THE CONTRIBUTION OF REMOTE SENSING IN HIGHLIGHTING THE RESILIENCE OF RANGELANDS THROUGH INDICATORS OF LAND SURFACE TEMPERATURE AND THE NORMALIZED DIFFERENCE VEGETATION INDEX IN THE TIHAMA ALLUVIAL PLAIN

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DOI: 10.21163/GT_2024.192.11

ABSTRACT

The rangelands form a precious heritage of an ancient agro-pastoral system in Saudi Arabia, known for its livestock based on camel. The extensive rangelands in the Tihama alluvial plain are facing a deterioration in climatic conditions. In the past, the monitoring of these rangelands, in general, was done by direct vegetation surveys in the field. Currently, researchers have greatly benefited from the contribution of remote sensing, especially with the eighth generation of Landsat satellite images, making it possible to provide values relating to the thermal emissivity of the ground surface, obtained in the two bands 10 and 11. This method allows the calculation of algorithms and the creation of advanced models. The creation of a multi-source database established on the exploitation of the Geographic Information System and remote sensing was necessary to identify the local conditions that have favored the resilience of the plant cover, and the identification of multiple intervention methods appropriate to each sector according to its state of resilience. The results revealed a reduction in soil temperature average, increasing from 29.5 - 42.5°C in 2013 to 38.2 - 25.3°C in 2022. These changes are accompanied by a significant expansion of the vegetation cover, estimated at 26% over the same period despite the substantial climate changes the region has experienced. In the Tihama plain the LST index is significantly influenced by the type of deposit, soil salinity, soil moisture, as well as the density of soil benches. On the adjacent eastern and north-eastern slopes, the values are much lower due to the altitude, the sheltered position, the inclination of the angle of incidence of the sun's rays and the disparity in the colours of the rocky outcrops.

Key-words*: LST index, NDVI index, thermal comfort, plant resilience, rangelands, surface humidity.*

1. INTRODUCTION

In the present study, attention will be focused on the alluvial plain of the Hili and Yabbah wadis, which has undergone complex geomorphological dynamics in which forms of hydric origin mingle with those of eolian origin to give rise to a green space in an arid zone, despite the climatic changes that are in vigour. Although the scientific communities agree on the role of the mountains as the driving force behind the major local climatic constraints, certain disparities are sometimes noted in the plains, where local climatic and edaphic conditions are very favourable for the rehabilitation of natural plant cover. In the same perspective, the Tihama plain constitutes a real experimental laboratory to identify the different facets of landscape changes that have occurred during the last decade. The study area has special morphoclimatic characteristics due to its position between the sea and the Sarawat mountain range, which have largely conditioned a geomorphological dynamic controlled by the combined effects of water flow and wind. In order to enhance our understanding of these recent vegetation dynamics, it was necessary to accurately identify the contribution of the associated geomorphological forms and the role of different natural and anthropogenic factors in enhancing the state of the vegetation cover. Thus, a number of remote sensing indices were developed by multidisciplinary researchers to determine the behaviour of the soil related to hydro-climatic and human factors. The two most widely used indices are the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI).

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Recently, several studies have been carried out investigating the identification of the LST parameter, which is mainly used in the estimation of thermal comfort in urban and peri-urban areas, in the delimitation of urban land and in the determination of the role of vegetation cover in the restoration of living conditions in large cities (Sobrino et al., 2004; Tahouri et al., 2017). Many others fields of investigation are particularly relevant to LST index as a crucial input parameter, such as drought, forestry, pasture monitoring, climate comfort studies, urban heat islands and so on (Ivan and Benedek, (2017), Roy and Bari, 2022; Varamesh et al., 2022; Degefu et al. 2023). There for, many researchers have explored this research area and they have provided valuable insights into the LST index and how it affects pasture conditions (Gleyce et al., 2019). Guha and Govil (2020) have revealed an inverse relationship between LST and NDVI values using the principal components statistics method. They have also shown that the LST index is strictly controlled by surface characteristics and seasonal changes. The accuracy of this key parameter was judged in order to achieve an optimum improvement in the results, so (García-Santos et al., 2018) tried to test a correction algorithm on band 11 of Landsat 8 satellite images to reduce the error caused by stray light.

Three algorithms (mono-window algorithm, split window algorithm (SWA) and single-channel (SC)), were tested to extract the LST map from the Landsat 8. The results showed that the split window algorithm (SWA) was the least sensitive to error (Gerace and Montanaro, 2017; Jiang and Lin, 2021). In the present research, this index will be used to understand the causes of the increase in humidity and the proliferation of usable water reserves in the soil, despite the decrease in rainfall in terms of quantity and seasonal distribution. Moreover, the alluvial plain of wadis Hili and Yabbah has not been the subject of detailed scientific reflection using similar techniques.

