Zhongguo Kuangye Daxue Xuebao

2026 | Vol 31 | Issue 2 | Page 1-7
Journal Homepage: https://zkdx.ch/
DOI: 10.1654/zkdx.2026.31.2-01

Monitoring Vegetation Cover Degradation through Remote Sensing

A Soil-Adjusted Vegetation Index (SAVI) Analysis for the Ouled Djellel Region, Algeria

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Abstract
The principal objective of this research is to evaluate the spatial extent and severity of degradation in the natural rangelands of the Ouled Djellal region. Geographically situated on the slopes and southern escarpments of the Saharan Atlas in southern Algeria, these rangelands constitute vital pastoral landscapes supporting substantial livestock populations. The vegetation is characterized by shrub communities adapted to arid and semi-arid climatic regimes, forming the ecological foundation of these systems.

Since the onset of the 21st century, a pronounced decline in shrub cover has been observed across the region. This loss is critically significant from a geographical and ecological perspective, as the vegetation serves not only as a primary forage resource but also as a key stabilizing element for maintaining landscape ecological equilibrium. The resultant degradation has induced substantial socio-ecological challenges, disrupting the established pastoral economy.

The spatially variable density of the shrub cover is quantitatively assessed using the Soil-Adjusted Vegetation Index (SAVI). This remote sensing index is selected for its documented precision in detecting sparse and low-density vegetation in arid environments, offering a methodological advantage over the more commonly used Normalized Difference Vegetation Index (NDVI). The SAVI minimizes soil brightness interference, providing enhanced spatial resolution and sensitivity for accurately mapping vegetation density gradients and structural characteristics across these heterogeneous and environmentally constrained landscapes.

Keywords
Degradation, Livestock, GIS, Shrubs vegetation, SAVI

1. Introduction
The Ouled Djellal region constitutes a critical transitional landscape in southeastern Algeria, positioned at the ecotone between the Saharan Desert and the northern steppe zone. This biogeographical location underpins its dual function as a combined pastoral and agricultural system. Historically, its viability has been supported by desert-specific agro-pastoral adaptations, notably linear oasis agriculture along the northwest-southeast axis of the Wadi Djedi. Adjacent to these riparian zones, expansive rangelands host diverse xerophytic shrub communities that sustain traditional livestock husbandry, including sheep, goats, and camels

Over the past three decades, however, the region has undergone significant environmental change. Pronounced climatic shifts toward increased aridity have driven a marked regression of its endemic shrub formations. This phytogeographical retreat has directly diminished forage biomass, compelling pastoralists to increasingly rely on state-subsidized fodder to meet livestock nutritional demands—a socio-ecological shift indicating systemic rangeland stress.

To spatially quantify the degradation of these ecologically and economically vital grazing lands, this study employs a multi-temporal remote sensing approach. Satellite imagery from 1995, 2005, and 2020 was analyzed to map and measure changes in vegetation cover across the provincial extent. This longitudinal design captures the spatiotemporal dynamics of environmental degradation. The inherent resistance of plant communities to water deficit is not uniform but exhibits distinct spatial patterning. This heterogeneity is a function of bio-physical and anthropogenic variables, notably localized grazing pressure and species-specific root system architecture. Areas under intense herbivory pressure with shallow-rooted species demonstrate pronounced susceptibility to desiccation, leading to a fragmented landscape of degradation. Consequently, these processes have accentuated pre-existing environmental gradients, manifesting in a discernible southward and eastward shift in vegetation density—a spatial expression of the region's advancing aridity.

The analytical framework utilized Geographic Information Systems (GIS) to perform a comparative change detection analysis on the multi-temporal satellite imagery. This methodology accounts for sensor-specific characteristics across successive Landsat platforms (Landsat 4-5 Thematic Mapper and Landsat 8 Operational Land Imager) to ensure radiometric consistency and enhance the reliability of longitudinal quantitative assessments. The integration of remote sensing and GIS thus facilitates a robust spatial-historical reconstruction of vegetation cover change, providing critical insight into the trajectory of landscape degradation in this vulnerable transitional zone.

