EXPLORING THE ASSOCIATION BETWEEN VEGETATION COVER AND LAND SURFACE TEMPERATURE IN CONSTANTINE; A COMPARATIVE ANALYSIS

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Abstract

This research focuses on the significant influence of vegetation cover on the distribution of land surface temperature (LST) in the city of Constantine. It aims to study the correlation between the normalized difference vegetation index (NDVI) and land surface temperature (LST) using satellite images from the Landsat 8 and Landsat 9 satellites, specifically the LC08L2SP L02T1 product, as well as images processed on the Google earth engine platform. The main objectives of this study are to collect values of land surface temperature and to carry out an in-depth analysis of the relationship between LST and NDVI. The NDVI is an index for quantifying the presence of vegetation and understanding its impact on thermal conditions. It can therefore be used to establish a link between thermal behavior and the amount of vegetation cover. In this study, the statistical method of regression was used to obtain the correlation between LST and NDVI. The results show a negative correlation between NDVI and LST. The approach of combining LST satellite data with visual information offers an effective method for identifying local warming and cooling hotspots. This approach makes it possible to locate specific areas experiencing higher or lower than average temperatures, which is crucial for monitoring the effectiveness of municipal policies aimed at mitigating the effects of heat stress. In addition, these results can guide future policy decisions by providing valuable information on areas that require special attention.

Key words:NDVI, LST, Google earth engine, significant correlation and Constantine.

EXPLORATION DE L'ASSOCIATION ENTRE LE COUVERT VEGETAL ET LA TEMPERATURE DE SURFACE A CONSTANTINE ; UNE ANALYSE COMPARATIVE

Résumé

Cette recherche se concentre sur l'influence significative du couvert végétal sur la distribution de la température de surface du sol (LST) dans la ville de Constantine. Elle vise à étudier la corrélation entre l'indice de végétation par différence normalisé(NDVI) et la température de la surface du sol en utilisant des images satellitaires Landsat 8 et Landsat 9, en particulier le produit LC08L2SP L02T1, ainsi que des images traitées sur la plateforme Google earthengine. Les principaux objectifs de cette étude sont de collecter les valeurs de la température de la surface terrestre (LST) et d'effectuer une analyse approfondie de la relation entre la LST et le NDVI. Le NDVI est un indice qui permet de quantifier la présence de la végétation et de comprendre son impact sur les conditions thermiques. Il peut donc être utilisé pour établir un lien entre le comportement thermique et l'importance du couvert végétal. Dans cette étude, la méthode statistique de régression a été utilisée pour obtenir la corrélation entre LST et NDVI. Les résultats montrent une corrélation négative entre NDVI et LST. L'approche consistant à

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combiner les données satellitaires LST avec des informations visuelles offre une méthode efficace pour identifier les points chauds de réchauffement et de refroidissement locaux. Cette approche permet de localiser des zones spécifiques connaissant des températures plus élevées ou plus basses que la moyenne, ce qui est crucial pour contrôler l'efficacité des politiques municipales visant à atténuer les effets du stress thermique.

Mots clés: NDVI, LST, Google earth engine, corrélationsignificativeet Constantine.

Introduction

Climate change is having a serious impact on the environment and human beings [1]. These consequences include an increase in extreme weather and climate events, causing significant damage to nature and people[2].Cities are particularly vulnerable to the impacts of climate change because of their high population density. Urban areas tend to experience higher temperatures than surrounding areas due to the urban heat island (UHI) effect [3].

One of the most significant environmental issues facing people today is global warming. Understanding how these elements affect humans and improving their reliance on the surface environment are essential needs [4]. The study of the link between natural causes and land surface temperature (LST) has recently taken several new avenues.

The Earth's surface temperature is influenced by several factors, including heat release from energy consumption, increased surface cover with artificial materials with high thermal conductivity, and decreasing vegetation and water-permeable surfaces, which reduce surface temperature through evapotranspiration [5]. In the context of the urban thermal environment, remote sensing provides an effective and sustainable method for studying urban vegetation [6]. In addition to measuring radiant surface temperature, remote sensing instruments can collect measurements of reflected energy in the red and near infrared (NIR) bands of the electromagnetic spectrum, which can be used to assess the extent and variations of urban vegetation [7].

Studies looking at the climatic effects of changes to land-use/land-cover (LULC) have demonstrated that such a difference can be important [8; 9]. These studies examine the impact of various LULC kinds, but they do not concentrate on the urban setting, therefore they fail to account for regional variations in the possible cooling effects of urban trees and treeless urban green spaces [10]. Studies that specifically examine various LULC in urban settings frequently concentrate on a particular area, but do not examine how various LULC types impact temperatures in various geographic areas [11].