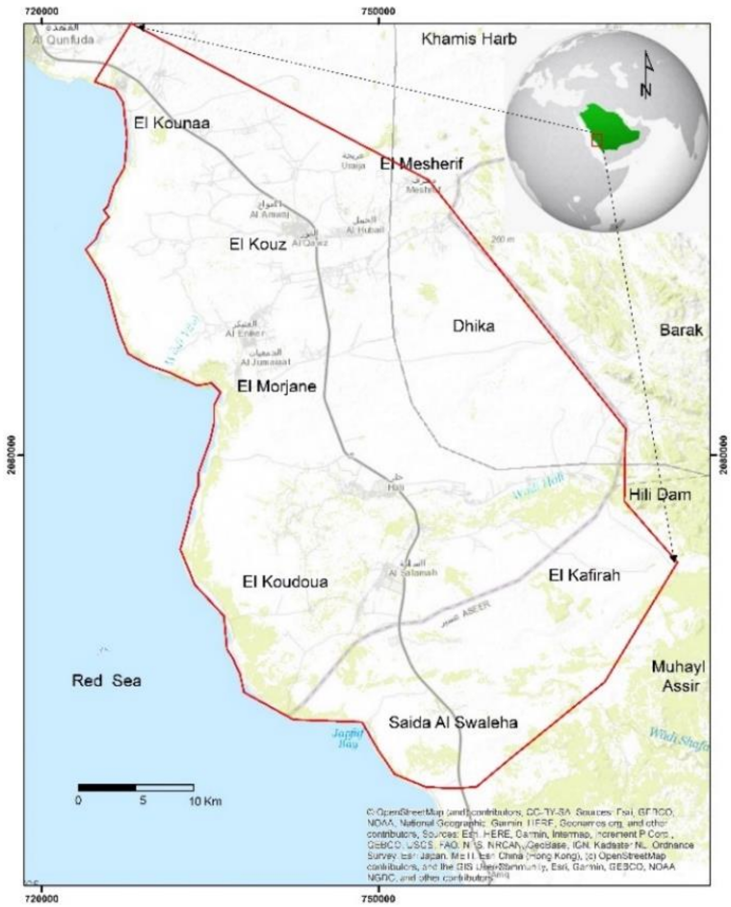

Fig. 1. Location map of the study area.

2. STUDY AREA

The study area extends over a 50 km long and 30 km wide strip in the west of Saudi Arabia. It lies between the El Gonnaa-El Msherif sector in the north, the Saida Soualha plain in the south, Khamis Harb in the north-west and the Wadi Hili dam in the south-west. Its altitudes range from 0 m in the west to 210 m in the east. It is characterized by a variable climate throughout the year (**Fig. 1**).

It is hot and moist in summer, hot and dry in winter, and winter rains are rare. Dusty winds are very frequent in autumn. With no topographical obstacles on the seaside, the alluvial plain is widely open to the prevailing winds blowing from the west-southwest with a speed between 10 and 20km/hour (Meteoblue, 2022). The sand and fine alluvium are constantly swept over short distances by a modest, almost monodirectional wind.

Several studies that are interested in wind activity show that gusty winds seem to be very rare in the region. Thus, microbursts and calm winds were the most frequent winds with 26 occurrences for wind blowing from 5 to 10 km/hour and 9 occurrences for 15 to 20 km/hour on an annual scale (Yu et al, 2015; Albugami et al, 2019). A detailed study of wind in Saudi Arabia over a long period (1978-2013 series), shows a trend towards a noticeable decrease in wind speed (**Fig. 2**).

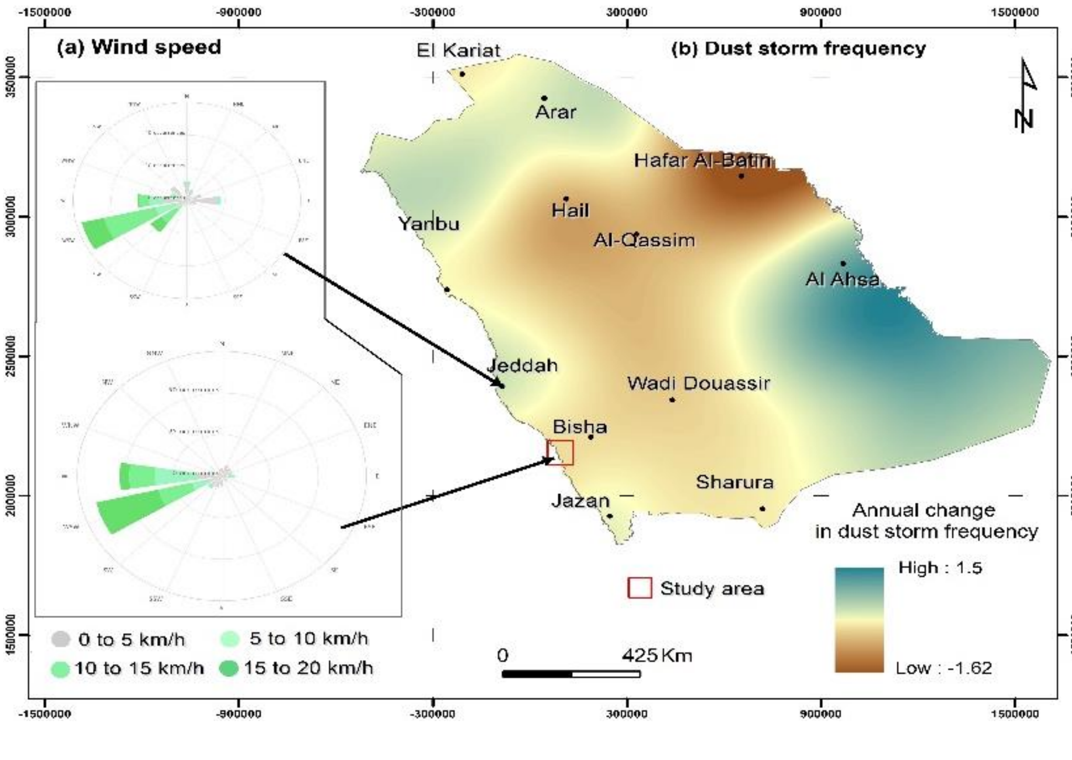

Fig. 2. Annual change in dust storm frequency (number of events/year) (b) and wind speed (a) over Saudi Arabia between 2000/2017. (*Source: Saudi Meteorological Authority and Meteoblue, 2022*).