2. Methods

2.1 Study Area and Dataset used

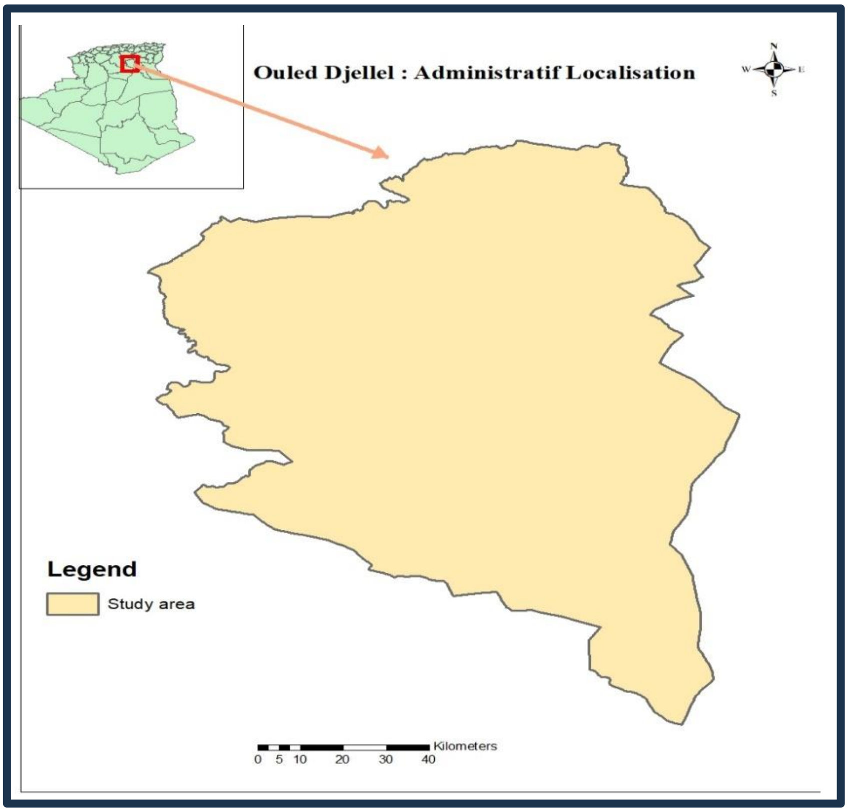

Fig. 1 Administratif Localisation

The Ouled Djellal Province (Wilaya) is one of the newly established administrative divisions created under Law No. 19-12, dated December 11, 2019, which pertains to the territorial organization of the Algerian state. Prior to the enactment of this legislation, it was administratively integrated into the Biskra Province. Geographically, Ouled Djellal constitutes a transitional zone between the steppe and the Sahara Desert. It is located between the longitudes of 4° and 6° East and the latitudes of 32° and 35° North.

2.2 A desert region distinguished by shrubby vegetation cover

Given that the region lies within the Saharan regional zone, it contains shrubs adapted to this zone, forming various, intertwined groupings that often constitute biological diversity. However, after years of drought and aridity, and with unintentional human contribution, this diversity now only appears in limited areas.
Among the widespread plant formations are:

2.2.1 Arthrophytum scoparium Formations (Remth)

These are found in the *Besbes* area and the far west of *Ras Al-Miad*, growing on calcareous-magnesic soils. Arthrophytum scoparium formations cover an area of 170,000 hectares around the *djadi* river and *Besbes* river regions, primarily located on remnants of ancient Villafranchian surfaces. These surfaces are characterized by the spread of hamadas (rocky deserts), formed due to aridity, combined with tectonic stability that led to the development of a calcareous crust resistant to erosion, with outcrops of gypsum appearing.

Fig. 2 *Arthrophytum scoparium*

Fig. 3 *Stipa tenacissima*

The scientist Quezel (1965) linked the presence of Arthrophytum scoparium to the presence of gypsum. However, an exception in its distribution exists, with considerable areas also found on the Reg (a desert pavement), which represents a continental Pliocene surface with a calcareous crust overlying the red sands of the Tertiary period.

2.2.2 Stipa tenacissima Formations (Alfa Grass)

These are located in the northwestern part of the study area, marking the initial convergence of the Saharan zone with the steppe zone, where annual precipitation approaches 100 mm.

2.2.3 Artemisia herba-alba Formations (White Wormwood)

Found in narrow, limited areas within the same zone as Stipa tenacissima.