The substantial degree of uncertainty in the remote sensing estimated LST and model flaws were cited as the causes of the discrepancy between remote sensing and model simulation [12; 13]. LULC, one of the primary surface factors affecting surface heterogeneity, has a substantial impact on LST through a variety of geophysical impacts, including the land surface albedo, evapotranspiration and surface roughness [14]. Urbanisation significantly increases the amount of ecological stress by warming local or global cities [15]. Many metropolitan areas are currently suffering from extensive land conversion and the resulting new heat zones [16; 17]. Remote monitoring methods are highly successful in identifying changes in land use and/or land cover (LULC) and their effects [18].

Land surface temperature (LST) is a key factor in land surface dynamics, involving interactions between the surface and the atmosphere, as well as energy fluxes between the atmosphere and the ground [19; 20]. Because of the interactions between the land surface and the atmosphere, the heterogeneous geographical distributions of land surface temperature (LST) play a significant role in the earth system [21]. The quality of the LST spatial dispersion simulation significantly depends on the precision of the aspects of the land's surface [22], such as land use/land cover (LULC). Numerous investigations have Shawn that the model's predicted LST may differ noticeably from measurements based on remotely sensed data and on-site observations [17; 23].

Normalised difference vegetation index (NDVI) has an excellent capacity to communicate across yearly and seasonal variation in the activity of the plant cover andvegetation's reaction to climate change [24]. The biological activities of the plant were related to the NDVI values, and changes in the NDVI reflect the many biological processes occurring in plants [25]. The NDVI value, which represents the status of the vegetative cover, may be used to readily characterise the daily fluctuations in LST [22].

When analysing remote sensing data, frequently from a space platform, the NDVI is a straightforward graphical indication that may be used to determine whether or not the object under observation has living green vegetation [26].Monitoring vegetation recovery is crucial for planning resource management strategies, habitat restoration efforts, and research on ecological and complex economic activities related to wildfires. Areas with high NDVI are generally associated with lower TST[9]. Studies have shown a slightly stronger negative correlation between vegetation fraction and TST. In addition, the mean values of TST and NDVI vary significantly according to the different types of land use. Joshi and Bhatt also pointed out that areas with dense vegetation and water bodies have lower temperatures compared to urbanised areas [27]. The correlation between TST and NDVI is positive in winter and negative in warmer seasons [18].

In this paper, Landsat 8 and Landsat 9 satellite images (LC08 L2SP L 02 T1) from the years 2014, 2018 and 2022 are used to calculate the land surface temperature and NDVI of the city of Constantine. The aim is to analyse the relationship between NDVI and land surface temperature.

MATERIAL AND METHODS

Study area

The study area chosen for this research is Constantine, the capital of eastern Algeria. Constantine is located approximately 431 km south-east of Algiers, the country's capital. It is ideally situated equidistant between the country's northern coast and the Aurès massif to the south, making it a staging post between the southern regions and the coastal towns. Its strategic position makes it particularly important. Constantine covers an area of around 2297.20 km², at altitudes ranging from 350 to 1100 meters. The city's geographical coordinates are approximately 36°17' latitude and 6°37' longitude.

The provincial capital of Constantine in northeastern Algeria is Constantine, also known as Kasantina. Cirta, its previous name in Roman times, was changed to "Constantina" in honour of Emperor Constantine the Great. On the banks of the Rhumel River and a little inland, Constantine lies about 80 km (50 miles) from the Mediterranean coast. With a population of over 450000, Constantine is third in size in Algeria behind Algiers and Oran. It is considered the capital of eastern Algeria and the commercial hub of its region. Around the city are a number of museums and historical places. Around the city are a number of museums and historical places. Due to the numerous magnificent bridges that connect the different hills, valleys, and ravines that the city of Constantine is constructed on and around, the name "City of Bridges" is frequently applied to it. In 2015, Constantine was designated as the Arab Capital of Culture.

The total population of the wilaya (province) of Constantine is estimated at 836977, corresponding to a population density of around 400 inhabitants per km².

The average annual population growth rate is -0.68%. (See Fig. 1). The geology of the Constantine area includes Recent-Quintenary sediments, Cenozoic marine sedimentary, Cenozoic volcanic, Cretaceous sedimentary, Triassic to Jurassic sedimentary, carboniferous sedimentary, Devonian sedimentary, Cambrian to Silurian sedimentary, and Precambrian undifferentiated sediments.Cenozoic marine sedimentary, Cretaceous sedimentary, Carboniferous sedimentary, and Precambrian undifferentiated deposits make up the majority of the research region.