For the sake of conciseness, this study is based on the above results, insofar as it took into consideration the winds measured near the ground, which can have a direct effect on the mobilisation of medium to coarse sand. Indeed, this study found almost consistent results with another study conducted on the annual evolution of dust storms. The negative relationship observed between light and gusty winds implies that sand winds have become increasingly weaker especially during spring and summer due to the increased humidity caused by the high evaporation in the Red Sea. The situation is closely related to seasonal maximum temperatures occurring between July and September which coincide with a reduction in precipitation, yet dust storms remain less frequent over the western coastal strip of Saudi Arabia due to the high humidity (Albugami et al, 2019). Dust clouds can only be generated by microbursts or by adiabatic upwelling of dry continental air. All these facts explain a certain stabilization of the dunes, especially those close to the sea, promoting the growth of a basic vegetation that has adapted very quickly to give rise to a vegetation cover with a great pastoral potential. In contrast to this western wind dynamic, the study area is constantly confronted with a hydric dynamic, which becomes apparent in rainy years (Shi, 2014; Azaiez, 2021).

The inhabitants are prepared for untimely floods and are called upon to manage huge quantities of water from temporary torrents. These torrents flow down the mountain in deep valleys to the alluvial plain in the form of a large pool (Shi, 2014). The flood waters are diverted from the main channel and then directed towards the farming plots and rangelands by a system of benches which favours the storage of water in the soil. (Mollard et al, 2008). By slanting ditches oriented upstream diagonally with the channel, the farmers seek to create a counter-slope of the water upstream to favor a maximum lateral submersion of the land located on both sides of the watercourse, sometimes, quite far from it. The diagonal shape of the dikes avoids any direct position with the main flow that could cause their breach. On the upstream limits, several shallow channels guide the slow-moving water towards the various cultivated plots and rangelands. The main problem lies in the unpredictability of the magnitude of the floods. When they are strong, they wash away the dikes of the closest plots but properly submerge the more distant ones. By contrast, a weak flood correctly irrigates the upstream plots, close to the waterway, but plots located further downstream are deprived of water. In fact, the choice of water mobilization in the spreading plain would not be without consequences because of the sporadic character of the floods. The farming practices in the study area depend on rainfall and the distribution of fertile clay soils, or slightly sandy soils. (Shi, 2014).

3. METHODOLOGY AND TOOLS

There are many options for studying changes in rangelands landscapes. Remote sensing indices are a complementary tool to the traditional prospective method based on fieldwork. They have made a useful contribution to monitoring soil surface temperature since the appearance of the new generation of high-resolution Landsat (8 and 9) satellite images (Oguz, 2013; Bindajam et al, 2020). These images make it possible to study the functioning of the Soil-Atmosphere-Vegetation system and to focus on salinisation processes in relation to a new environmental trend and attempts by local populations to benefit from flood spreading. To explain the improvement in pastoral conditions in the Tihama plain, a multi-source approach based on remote sensing, statistical analysis and cartographic method was used. As a result, the two red and near infrared bands (5 and 4) were used to calculate NDVI and soil moisture indices. Bands 10 and 11 were used to estimate the LST index.The maps produced represent changes in thermal conditions and, consequently, variations in vegetation cover in terms of quantity and quality. The analysis was based on a diachronic approach with reference to Landsat 8-9 OLI/TIRS C2 L2 images of 2013 and 2022. Three parameters (LST, NDVI and soil moisture index) were calculated to obtain a more reliable estimations of the rangeland’s aspects.

3.1. Land Surface Temperature changes between 2013-2022 depending on the NDVI index

The Land Surface Temperature (LST) index is considered a parameter of paramount importance. The good results have aroused great interest for geographers. Amongst others, it allows us to identify changes in land use and to improve our knowledge of the water status of the soil before and after the installation of embankments and flood control channels. The objective is to develop flexible solutions and to think about the possibility of generalizing this experiment to regions with similar environmental conditions (Oguz, 2013; Bindajam et al, 2020; Mallick et al, 2020). As a first step, two satellite images 2013 and 2022, taken during the spring, were selected. Then geoprocessing is performed in Arc GIS, starting with a composition of the bands under the "raster processing" tool. It should also be noted that both images have undergone an atmospheric correction to get rid of the potential effects of the different atmospheric components (cloudiness, aerosols...).

-Top of Atmosphere Radiance TOA (L) = ML * Qcal + AL (1)

with:
Qcal = quantized and calibrated standard product pixel values;
ML= Band-specific multiplicative rescaling factor from the metadata (Reflectance_Mult_Band_X);
Al = Band-specific additive rescaling factor from the metadata (Reflectance_Add_Band_X).

