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The Correlation between LST (Land Surface Temperature) and SAVI (Soil-Adjusted Vegetation Index) In Arid Region Case of Ouled Djellel-Algeria by Using GIS Technology

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ABSTRACT:

Arid regions are characterized by fluctuating vegetation cover and elevated temperatures, presenting unique challenges for ecological and climatic studies. This research investigates the relationship between limited vegetation cover and temperature variations. Consequently, it is imperative to consider vegetation cover when analysing any temperature-related indices. To this end, we selected the Soil-Adjusted Vegetation Index (SAVI) as our primary focus, as the Normalized Difference Vegetation Index (NDVI) proved inadequate for accurately assessing vegetation cover in these environments. This study aims to ascertain the extent to which sparse and less verdant plant life influences surface temperature. Furthermore, we explore the potential of utilizing vegetation fraction as a criterion for temperature calculations in arid landscapes.

Keywords: LST, SAVI, CORRELATION, GIS, ARID, Fluctuating végitation

1. Introduction

The Ouled Djellal region exemplifies a transitional ecotone between the Sahara and steppes in the East of Algeria, thereby delineating a boundary between arid and semi-arid climatic zones.

This geographical positioning fosters a distinctive integration of oasis agricultural practices with extensive livestock grazing.
The landscape is characterized by sparse shrub communities, which function as crucial grazing resources for substantial livestock populations.
However, the region has experienced significant environmental degradation. Prolonged drought conditions over the past three decades have led to the deterioration of numerous shrub communities in arid zones, including the Ouled Djellal area.
This degradation has precipitated a reduction in available fodder and a decline in the abundance of both shrub and grass species.
Concomitantly, there has been an observed increase in regional temperatures and an exacerbation of sand encroachment in these degraded areas, creating significant ecological challenges for areas adjacent to the southern piedmont of the Saharan Atlas.
These adverse changes indicate an ongoing transition from semi-arid to arid conditions, contributing to a progressive desertification process within these vulnerable regions
In this work, we attempt to find the correlation between SAVI (Soil Adjusted Vegetation Index) and LST (Land Surface Temperature). Previous studies have made attempts to establish a link between vegetation cover (NDVI) index with rising temperatures. However, in arid regions such as our study area, we attempt to identify the relationship between SAVI and desertification, which is driven by a range of human factors, including overgrazing, irregular plowing, and sand encroachment. The latter has been exacerbated by the absence of shrub communities that previously acted as a barrier to sand movement.
The use of Geographic Information Systems (GIS) is capable of accurately representing this relationship between indices by using remote sensing and then processing the data across different time periods.

2. Research methods

Study Area and Dataset Used

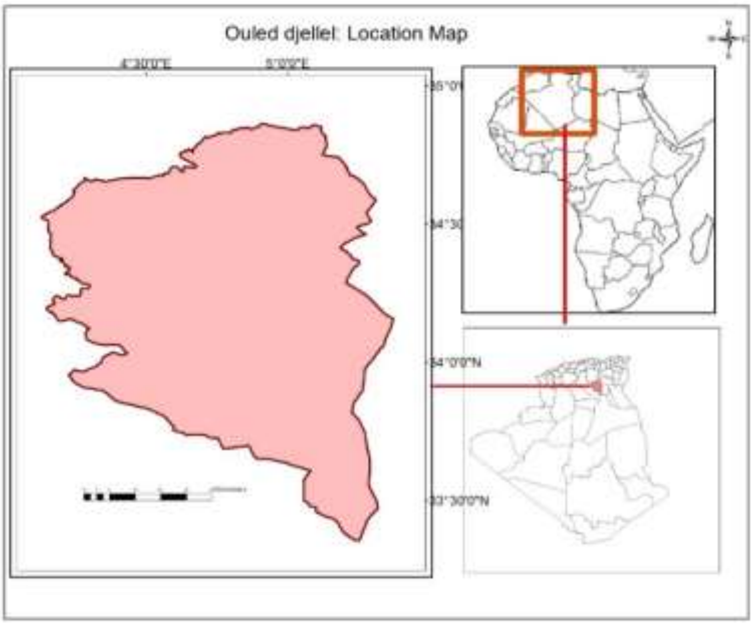

Fig1

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.

