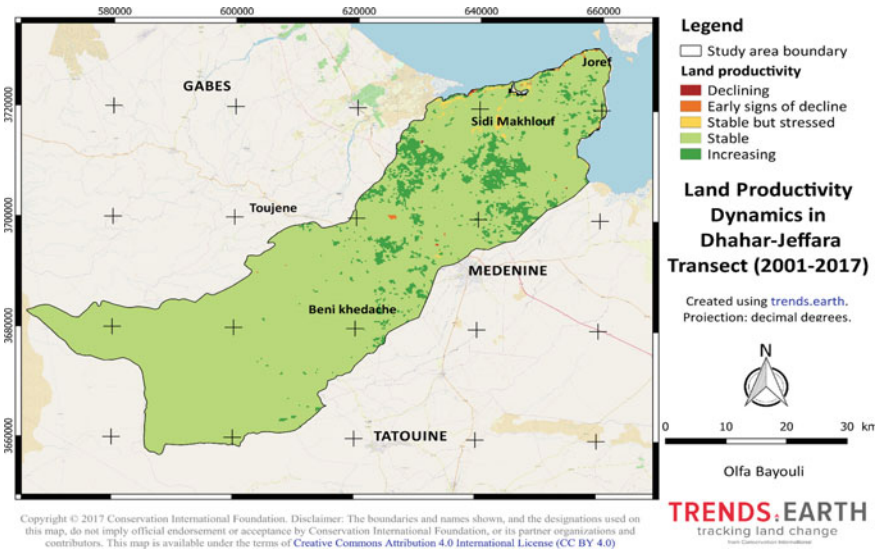
Considering the interest of the study and dominant land cover types, five main classes have been identified from the classification results. Few other land cover classes can be generated but their proportions are too small or not even reflected visibly. The ultimate classification products provide a clear idea of the major LC categories over the Dhahar-Beni Khedache-Jeffara transect for the baseline year (1999) and the target year (2015), revealing, hence, five main classes: Cropland, Grassland, Wetland, Bare soil, and Artificial surfaces (Fig. 2).

#### 3.2 Land Productivity and Land Productivity Change

The analysis of the land productivity dynamics proved that the study area had predominantly stable productivity (91%). It represents an increased Land Productivity (LP) across 8% of the Dhahar-Jeffara transect over the time period from 1999 to 2017, which prevails mainly in its downstream part, and declines to only 0.65% of the land area. Early signs of productivity decline were observed across a limited area



**Fig. 2** Land cover transition map (1999–2015) of the Dhahar-Jeffara transect, using Trends.Earth tool under QGIS environment

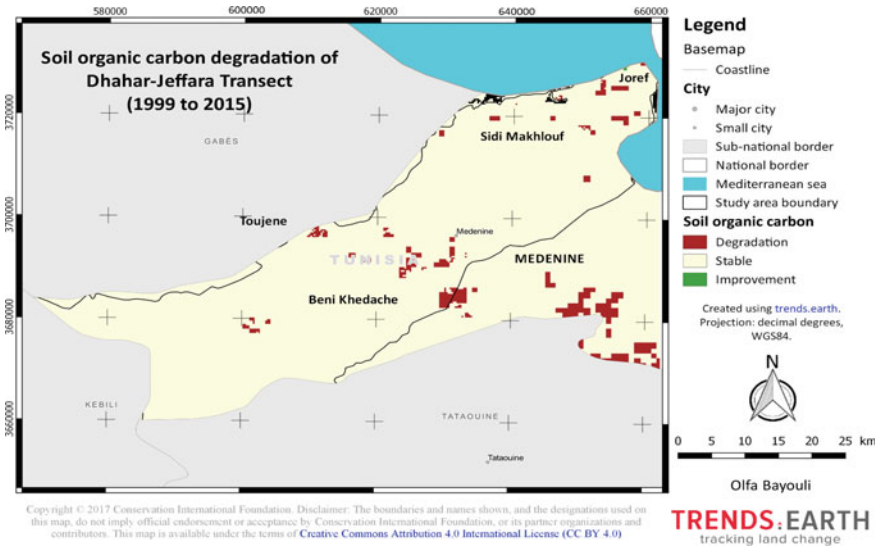


**Fig. 3** Land productivity dynamics in the transect of Dhahar-Jeffara (2001–2017)

in the center of the study area. Stable but stressed land was moderately higher than declining productivity areas. This class is displayed in some coastal zones (Gourine), and in Sidi Makhoulouf and thereabout areas (Fig. 3).