Brightness Temperature (BT) defined as a radiation luminance and was transformed in (°C), using the following equation:

$$BT = \frac{K2}{(\ln (K1 / L) + 1)} - 273.15 \quad (2)$$

$$\text{-Normalized Difference Vegetation Index (DVI)} = \frac{(\text{Band } 5 - \text{Band } 4)}{(\text{Band } 5 + \text{Band } 4)} \quad (3)$$

$$\text{-Portion Vegetation (PV)} = \frac{((NDVI - NDVImin)}{(NDVImax - NDVImin))} \quad (4)$$

With Surface Emissivity Retrieval (ε) = 0.004 * Pv + 0.986 (5)

$$\text{-Land Surface Temperature (LST) index} = \frac{BT}{(1 + (0.00115 * BT / 1.4388) * Ln(\varepsilon)))} \quad (6)$$

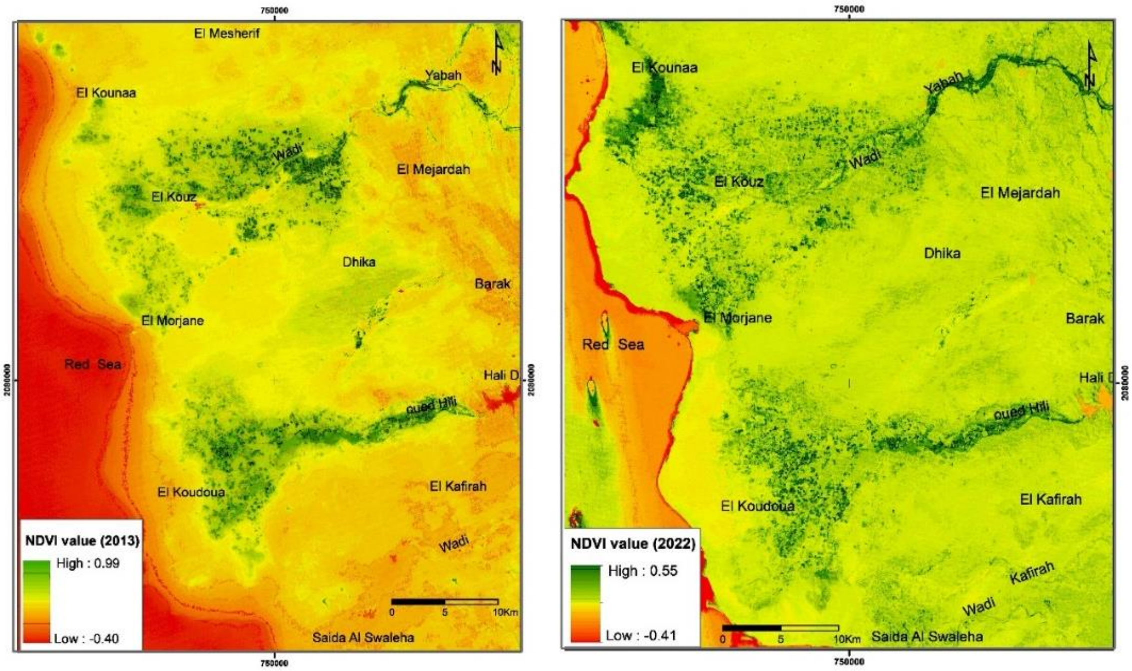

Fig. 3. Normalized difference vegetation index (NDVI) maps at the southern part of the alluvial plain of Tihama in 2013 (A) and 2022 (B). (*Source: Landsat 8-9 satellite images*).

The detailed mapping of this parameter reveals that LST values differ significantly according to land use patterns. The highest value was found in the bare land and the lowest LST was in pasture areas. The modelling of two parameters, the LST and NDVI indices, illustrates that they are closely related.

The (LST) values are inversely proportional to the NDVI values for the year 2013 as for the year 2022. Good soil cover results in lower soil surface temperature. The NDVI values are higher in 2022, although spring 2013 was wetter (**Fig. 3**). This situation clearly confirms the improvement in soil moisture conditions.

3.2. Land use changes between 2013 and 2022

One of the main observations obtained from the modeling is the proliferation of vegetation covering, which contrasts with the regional aridity. An increase of 26% in the planted area occurred in less than 10 years (**Fig. 4**). These are the coastal plains and the alluvial plain of the wadi Hili which have benefited the most from this new situation. A second highly localized proliferation in the intermediate sectors has accompanied the reforestation programs. Detailed mapping on a more accurate scale will undoubtedly be interesting for identifying the relationship between the ground temperature index (GTI), salinization and the changes in the vegetation cover. The surface skin temperature of the soil is of primary importance. It conditions the rhythm of heat and water exchanges with the atmosphere and determines the length of the vegetation season and the water balance in the soil. However, the involvement of other geographical and atmospheric factors should not be overlooked. The bay's position allows for more pronounced warming of the water, which causes additional evaporation along the shoreline. Thus, a sea breeze loaded with moisture can travel several kilometers inland during the day through the bay El Morjane and that of Saida Swaleha. In bad weather, this breeze can contribute to the onset of rains and thunderstorms in the hinterland in the plain of El Kouz-el Koudoua (spreading plain of Hili and Yabbah). Through earth levees and benches, farmers were able to create a traditional system of conducting water from the wadis Hili and Yabbah coming from the high mountain peaks of Sarawt and crossing extremely steep slopes to reach a depressed plain, where the flow was slow and difficult, due to the low slope and the presence of alluvial fans. The wind deflation causes a strong mobility of the dunes that are repeatedly carried away by an active wind. Almost all the rangelands of the Tihama plain are exposed to the combination of two phenomena that are likely to produce devastating effects.