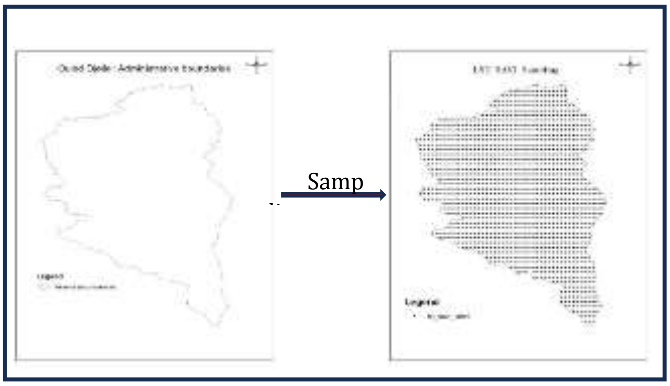

Fig2

Calculation and comparison of Land Surface Temperature (LST) and Soil Adjusted Vegetation Index (SAVI)
To calculate SAVI and LST, we used remote sensing through Landsat 8 satellite imagery. The images were imported into the GIS system, which serves as the platform for image input and processing using the following method.

After downloading the satellite imagery for the study area, of landsat 8 with a spatial resolution of 30 meters, we imported the data into the QGIS platform and utilized its various layers and spectral bands. Using the Raster Calculator, we applied several equations aimed at distinguishing areas covered by vegetation or certain plant species, considering the fluctuation in their distribution. Regarding land surface temperature (LST), we followed a similar spectral-based approach to differentiate temperature variations across the entire study area.

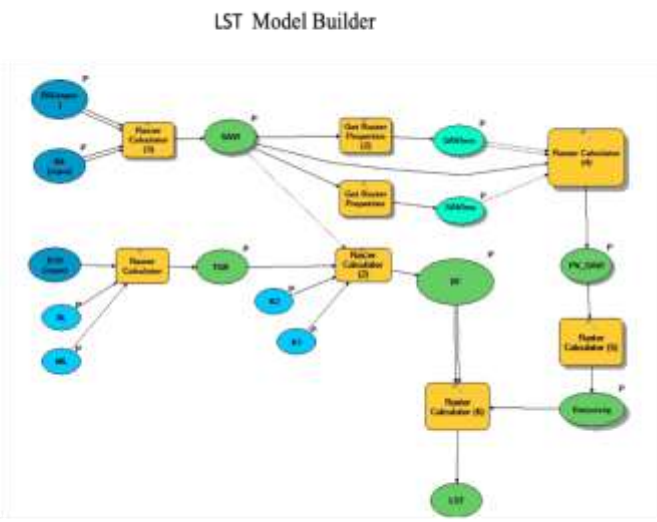

Fig 2

1.1 Calculating LST (Land Surface Temperature)
LST is not the same as air temperature. It represents the radiative temperature of the Earth’s surface.

NDVI and emissivity values should be adjusted based on local conditions and image metadata. But we take SAVI and the portion of vegetation using the $SAVI_{max}$ and $SAVI_{min}$ like parameters as explained in the following model builder:
Several other equations are used to derive the equation to calculate TOA (Top of Atmosphere), where

$$TOA(L) = ML \times Qcal + AL \quad (1)$$

Here, ML represents the RADIANCE_MULT_BAND for Band 10, which is 0.00033420, and AL is the RADIANCE_ADD_BAND_10, equal to 0.10000.

$$BT = \left(\frac{K_2}{\ln\left(\frac{K_1}{L}\right)+1}\right) - 273.15 \quad (2)$$

Where K_1 and K_2 are constants specific to Landsat 8 Band 10, with values of 774.8853 and 1321.0789, respectively. L refers to the TOA radiance calculated in the previous step. E is the land surface emissivity:

$$E = 0.004 \times PV \times 0.986 \quad (3)$$

knowing that:

$$PV = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (4)$$

this equation is replaced in our study by the following equation:

$$PV = \left(\frac{SAVI - SAVI_{min}}{SAVI_{max} - SAVI_{min}}\right)^2 \quad (5)$$

Finally, after using all the previous equations, the calculation of the surface temperature value is as follows:

$$LST = \frac{BT}{\left(1+0.00115 \times \frac{BT}{14388}\right) \times \ln(E)} \quad (6)$$

1.2 Calculate SAVI

To calculate the Soil Adjusted Vegetation Index (SAVI) using Landsat 8 data, we will need Band 4 (Red) and Band 5 (Near Infrared - NIR). The formula is:

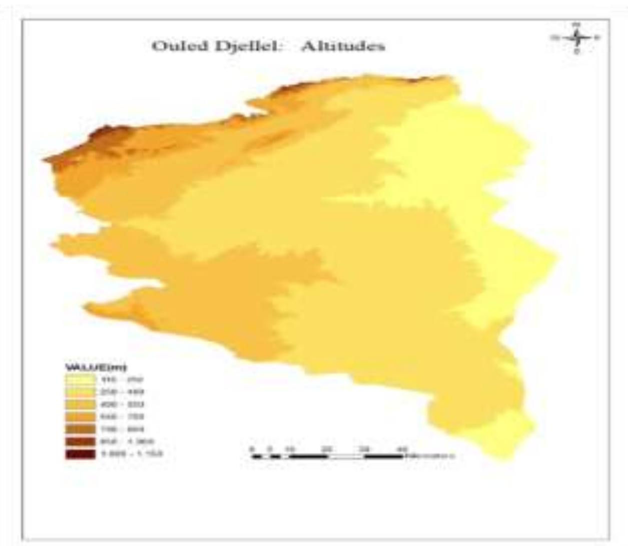

Fig4

$$\text{SAVI} = (\text{Band5} - \text{Band4}) \times (\text{Band5} + \text{Band4} + L) \times (1 + L) \quad (7)$$

where L is a correction factor that is generally set to 0.5 for areas with varied vegetation cover.

1.3 Elevation And Temperature

Elevation plays a significant role in temperature variation. Generally, for every 150 meters of altitude, the temperature decreases by approximately one degree Celsius.

In the given map in fig 4, the contour interval is 150 meters to distinguish temperature changes of one degree Celsius per elevation change. This allows us to exclude high-altitude areas when comparing surface temperature with the Soil-Adjusted Vegetation Index (SAVI).

In addition to the elevations in the north, which exceed 600 meters, there is a significant shrub vegetation cover in these high-altitude areas. Thus, a similarity in surface temperature is observed in the north.

2 Results and Discussion

2.1 Correlation Between LST and SAVI

Using SAVI instead of NDVI in the study because of the sparse, scattered, and fluctuating vegetation cover as a result, the NDVI vegetation index does not provide a true and accurate representation of vegetation cover in arid regions. Therefore, we used SAVI to obtain more precise results in terms of the correlation between SAVI and LST.

To accurately define the correlation between the two indices, by using QGIS (the CreateFicheNet tools) to insert the values into an attribute table by extraction multi values to points that compile the fields of each attribute.(Fig2)

From the four maps drawn in fig 5, based on the previous equations for calculating land surface temperature and SAVI, we can conclude that there is a variation in land surface temperature during the thermally moderate seasons, autumn and spring. This variation depends on changes in vegetation cover in both seasons. Therefore, we deduce that vegetation cover, despite its scarcity and fluctuations, has an impact on land surface temperature, particularly in the flat areas in the central and southern parts of the study area, this later contains some scattered sand dunes.

In the region under study, the vegetation cover comprises diverse shrub communities that play a crucial role as a food source for extensive livestock populations, notably sheep and camel herds. These shrubs