2.2.4 Lygeum spartum Formations

Fig. 4 *Lygeum spartum*

Fig. 5 *Artemisia herba-alba*

Fig. 6 *Ephedra alata* Decne

These are highly valuable pastoral plants, effective at soil stabilization due to their extensive root systems. They are used for protecting degraded pastoral areas through replanting by specialized institutions involved in steppe development. Their range coincides with that of *Stipa tenacissima* and *Artemisia herba-alba*, but they exhibit greater tolerance to drought.

2.2.5 Ephedra alata Decne. Formations ('Alanda)

These occur on gravelly areas with calcareous-gypsum crusts between *Douihba* river and *djadi* river, extending further west where they become more widespread, covering an estimated area of 5,992 hectares. They occupy heterogeneous, eroded depressions on old Quaternary surfaces subjected to wind erosion. This plant species only covers about 9% of its potentially suitable area.

Other plant formations also exist in the region alongside those mentioned above, but their areas have become restricted over the years. These include: Traganum nudatum, Anabasis articulata shrubs, Rhanterium adpressum.
Furthermore, some shrubs serve as indicators of arid and degraded areas, among them:
· *Astragalus armatus* (a thorny plant), and
· *Peganum harmala* L., which is often the last remaining species following the degradation of the surrounding vegetation

2.3 How to Calculate SAVI

The Soil-Adjusted Vegetation Index (SAVI) is employed to mitigate the influence of soil brightness, making it particularly suitable for arid and semi-arid zones characterized by sparse vegetation cover.

$$\text{SAVI}=\left(\frac{NIR-RED}{NIR+RED+L}\right)*(1+L) \quad (1)$$

-NIR: Near-Infrared band (reflectance from healthy vegetation). Its the Band 4 for Landsat 4 et 5, and Band 5 for Landsat 8.
Red: Red band (absorbed by chlorophyll). Its the Band 3 for landsat 4 and 5, and the Band 4 for Landsat 8.
- L: Soil adjustment factor (typically 0.5 for moderate vegetation; ranges from 0 to 1) .

Following the download of satellite images from the USGS Earth Explorer portal, summer-acquired scenes were deliberately selected to minimize the influence of seasonal ephemeral vegetation. The selected images were processed in

ArcGIS, where the three scenes covering the study area were mosaicked into a composite raster. Subsequently, the study area was extracted using a clipping operation.

The Soil-Adjusted Vegetation Index (SAVI) was then computed using the **Raster Calculator** function within the Map Algebra framework. To address sensor discrepancies between the **Thematic Mapper (TM)** on Landsat 5 and the **Operational Land Imager (OLI)** on Landsat 8, cross-sensor normalization was applied using the following equation:

$$P\mathrm{OLI}=a * P\mathrm{TM}+b \qquad (2)$$

b = 0.0004 for Band 5 and 0.0001 for Band 4
a=0.996 for Band 5 and 1.005 for Band
in other way :
("B5" - 0.0004) / 0.996
("B4" - 0.0001) / 1.005

Table 1 Summary of Landsat 8 bands used in the study

Band Number	Name	Wavelength (µm)
4	Red	0.64 – 0.67
5	Near_Infrared	0.85 – 0.88

3. Results

Given the sparse, scattered, and dynamic nature of vegetation cover in arid regions, the Normalized Difference Vegetation Index (NDVI) does not accurately represent vegetation conditions. Consequently, the Soil-Adjusted Vegetation Index (SAVI) was employed to more reliably assess vegetation cover and enhance the precision of degraded area calculations. Following raster-to-vector conversion, the resulting polygons were classified by map color, each representing a distinct soil cover type. The area of each class was then computed using the attribute table associated with each thematic map. The findings are presented below ;

Table 2 Degraded area

Year	1995	2005	2020
Degraded area (ha)	127428,59	341528,71	503225,7
Vegetation (ha)	986494,53	777800,17	612008,7

The degraded area in rangelands from 1995 to 2005 amounted to 208,694.5 hectares over a 10-year period, while 165,792 hectares were degraded between 2005 and 2020 (a 15-year span). This change in végétation area—primarily consisting of shrub communities critical for livestock forage (supporting thousands heads of livestock)—reflects a clear deterioration trend.

As illustrated in **Fig.** (7), this degradation is concentrated in the eastern and southeastern parts of the study area, characterized by higher temperatures and lower precipitation. In contrast, the northern and western regions exhibit more complex topography, including elevated and mountainous terrain, where shrub communities have persisted due to the difficulty of grazing access.