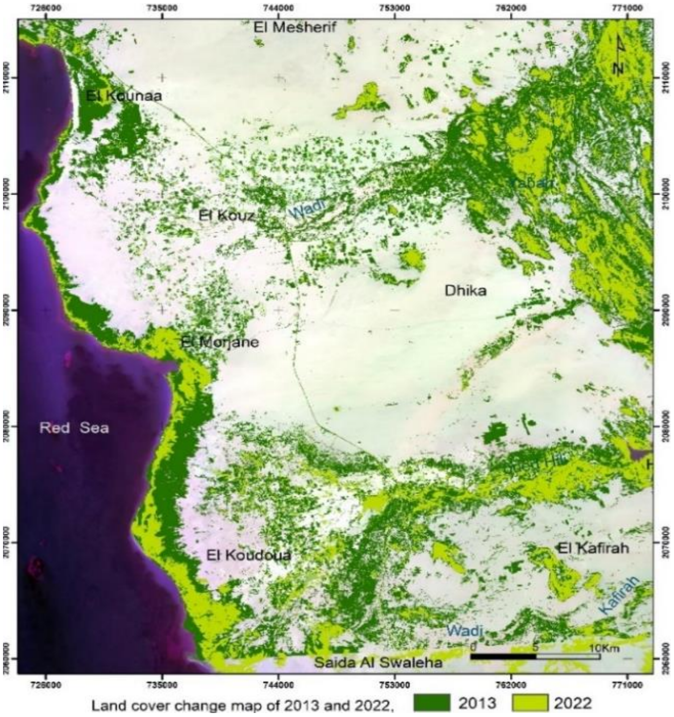

Fig. 4. Vegetation Change between 2013-2022. (*Source: Landsat 8-9 satellite images (2013/2022*).

Dust storms and sandstorms on the one hand and occasional floods on the other. Thus, some rainfall events are difficult to manage because of the peculiarity of the study area and the unpredictability of floods, although ordinary floods have been beneficial for the most part. The study area has recorded dust storms respectively between 1and 2 in spring and winter and autumn and between 4 and 5 storms in summer between 2000 and 2017 (Albugami et al, 2019). These recorded values are among the lowest recorded in the country since the year 2000. This clear decrease is closely related to low wind speeds. The prevailing wind is essentially from the west-southwest. It follows a maritime trajectory which is the source of the high humidity. The most dust storms occurring during the summer season come from the Sudano-Egyptian desert. The influence of these dust storms increases on the western shore of the Red Sea and gradually fades on the eastern coast (**Fig. 5**).

The notable decrease in wind speed and the number of dust storm days may be the reason for the recent stability of the dunes and the rehabilitation of the natural vegetation cover that acted as a windbreaker. Indeed, these results underline the community efforts to manage water resources and combat desertification. In the same perspective, Saudi Arabia is distinguished by its commitment in an ambitious program to improve rangeland and dune fixation in two pilot areas (Douassir and El Quenfudah).

Based on the available water resources, coming from the wadis, the local authorities with the help of farmers, have been able to set up an adequate drainage system based on ridges and benches allowing a more balanced redistribution of water availability based on the spreading of flood waters, by helping the vegetation cover to develop in areas formerly subject to a very strong wind deflation. Thus, a fixation of dunes can be established in the short and medium terms.

Fig. 5. Direction of dust storms spread from the Sudan-Egyptian desert towards Saudi Arabia for some key dates selected. (*Source: These top images were acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite at 11:10 a.m. The lower image is from the MODIS sensor on NASA's Aqua satellite, acquired at 2:20 p.m.*).

4. RESULTS AND DISCUSSION

According to the comparative study of natural vegetation cover through the modelling of certain remote sensing parameters, it was found that a resilience of vegetation cover is confirmed, despite the deterioration in climatic conditions and the increase in the frequency of extreme climatic events during the last decades globally and locally. The direct interpretation of the (LST) maps from the modeling reveals two gradients. A first main latitudinal gradient ascending south-north that follows in accordance with the increase in the incidence angle of solar radiation and the duration of sunshine with a gradient starting from 34 °C to 38.5 °C in 2022 (**Fig. 6**).

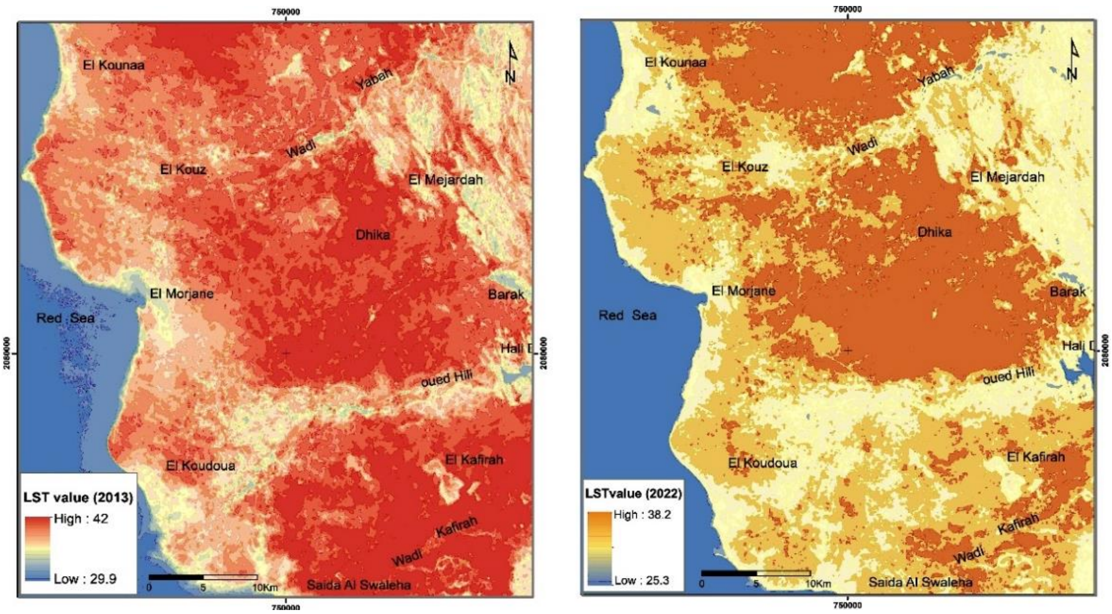

Fig. 6. The Land surface temperature (LST) maps of the study area in 2013 (A) and 2022 (B). (*Source: Landsat 8-9 OLI/TIRS C2 L2 images of 2013*).