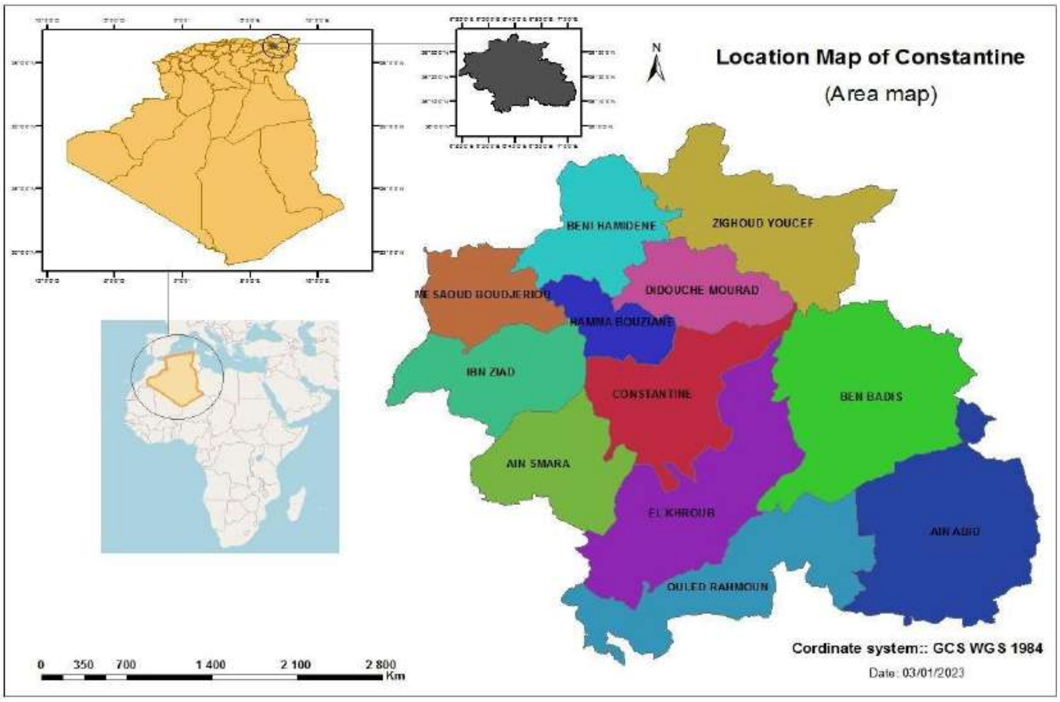


Fig. 1. - Geographical location of Constantine (Arcmap).

Data acquisition and preparation

To study the small-scale characteristics of Constantine in Algeria, we used Land Surface Temperature (LST) data from Landsat 8 Level 2, Collection 2, Tier 1 products, derived from Landsat satellite thermal bands [4] and having a spatial resolution of 30 meters. The Landsat archive provides a continuous record of LST data from 1982 to the present day (Table 1).The datasets used include atmospherically corrected surface reflectance and LST obtained from Landsat 8 OLI/TIRS Level 2 sensors. Landsat 5 and Landsat 8 LST data were extracted from the Landsat 8 Level 2 collection, which also incorporates other datasets [12].The initial spatial resolution of the thermal data is 120 meters for Landsat 5 and 100 meters for Landsat 8. However, these data have been interpolated to a 30m resolution grid in the final Level 2 product [24].

Table 1. - Band's resolution.

Name	Min	Max	Climbing	Compensate	Wavelength	Description
SR_B1	1	65455	2.75e-05	-0,2	0.435-0.451	Band 1 surface reflectance (ultra blue, coastalaerosol)
SR_B2	1	65455	2.75e-05	-0,2	0.452-0.512	Surface reflectance of band 2 (blue)
SR_B3	1	65455	2.75e-05	-0,2	0.533-0.590	Surface reflectance of band 3 (green)
SR_B4	1	65455	2.75e-05	-0,2	0.636-0.673	Band 4 (red) surface reflectance
SR_B5	1	65455	2.75e-05	-0,2	0.851-0.879	Surface reflectance band 5 (near infrared)
SR_B6	1	65455	2.75e-05	-0,2	1.566-1.651	Surface reflectance of band 6 (short-wave infrared 1)
SR_B7	1	65455	2.75e-05	-0,2	2.107-2.294	Band 7 surface reflectance (shortwave infrared 2)

To calculate the normalised vegetation index (NDVI), we used the atmospherically corrected near-infrared (NIR) and red bands (bands 3 and 4 for Landsat 5; bands 4 and 5 for Landsat 8) from the Landsat 2 collection. The data were collected from Google Earth Engine, and then exported to ArcGIS for further processing.