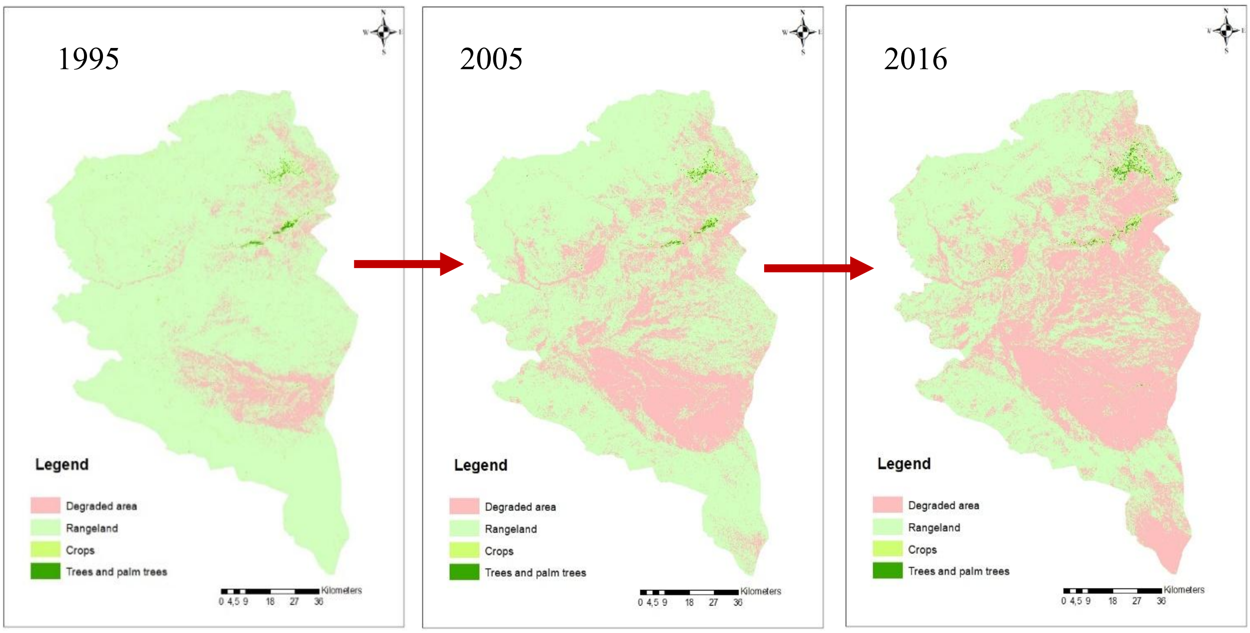

Fig. 7 Vegetation cover decrease in the study area

4. Discussion

The degradation of vast areas of already fluctuating vegetation cover—which once served as a major grazing resource has coincided with an expansion of arid lands **Fig**. (7) now at risk of desertification. This decline has also triggered a severe shortage of livestock forage, compelling herders to import large quantities of feed to compensate for the deficit in their herds' nutritional needs.

This large-scale regression in the region stems from multiple factors, including climatic drivers and anthropogenic pressures related to grazing management. For instance, the western zone, where vegetation cover remains relatively intact, has experienced a near-total absence of grazing activity for years due to security concerns linked to Algeria's past instability, particularly in mountainous areas.

Beyond climatic influences, overgrazing and encroachment into fallow lands have exacerbated the degradation. The dual pressures of rising livestock numbers and uncontrolled plowing have significantly reduced shrub communities, depriving them of the opportunity for ecological recovery.

The region contains a total of 476,000 heads of livestock, including 415,000 sheep and 61,000 goats. This substantial livestock population requires adequate pastureland to provide sufficient food and grazing resources

Fallow and pastoral lands account for 78% of the total area of the region, which is 1,127,800 hectares. More than half of these lands have deteriorated over the past 25 years and have become non-grazing areas. The remaining half has an average productivity of 250 feed units (FU) per hectare.

Since the feed requirement of sheep is estimated at 420 FU, and the feed requirement of goats is 350 FU.