A second altitudinal gradient ascending from east to west from 25.3°C in the mountain sectors to 38.5 °C at the coastal plain for the same year. A meticulous interpretation of the research results carried out at a finer scale in the Tihama plain, showed that the LST index is significantly influenced by the type of deposit (alluvial or aeolian), the salinity of the soil, its humidity, as well as the density of the soil benches and ridges (Azaiez, 2021). However, the hottest sectors are in the intermediate zone between two spreading cones, considered the zone least supplied with runoff water. A clear drop in temperature occurred on the outskirts of the spreading plain with the establishment of plant cover, under the effect of shading and partial absorption of the sun's rays during the operation of photosynthesis. This decrease is illustrated by the trend curve of 3 simulated indices (**Fig. 7**).

On the adjacent slopes on the east and northeast side, the values are much lower due to the altitude, the sheltered position of some slopes, the inclination of the angle of incidence of solar radiation and the disparity of colors of the rocky outcrops.

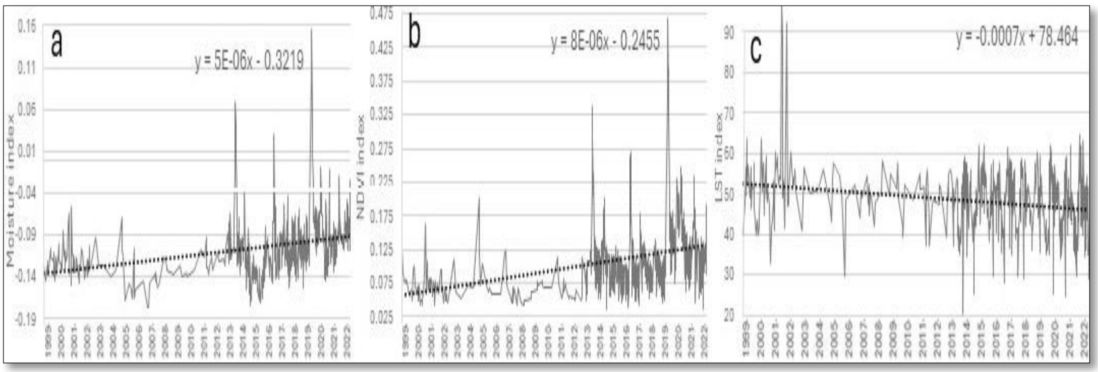

Fig. 7. Changes in soil moisture (a), NDVI index (b) and LST index (c) in the alluvial plain of wadi Hili between 1999 and 2022. (*Source: Processing of data available on the climate Engine website).*

The typical vegetation cover of the study area is characterized by trees with a broad and very branched framework, which provide permanent shade and continuous storage of moisture in the soil over a long period, which explains the persistence of the vegetation cover and its proliferation. However, the beneficial effect of some windbreakers formed by Salvadora persica and Gasuarina should not be overlooked. Their implementation comes as a state response to the specific requirements of windbreaks to fight against desertification. This state intervention has been limited to sectors in intermediate positions in relation to the two alluvial plains of the wadis Hili and Yabbah. In these sectors, the wind dynamics are even more active because the soil lacks moisture, which gives a more free and devastating wind action. Since 2004, the implementation of a single windbreak curtain arranged in a zigzag pattern over 1.5 km in the Al Konnaa plain to limit the effect of wind blowing from the west and west-southwest, has shown encouraging results and exceeded expectations within a decade. In the Al Konnaa plain, the vegetation cover increased to 92.5% within a decade (**Fig. 8**). Farmers responded by developing stepped sills along the Hili and Yabbah streams to slow the flow and by raising multi-directional soil ridges on both sides of the streams to counteract the adverse effects of flooding and to ensure a more balanced distribution of floodwaters among the different agricultural plots and rangelands.

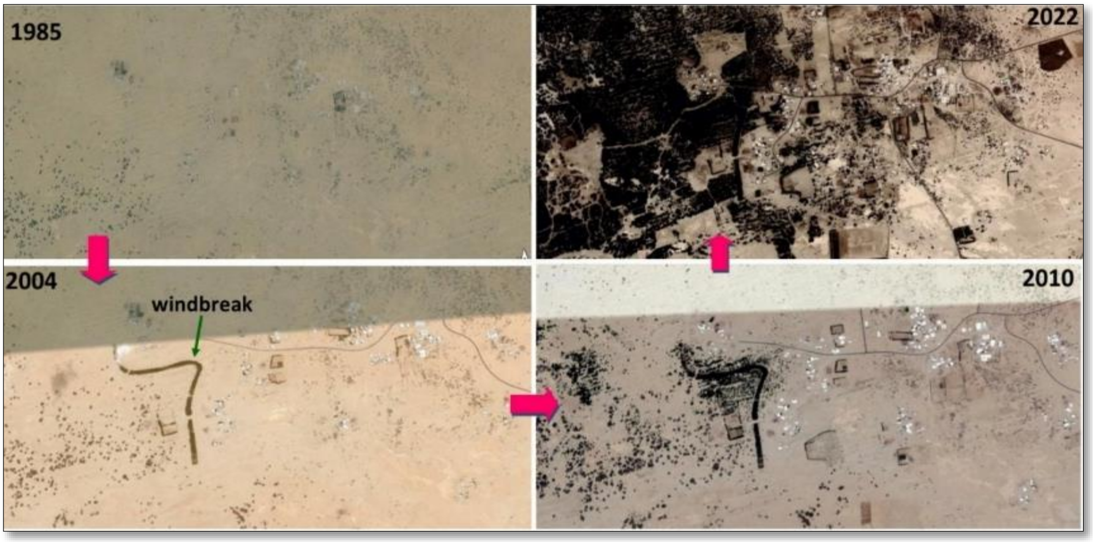

Fig. 8. Proliferation of vegetation cover following reforestation efforts in the Kounaa sand dunes between 1985-2022. (*Source: Image Google Earth Pro).*