NDVI is calculated from bands 4 (red) and 5 (near infrared) of the Landsat 8 satellites, using the standard formula: NDVI = (PIR - RED) / (PIR + RED). NDVI values range from -1 to 1, with positive values indicating higher vegetation density. NDVI can be used to distinguish between vegetated and non-vegetated areas by highlighting variations in plant biomass.When leaves are green, they contain a large amount of chlorophyll, which absorbs all colours except green, which is reflected. When the plants reach maturity, they absorb all colours except yellow-orange (around 580-590 nm), giving the leaves a yellow-orange colour.

Satellite sensors detect these changes in reflectance and calculate the NDVI accordingly. Vegetation indices, such as NDVI, provide valuable information on biomass productivity and vegetation health[24].

The NDVI images generated for the study area visually illustrate active vegetation, represented by values greater than 0.0, while negative values indicate inactive vegetation, residential areas, roads, bare soil and water.

Surface temperature is an essential geophysical parameter that measures the temperature of the Earth's surface in Kelvin units. It plays an important role in global energy balance studies and hydrological modelling. Measuring surface temperature is also useful for monitoring the health of crops and vegetation, as well as for detecting extreme heat events such as natural disasters (e.g., volcanic eruptions, forest fires) and urban heat island effects.

To calculate surface temperature (LST) from Landsat 8 Level 2 maps, the following equation is used [12]:

$$LST = (band10 * 0.00341802) + 149.0 - 273.15$$

In summary, we used LST data from Landsat 8 Level 2, Collection 2, Tier 1 products, with a spatial resolution of 30 metres, to study the small-scale features of Constantine. Thermal bands 10 and 11 were used to obtain more accurate surface temperatures, while bands 4 and 5 were used to calculate NDVI (Fig. 2).