The degradation of extensive areas of previously variable vegetation cover—historically a critical grazing resource—has coincided with the expansion of arid zones, as illustrated in Figure 7. These lands are now at risk of desertification. This decline has precipitated a severe shortage of forage for livestock, compelling pastoralists to import substantial quantities of feed to compensate for the nutritional deficit in their herds.

This large-scale environmental regression is driven by a confluence of climatic stressors and anthropogenic pressures, primarily related to land management practices. Notably, the western zone, where vegetation cover remains comparatively intact, has experienced minimal grazing pressure for years due to security constraints stemming from past instability in Algeria, particularly in mountainous regions. Beyond climatic variability, anthropogenic factors such as overgrazing and the encroachment of cultivation into fallow lands have significantly accelerated degradation. The combined pressures of increasing livestock densities and unregulated plowing have critically diminished shrubland communities, inhibiting their capacity for ecological regeneration.

The region supports a total livestock population of 476,000 head, comprising 415,000 sheep and 61,000 goats. This substantial population necessitates sufficient pastoral land to meet its foraging requirements. Fallow and pastoral lands constitute 78% of the region's total area of 1,127,800 hectares. However, more than half of these lands have degraded over the past 25 years and are no longer viable for grazing. The remaining productive area has an average forage productivity of approximately 250 Feed Units (FU) per hectare.

Given that the annual feed requirement is estimated at 420 FU per sheep and 350 FU per goat, the current productive land base is insufficient to meet the total livestock demand, underscoring the severity of the pasture deficit and its implications for sustainable land use.

The deficit can therefore be calculated as follows:

- Sheep requirement: 415,000 heads × 420 FU = 174,300,000 FU per year (1)
- Goat requirement: 61,000 heads × 300 FU = 18,300,000 FU per year (2)

The total feed requirement amounts to 192,600,000 FU per year. (3)

The available quantity is:

612,008.7 ha × 250 FU/ha = 153,002,175 FU per year (4)

The deficit incurred here is estimated at 39,597,825 UF per year (5)

Livestock breeders resort to compensating with alternative fodder or relocating the animals to areas with better pastures outside the region.

5. Conclusion

Natural pastures constitute a critical component of the pastoral economic system, functioning as the primary forage base for extensive livestock populations. Concurrently, they play a vital role in maintaining ecological equilibrium within arid and semi-arid ecosystems. The preservation of vegetative cover in areas susceptible to desertification represents a strategic environmental priority for national policy.

The Ouled Djellal region serves as a significant biogeographical and socio-economic nexus between northern and southern Algeria, as well as between eastern and central provinces. Within this region, livestock husbandry ranks as the secondary economic activity after Saharan agriculture. Consequently, the ongoing degradation of pastoral landscapes presents a substantial threat to local populations whose livelihoods are intrinsically linked to these agro-pastoral systems.

The application of Geographic Information Systems (GIS) for monitoring vegetation regression has emerged as an indispensable scientific methodology within environmental management. This geospatial technology enables the precise identification of degraded zones, quantification of their spatial extent, and formulation of targeted remediation strategies. Key restorative interventions include the rehabilitation of denuded areas through re-vegetation, implementation of controlled grazing regimes, and support for pastoralist communities in sustaining these fragile ecosystems.

The utilization of the Soil Adjusted Vegetation Index (SAVI) is particularly advantageous in arid and semi-arid regions due to the characteristically sparse, heterogeneous, and spectrally indistinct nature of vegetative cover. This index compensates for soil brightness variations, thereby enhancing the accuracy of biomass assessments from remote sensing data. Furthermore, accounting for inter-sensor variability among satellite platforms is essential to ensure the temporal consistency and reliability of derived environmental information.

Spatial variability in vegetation degradation across the region is attributable to two principal factors. The primary climatic driver is elevated temperature regimes, particularly pronounced in southern and eastern sectors. Secondary anthropogenic pressures relate to differential grazing intensities; western areas have historically experienced lower exploitation pressure due to topographic constraints and periods of perceived insecurity, resulting in the preservation of comparatively denser shrubland communities.

Rehabilitation protocols for degraded rangelands involve multifaceted approaches. These include the provision of supplemental fodder resources to support livestock populations, coupled with the large-scale establishment of cultivated forage crops on degraded lands to create irrigated pasture systems. Furthermore, pastoral activities are being systematically reorganized through the implementation of regulated grazing schedules within carefully delineated management units.

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