A survey of some farmers confirms a significant increase in soil water potential and a stabilization of moisture in fine-textured soils during periods of low water. A new vegetation has developed spontaneously to give rise to small livestock in the village settlements around the El Quenfudah area. The improvement in environmental conditions is attributable to the serious commitment of the state to a strategy of collaborative efforts with local communities to combat desertification. This is indeed a very ambitious program that meets the medium and long-term objectives of local communities in the field of agriculture and livestock farming in the region of El Quenfudah and its surroundings. In addition, the problem of water scarcity is expected to be aggravated with the increasing pressures on water resources, especially in the context of conflict between domestic, tourism, and agricultural uses. The program requires additional monitoring and more detailed data collection on soil moisture variation. The normalized humidity difference modeling shows a close relationship between humidity and canopy density, with a slight difference between the alluvial plain of Hili and that of yabbah. The latter showed less moisture retention, although wadi Hili is blocked by a dam located 10 km upstream of the plain. (**Figs 4** and **8**). Indeed, the seasonal monitoring of soil moisture is a key parameter in identifying periods of water stress. These regions are home to a significant portion of Saudi Arabia's rangelands. A comparison between the two situations of 2013 and that of 2022 shows an improvement in soil moisture and NDVI index in terms of value and distribution (**Figs 3,7** and **9**).

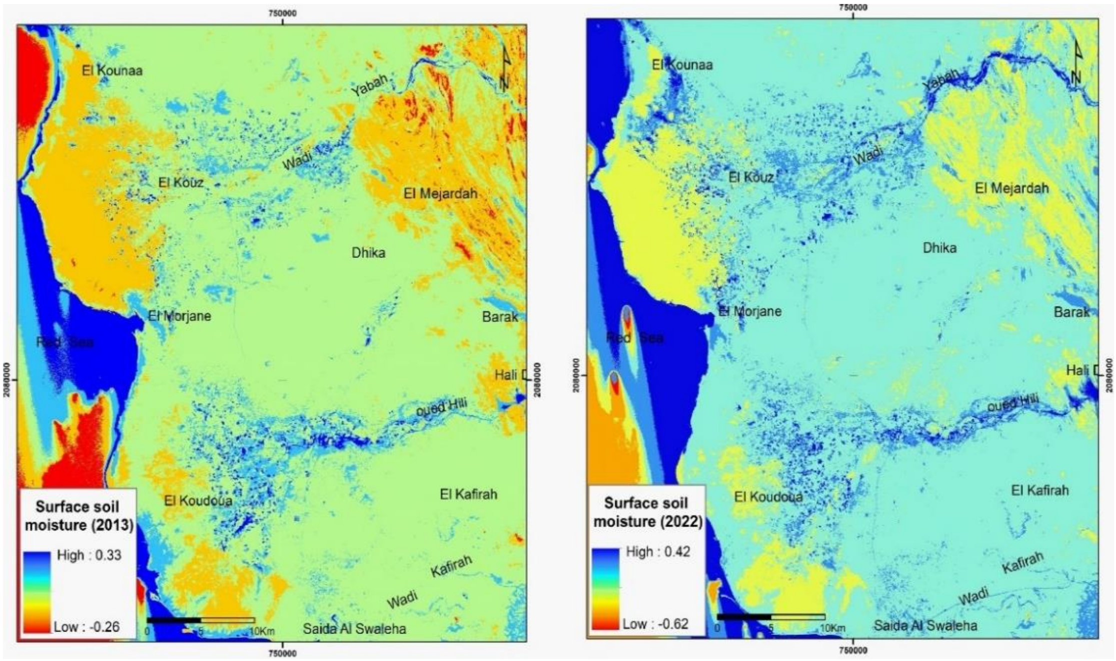

Fig. 9. Maps of the surface soil moisture distribution for the month of April, estimated from the Landsat 8-9 satellite images 2013 (A) and 2022 (B). (*Source: Landsat 8-9 satellite images).*