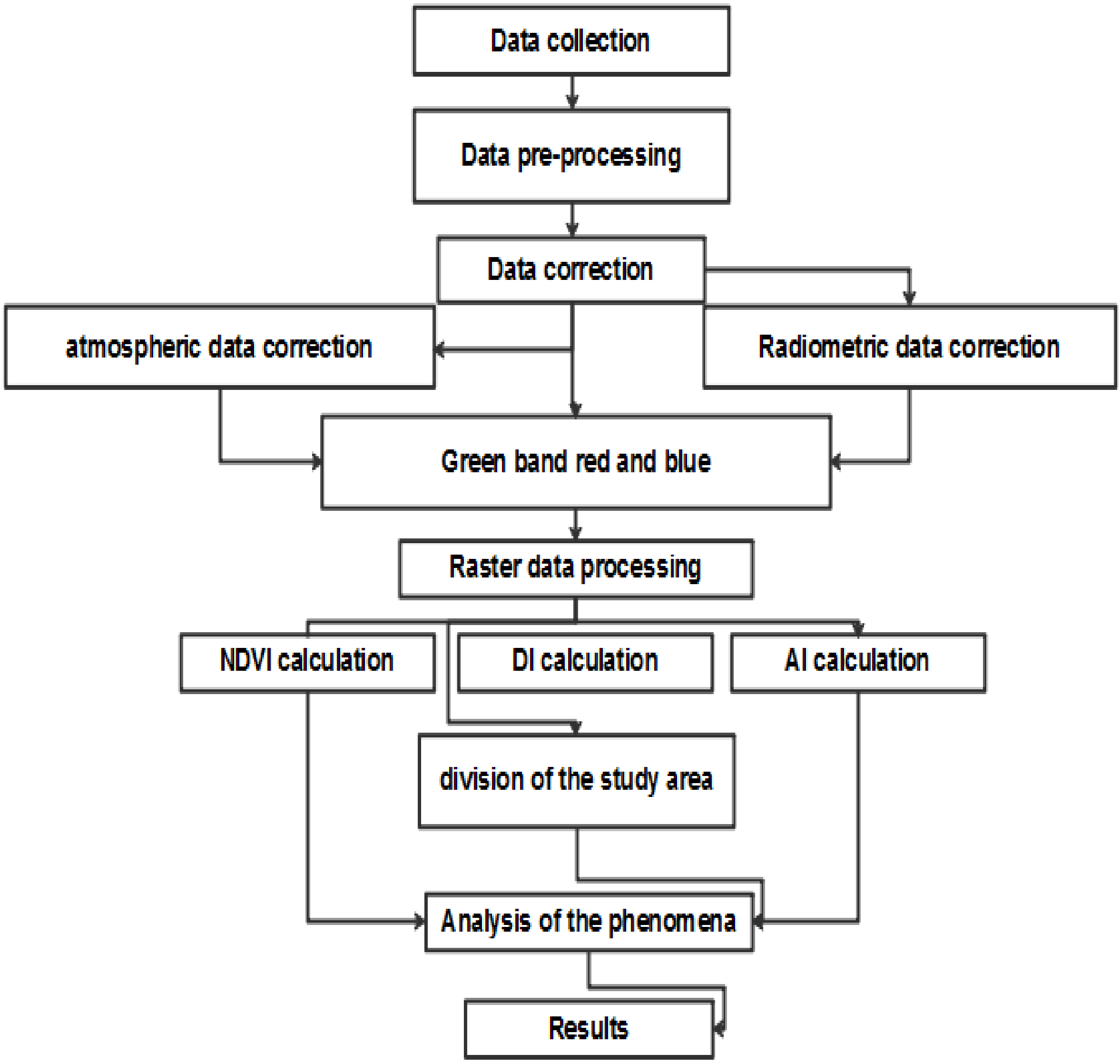


Fig. 2. - Methodological approach's histogram

RESULTS AND DISCUSSION

The NDVI shows in the year of 2014 resultant as 0.58 is a maximum and minimum of -0.16, the year of 2018 resultant as 0.39 is a maximum value and minimum value is -0.03 and, in the year of 2022, shows as 0.49 is as maximum value and minimum value is -0.0035. Over all analysis of NDVI for Constantine region shows highest maximum value and minimum arise in the year of 2014. In the year of 2014 most of region covers by the inactive vegetation and some of the regions are active vegetation in the year of 2018. In the year of 2022 resultant partial inactive vegetation covers the most of the region of Constantine (Fig. 3).

Fig.4 shows the mean and trend profile line of normalized difference vegetation index resultant as decrease in the year of 2001 and 2002. Sightly increase in the year of 2003 and decrease continuous along the years of 2004, 2005 and 2006. Trend continuous increase towards up to 2011, decrease and increase simultaneously along the periodically years increases. From the year 2018 sightlydecreasetowards the recentyear 2022.

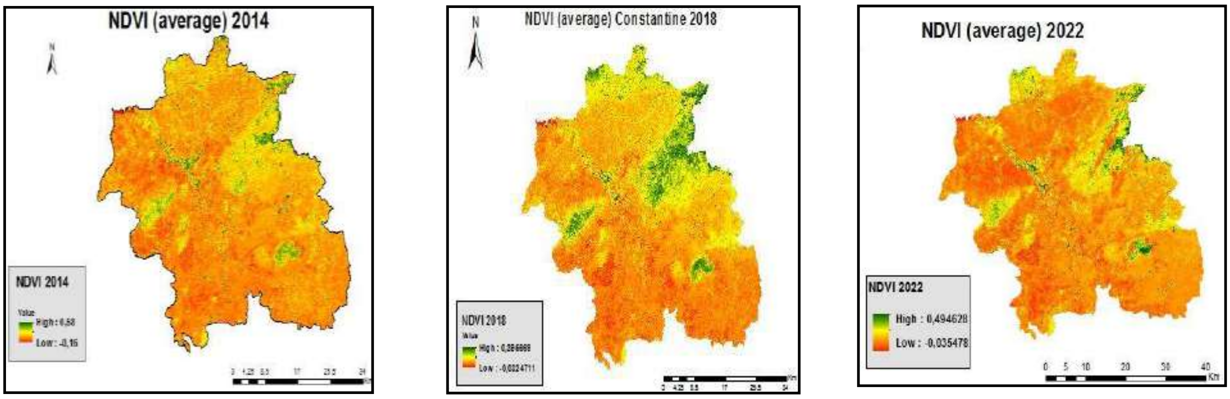


Fig.3. NDVI maps' Constantine.

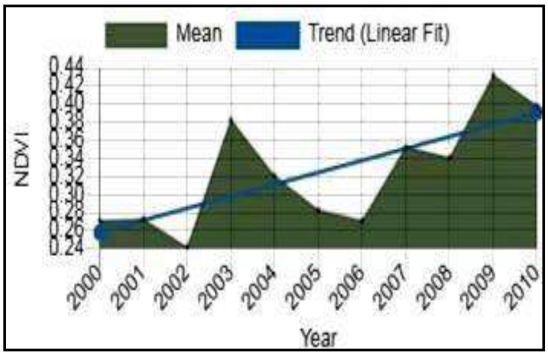


Fig.4. - NDVI mean 2000-2022.

The final land surface temperature images generated for the study area are shown in (Fig.).

LST shows in the year of 2014 resultant as 49.27 is a maximum and minimum of 28.52 the year of 2018 resultant as 43.27 is a maximum value and minimum value is 21.52 and, in the year of 2022, shows as 44.28 is as maximum value and minimum value is 21.05.