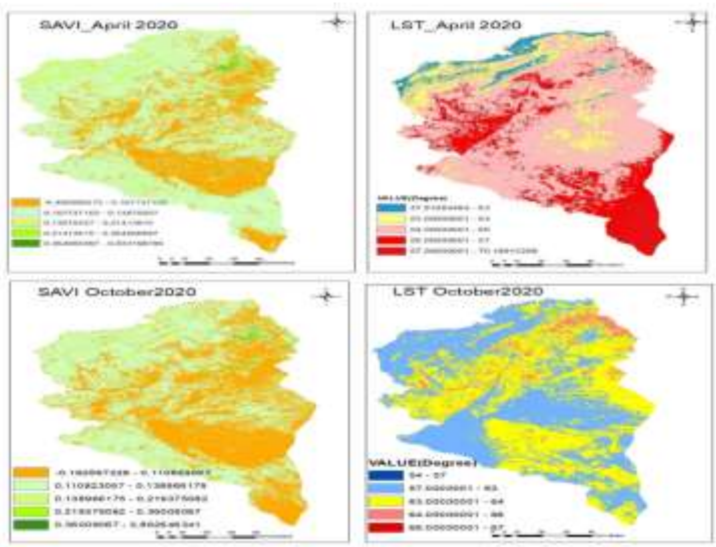

Fig5

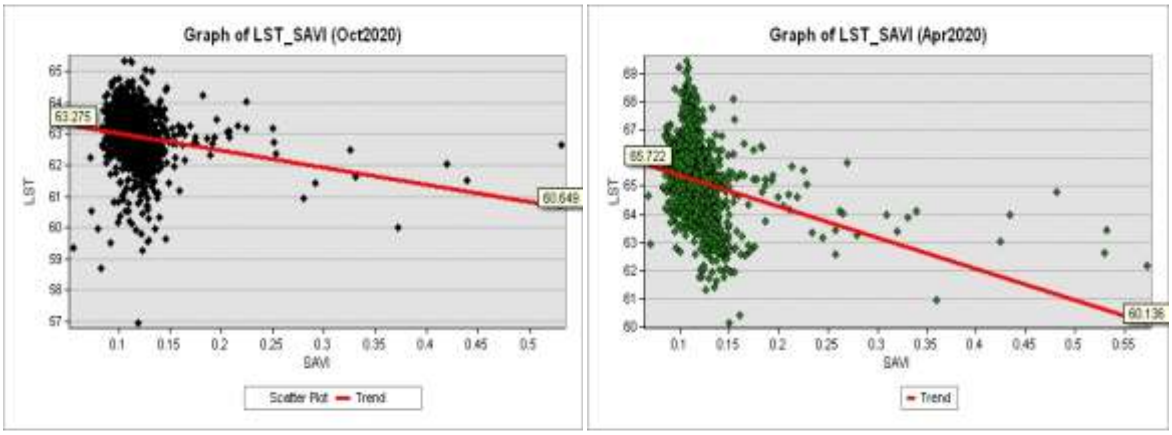

Fig6

also function as a protective barrier against soil erosion in an area marked by environmental vulnerability.

In the northern part of the region, specifically on the slopes of the Saharan Atlas, the landscape features a cover of *Alfa grass* (*Stipa tenacissima*) interspersed with shrub communities of *Artemisia herba-alba*, predominantly found at elevations above 700 meters. In contrast, the southern and central regions exhibit intercalary plant communities characterized by a variety of shrub species, including *Ephedra alata, Gymnocarpos decander, Aristida pungens,* and *Anabasis articulata*. This spatial distribution of vegetation types reflects the region's complex ecological dynamics and highlights the importance of these plant communities in maintaining environmental stability

From the graph in fig 6, we observe an inverse relationship between Land Surface Temperature (LST) and SAVI. This indicates that vegetation cover in the study area influences surface temperature, despite its low density. The temperature reaches approximately $66^{\circ}C$ in the absence of any vegetation cover and decreases to $59^{\circ}C$ when the SAVI value reaches 0.8.

3 Conclusion

The interrelationship between various environmental indicators, particularly the association between vegetation indices and land surface temperature (LST), has been the subject of extensive research globally. However, in arid regions, the dynamics of fluctuating vegetation cover and its correlation with LST have not been sufficiently explored. This vegetation, which has undergone significant degradation in recent years, critically influences the interaction between LST and vegetation cover.

The application of Geographic Information Systems (GIS) and remote sensing technologies has been instrumental in evaluating changes in vegetation indices and fluctuations in LST. This assessment has been facilitated through raster computing techniques and specialized equations that utilize specific spectral wavelengths.

The land surface temperature can reach $70^{\circ}C$ in arid regions. Since Ouled Djellel is part of this region, surface temperatures during the moderate seasons range between $50^{\circ}C$ and $70^{\circ}C$. This value may exceed $70^{\circ}C$ during the summer.

An analysis of the Soil-Adjusted Vegetation Index (SAVI) and the Land Surface Temperature (LST) index revealed an inverse correlation between the two indices. The surface temperature

increases when the soil is completely devoid of shrubby pastoral groups and ephemeral seasonal grasses.
Despite its scarcity, fragmentation, and limited extent, vegetation cover in arid regions has a noticeable impact when analysed in relation to land surface temperature. This relationship becomes particularly evident during transitional seasons or in months with moderate temperatures, such as April and October. In spring, temporary seasonal grasses and pastoral shrubs emerge in arid areas, influencing surface temperature. However, by autumn, this vegetation declines due to the high summer temperatures and intensive grazing by livestock, as thousands of sheep graze in these regions.

Although the relative coolness of October compared to April in 2020, which was the time when the two satellite images were taken, the relationship between surface temperature and vegetation cover remained consistent, confirming the theory of an inverse correlation between the two indicators. This observation aligns with the geographical principle that surface temperature and vegetation cover often exhibit an inverse relationship, as vegetation tends to moderate surface temperatures through processes such as evapotranspiration and reflectance.

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