The sediments are deposited in separate spreading cones, having partially coalesced towards the extreme west of the Tihama plain. These outwash plains are characterized by varied deposits representative of former, sometimes contradictory, climatic periods. This conical arrangement allows an equitable distribution of humidity between the different compartments of the alluvial plain thanks to the good circulation of water in the surface horizon of the soil in the alluvial plain. Within this framework, special attention must be paid to the dunes for two reasons that are deemed fundamental (Azizov and Atbayev 1987) The first is the importance of dunes in terms of extension. They are the main component of the geomorphological landscape of the region of El Kouz and El Koudoua. The second is related to the exploitation of their possible water potential in the region. Thus, there is still work to be done to develop our knowledge on the distribution of the vegetation cover according to the vertical and lateral variation of the soil surface moisture (Guerf and Amriche, 2015). The monitoring of percolation, internal circulation and storage of flood water should be done sequentially and seasonally with a step of 30cm to a depth of 3.5m to 4m to better estimate its distribution and optimize the use of available water resources, choosing plants that adapt more easily with the local conditions of the region (Zribi et al, 2014; El Garouani et al., 2021). The correlation between vegetation and soil water conditions is also demonstrated by statistical analysis based on 500 random points, resulting in a positive correlation between the NDVI and moisture indices. However, the correlation is inverse between (LST) and NDVI values (**Tab. 1**). The evaluation of existing plant species remains a concern, especially for species that are favored by livestock. This study must be accompanied by a proposal of a wide range of plant species capable of establishing a better adaptation to the edaphic conditions and to overcome the climatic accidents that limit their growth. In many areas, the problem of degradation is essentially related to the distribution of livestock, in terms of the number and type of livestock and the type of breeding practiced, as well as the grazing behaviour of the livestock. The consideration of all these aspects will allow the development of adequate strategies for the improvement and preservation of these rangelands. Thus, the creation of a working team involving young multidisciplinary researchers is a vital element to achieve the objectives of Saudi Arabia's 2030 vision in terms of biodiversity conservation and rehabilitation of fragile natural environments that are sensitive to climate change (Getachew, 2017**)**.

Tab. 1.

Relationship between LST, NDVI and Soil Moisture indices.

Variables	LST index	moisture index	NDVI index
LST index	1		
moisture index	-0.71	1	
NDVI index	-0.679	0.899	1

The carrying out of a survey among farmers in pilot areas remains a very good method to know their habits in the rangelands and to highlight other facts acting on the evolution of the landscape. This is a crucial step to take decisive environmental actions in these rangelands that are recovering, but it is not yet at a perfect pace. Through multiple comparisons with other study areas, we can estimate the regional representativeness of the results to follow a rational intervention that respects the local and regional characteristics of each geographical unit in Saudi Arabia. Experimental results conducted at the College of Engineering in Saoud University showed a clear improvement in the engineering properties of sand dunes and their geotechnical properties after treating it from the surface by adding bentonite mineral, which made the treated dunes not move unless the wind speed exceeded 100 km/h.

The importance of this research comes from the specific nature of the Tihama coastal plain which constitutes a typical morphogenic system formed by coalescing alluvial fans in the north and individual ones in the south, where the accumulations are rapidly redistributed and reshaped by the different floods and rearranged by the wind. Another comparison of the LST index in the middle part of two alluvial plains showed lower LST values in the Wadi Hili plain than in the Wadi Yabbah plain. This variation is attributed to the phenomenon of bleaching of the surface soil horizon, which leads to a reflection of solar radiation and a reduced radiation balance. This different dynamic between the two plains is related to the large volumes of water drained and a specific mineralogical evolution in the plain of Wadi Hili, which deserves to be better analyzed in detail. The results in terms of tracing salinity have shown a concentration of salinity increasingly accentuated at the outlet of Wadi Hili compared to that of Yabbah.

In addition, the paper offers a useful information on environmental monitoring through a judicious mix of methods such as GIS and RS (Gomes and Caracristi, 2021; Hussain et al., 2023). New insights into the effectiveness, combination and implementation of the tools used for the novelty of rangeland monitoring in the context presented and this is provided by the detailed information offered on rangeland monitoring. It would be advantageous to extend the study area and incorporate a wider range of indices to provide more conclusive results and a more provide a more comprehensive perspective.

5. CONCLUSION

At the end of this research, monitoring the evolution of rangeland vegetation by evaluating the values of the (LST) and (NDVI) indices revealed a spatial variation in the distribution of plant cover that is closely linked to surface temperature variations. Obtaining LST values by using algorithms based on the integration of biophysical parameters and the exploitation of multispectral images is only one step among others. It has opened new paths of research that were previously uncommon and used for very strictly limited purposes.

The climatic index (LST) compared to a plant physiology index (NDVI) has shown the cooling effect of the vegetation cover and the shading effect in reducing evaporation. This fact is largely favored by water bodies, soil moisture and vegetation. However, the improvement of the water reserve in the alluvial plain still depends on the implementation of soft hydraulic techniques. The remote sensing makes a valuable contribution to the knowledge of the natural environment. The results showed very variable values of the LST index even within the vegetated sectors. The (LST) values are inversely proportional to the (NDVI) values and the density of the vegetation cover. Thus, with increasing (NDVI) values, the LST index decreased considerably to its lowest values in the alluvial plains that have dense vegetation cover, high humidity and intense agricultural activity.

The different vegetation composition probably influences the radiation balance of rangelands and agricultural plots (Gleyce et al., 2019). Vegetated areas with grass, bushes and trees do not necessarily have the same (LST) value because the rate of water consumption differs in accordance with the structure of the plant itself. The choice of the spring season of 2013 and 2022, is justified by similar climatic characteristics. Without denying the importance and validity of remote sensing, it does have its flaws. It is necessary to test the model several times, considering the season and time of acquisition of satellite images, because soil moisture and temperature are closely related to the solar radiation, water circulation, water exchanges between the water table and the topsoil and the speed and direction of wind.

The detailed study of these different elements of the natural environment and the comparison of the results will make it possible to partially overcome the shortcomings of the modeling and the algorithms obtained. Other studies have shown a strict relationship between the decrease of the LST value in the intermediate sector between two alluvial plains and the lowering of the water table each time we move away from the wadi axes. This hypothesis remains to be verified in the study area. The results may be improved by studying the vegetative cycle of annual plants, which are considered an additional source of fodder.

ACKNOWLEDGEMENT

The author wishes to extend her appreciation to the Deanship of Research and Graduate Studies at King Khalid University for funding this work through small group research under grant number RGP1/95/45.

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