Over all analysis of LST for Constantine region shows highest maximum value in the year of 2014 and minimum arise in the year of 2022.

In the year of 2014 and 208 most of region covers by the high land surface temperature and some of the regions are low land surface temperatures. In the year of 2022 resultant partial low land surface temperature cover the most of the north region of Constantine.

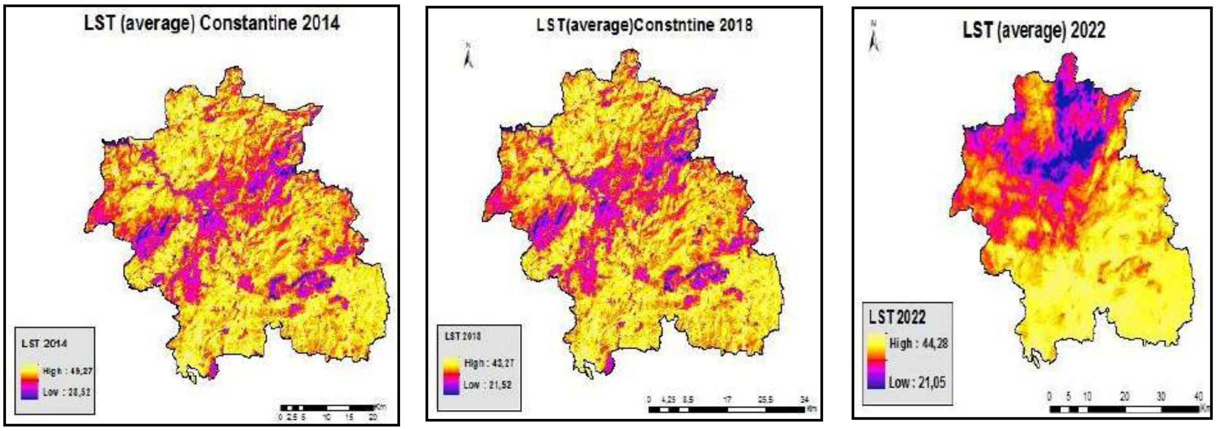


Fig.5. - LST maps' Constantine

The LST data revealed that the highest surface temperatures are found in the South-East and South-West regions, where there is mainly cultivated land and bare soil. However, in 2022, the DidoucheMourad and HammaBouziane regions experienced a drop in soil temperature due to the presence of vegetation. Since 2018, these regions have benefited from measures to increase vegetation cover, in particular through the creation of new green spaces. It should be noted that Constantine has a semi-arid climate, with areas of bare soil and around 60% cultivated land. The lowest surface temperatures are found in areas where vegetation is present.

Fig. 6 presents the correlation between NDVI and LST, and shows that NDVI is negatively correlated with surface temperature. The correlation coefficient obtained, R^2=0.028, confirms this negative relationship. In other words, it indicates that LST decreases when NDVI increases. Thus, areas with less vegetation cover tend to have higher surface temperatures.

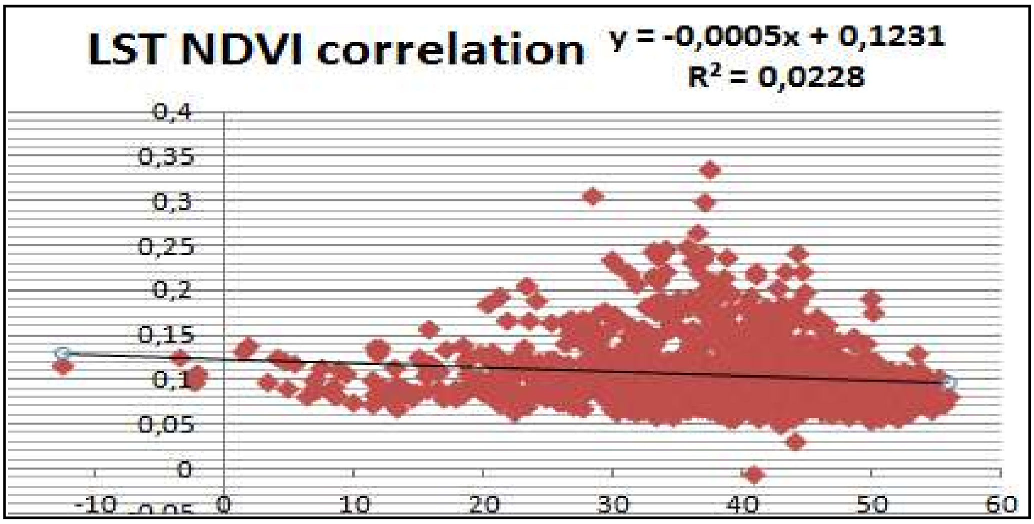
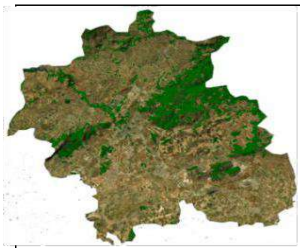


Fig.6.- LST-NDVI correlation.