### 3.3 Soil Organic Carbon (SOC) Change

The soil organic carbon change (Baseline year: 1999—Target year: 2015) revealed a stable state in the entire study area except for some degraded states in the coastal and the mountainous regions of Dhahar. Trends.Earth calculates soil organic carbon change based on annual land cover transitions. The target year soil organic carbon value used to produce this table accounts for all land cover transitions that occurred between the baseline and target years. An empty cell indicates that transition was not observed over the time period. The decline in SOC average content is resulting principally from the conversion of grasslands into bare soils (−16.5% of SOC change in grasslands). Since the cropland class presented a certain stability over the reporting period, a decrease of only 0.04% was detected. Whereas, the “other land” class revealed a positive change of SOC stock (2%) (Fig. 4).



**Fig. 4** Soil organic carbon degradation of Dhahar-Jeffara (from 1999–2015)

## 4 Discussion

Land resources are under constant anthropogenic pressure at the local level, where, depending on region, different land degradation drivers were targeted. The most frequent, direct drivers of land degradation across this region were land abandonment, floods, drought, erosion and urbanization, which are underpinned by the lack of responsible land use planning by local communities. Excessive, grazing activities contribute to the degradation of grassland, which is conducive to soil erosion. Agricultural regions are also vulnerable to extreme events like floods and/or droughts, which frequently affect agricultural communities, especially at the level of study area. Climate change forecasted for the study area will increase flooding events given changes in precipitation [5] and other human-induced drivers like excessive exploitation of natural resources especially in the vicinity of water sources, or changes in the grassland type due to overgrazing [6].

The selected LDN indicators dataset identified areas with decreased land productivity and SOC stock within the Dhahar-Jeffara transect. The grasslands in the foothill part of the study area were selected as pilot areas for LDN, since they have a large territory affected by declining SOC and LP contributing to bare land expansion. The integration of some land management practices placed as the highest priority for future interventions. Grasslands must be rested from grazing for at least two growing seasons. There are different reasons commonly cited for grassland resting: recovery of residual plants, regeneration of desirable plant species and accumulation of litter for soil stability. Otherwise, afforestation could be among the important and feasible

measures needed for land protection. Successful reforestation is conceived as a triple-win solution to regain ecological integrity, enhance human well being in degraded landscapes, and improve resilience to climate change. The Dhahar-Jeffara transect is an important agricultural region (especially as olive plantations) and a backbone of rural households' economic development. The decrease in land productivity is a consequence of several land degradation drivers, where extreme events of drought and floods, are identified as natural drivers on one side, and loss of organic matter, salinization and soil compaction as human-induced drivers on the other. Farmers of these regions have to be particularly interested in education and knowledge about sustainable land management and other possible measures that will help them to increase organic matter level, decrease existing over-usage of natural resources and ensure the sustainability of their land. The Tunisian Ministry of Agriculture, committed to this proposal, aimed to implement appropriate SLM measures that will additionally contribute to achievement of LDN.

## 5 Conclusions

The studied Dahar-Jeffara transect stretches over different natural regions in the southeastern part of the country, where clear evidence of degradation is apparent in these landscapes, coupled with adverse climatological and hydrological conditions. The present study has developed a method based on the integration of satellite images and cartographic data under a GIS environment to analyze and evaluate the land degradation status, and consequently, weighs the progress toward the Land Degradation Neutrality (LDN) at the study area scale. We identified that areas such as "Metamaeur", "Dkhilet Toujene" and "Amra" are showing positive changes (improvement) towards LD. The outputs of the application, mapped over a 20-year observation period in the Dahar-Jeffara transect, confirmed that it has a stable land degradation status (89%). Moreover, the statistical analysis demonstrated that 8% of the total study area has improved, while 3% of the transect is affected by LD. The observed degradation resulted mainly from the grassland loss where declines in land productivity and soil organic carbon stocks were identified. This helped to recognize the key degradation drivers in the study site. In fact, degradation generally results from the severe climate that the area was confronted to, with infrequent, yet intense, rainfall, water erosion (sand encroachment, overgrazing, especially in the plain area, and salinization nearby coastal zones). In order to achieve LDN in the Dhahar-Jeffara region, it is necessary to set the LDN baseline, target, and associate measures.

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