Fig. 7 shows the comparative vegetation map resultant consists of vegetation-based features which includes forest area, shrub area and grassland area. The actual size of study area is 2244 Sq.km. In the comparison of forest area in the area of 2015 and 2022 are 223.5Sq.km & 223.89. Shrub area consists of 309.89 Sq.km and 300.2 Sq.km. Grass land consists of 197.2 sq.km and 188.5 sq.km. without Grassland area consists of 1393.8 sq.km and 1404.9 sq.km.

			
Year: 2015 Actual surface: 2244 km² Forest area: 223.5 km² Percentage: 9.94%	Year: 2022 Actual surface: 2244 km² Forest area: 228.89 km² Percentage : 10.2%	Year: 2015 Actual surface: 2244 km² Shrub area: 309.89 km² Percentage : 13.81%	Year: 2022 Actual surface: 2244 km² Shrub area: 300.2 km² Percentage : 13.37%
			

Year: 2015 Actual surface: 2244 km² Grassland area: 197.2 km² Percentage : 8.78%	Year: 2022 Actual surface: 2244 km² Grassland area: 188.5 km² Percentage : 8.38%	Year: 2015 Actual surface: 2244 km² Grassland area: 1393.8 km² Percentage : 62.08%	Year: 2022 Actual surface: 2244 km² Grassland area: 1404.9 km² Percentage : 62.61%

Fig.7. - Comparative vegetation map 2015-2022.

CONCLUSION

In conclusion, the data analysis and results presented in this text highlight several key points concerning the relationship between vegetation, land surface temperature (LST) and the urban environment in Constantine, Algeria.

Firstly, the effects of climate change, particularly the increase in extreme weather events, are having a serious impact on the environment and human populations, especially in densely populated urban areas. The urban heat island (UHI) effect, characterised by higher temperatures in urban areas compared to surrounding areas, contributes to the vulnerability of cities to the effects of climate change.

Finally, the presence of vegetation plays a crucial role in moderating the Earth's surface temperature, and areas with more vegetation have lower surface temperatures.

Overall, these results highlight the importance of vegetation in mitigating land surface temperatures in urban areas. Improving vegetation cover by creating green spaces can help mitigate the urban heat island effect and strengthen the overall resilience of cities to climate change. NDVI analysis of 2014 shows high active vegetation in the small edge of north Constantine and little smaller region along the middle and south west region. In the year of 2018 shows maximum healthy vegetation along the north east of Constantine and less amount healthy vegetation in the year of 2022 when compare to 2018. LST analysis of 2014 shows maximum high land surface temperature in Constantine and little smaller region covers low land surface temperature along middle of the region. In the year of 2018 shows almost same results of 2014 and, in the year of 2022, covers extreme low and low surface temperature along the north region of Constantine and high temperature covers in the south-east, south-west and south region.

Due to the comparison of 2015 and 2022 vegetation features are forest area covers 9.94% and 10.2%, shrub area covers 13.81% and 13.37%, Grassland area 8.78% and 8.38% and grassless land area 62.08% and 62.61% of study area. Forest covers are increases and shrub area & grassland are decreases from the area of 2015 to 2022.

In conclusion, analysis of the data reveals a negative correlation between NDVI (vegetation index) and land surface temperature (LST) in Constantine, Algeria. Areas with less vegetation have higher surface temperatures, while areas with denser vegetation cover have lower temperatures. This relationship highlights the importance of vegetation in mitigating the effects of climate change and the urban heat island. Improving vegetation cover can play a key role in moderating temperatures and making urban areas more resilient to extreme weather conditions.

REFERENCES

[1] Smith P., Arneth A., Barnes David K. A., Ichii K., Marquet P.A., Popp A., Pörtner H-O, Rogers A.D., Scholes R.J., Strassburg B., Wu J., SmithHien N., 2022. How do we best synergize climate mitigation actions to co- benefit biodiversity? Global Change Biology,28(8): 2555-2577.https://doi.org/10.1111/gcb.16056

[2] Keerthi Naidu, B. N., Chundeli, F. A., 2023. Assessing LULC changes and LST through NDVI and NDBI spatial indicators: a case of Bengaluru, India. Geo. J., 1-16.DOI:10.1007/s10708-023-10862-1

[3] Damarla G.,Kavuri N.C., 2009. Comparison of a decade's data between LST and NDVI data for agricultural drought analysis in Rayalaseema region, AP, India. IOP Conference Series Materials Science and Engineering, 1136(1):012009.

[4]Li J., Chen B., 2020.Global revisit interval analysis of Landsat-8-9 and Sentinel-2a-2b data for terrestrial monitoring. Sensors. MDPI, 20(22), 6631.https://doi.org/10.3390/s20226631

[5] Kumar A., Kober B., 2012. Urbanization, human capital, and cross-country productivity differences. Economics Letters. Elsevier, 117(1):14–17.DOI: 10.1016/j.econlet.2012.04.072

[6] Bari E., Nipa N.J., Roy B., 2021. Association of vegetation indices with atmospheric & biological factors using MODIS time series products.Environmental Challenges, 5: 1-7.https://doi.org/10.1016/j.envc.2021.100376

[7] Gao W., Zheng C., Liu X.,Lu Y.,Chen Y.,Wei Y.,Ma Y., 2022. NDVI-based vegetation dynamics and their responses to climate change and human activities from 1982 to 2020: A case study in the Mu Us Sandy Land, China.Ecological Indicators, 1-17. https://doi.org/10.1016/j.ecolind.2022.108745

[8] Schwaab J., Meier R.,Mussetti G.,Seneviratne S., Bürgi C., Davin E.L., 2021.The role of urban trees in reducing land surface temperatures in European cities.Nature Communications, 12(1): 1-11.DOI: 10.1038/s41467-021-26768-w

[9]Xu Y., Yang Y., Chen X., Liu Y.,2022. Bibliometric Analysis of Global NDVI Research Trends from 1985 to 2021. Remote Sensing, 14(16): 1-20. doi: 10.3390/rs14163967.

[10]Karnieli A., Ohana-Levi N.,Silver M., Paz-Kagan T.,Panov N.,Varghese D., Chrysoulakis N., Provenzale A., 2019. Spatial and Seasonal Patterns in Vegetation Growth-Limiting Factors over Europe. Remote Sens. 11(20): 1-15.https://doi.org/10.3390/rs11202406

[11]Peng X.,Wu W., Zheng Y., Sun J., Hu T.,Wang P., 2020. Correlation analysis of land surface temperature and topographic elements in Hangzhou, China.Scientific reports,10: 104-51.https://doi.org/10.1038/s41598-020-67423-6

[12] Malakar N., HulleyG.,Hook S., Laraby K., Cook M., SchottJ., 2018. An operational land surface temperature product for Landsat thermal data: Methodology and validation. IEEE Transactions on Geoscience and Remote Sensing, 56(10): 5717-5735.DOI:10.1109/TGRS.2018.2824828

[13] IvanovaY., KovalevA.,Soukhovolsky V., 2020.Modeling the Radial Stem Growth of the Pine (*Pinussylvestris* L.) Forests Using the Satellite-Derived NDVI and LST (MODIS/AQUA) Data.Atmosphere, 12(1): 1-15.https://doi.org/10.3390/atmos12010012

[14] Sharma M.,Bangotra P., Gautam A.S., Gautam S., 2021.Sensitivity of normalized difference vegetation index (NDVI) to land surface temperature, soil moisture and precipitation over district GautamBuddhNagar, UP, India. Stoch Environ Res Risk Assess, 36(6):1779-1789. doi: 10.1007/s00477-021-02066-1.

[15]Fatemi M., Narangifard M., 2019. Monitoring LULC changes and its impact on the LST and NDVI in District 1 of Shiraz City. Arab J Geosci, 12: 127.https://doi.org/10.1007/s12517-019-4259-6.

[16]Kumar A., Kober B., 2012. Urbanization, human capital, and cross-country productivity differences. Economics Letters. Elsevier, 117(1): 14-17.DOI: 10.1016/j.econlet.2012.04.072

[17]Pan Y.,Gao Y., Li S., 2021. Impacts of Land Use/Land Cover Distributions and Vegetation Amount on Land Surface Temperature Simulation in East China. Earth and Space Science, 1-17.https://doi.org/10.1029/2020EA001544

[18] Prasad S., Singh R.B., 2022. Urban Heat Island (UHI) Assessment Using the Satellite Data: A Case Study of Varanasi City, India. Smart Cities for Sustainable Development. Springer, 287-299.DOI:10.1007/978-981-16-7410-5_17

[19]Singh P., Sarkar A., Chaudhuri P.,Verma P., Vivek Kumar Singh V., Raj Meena S., 2022. Earth observation data sets in monitoring of urbanization and urban heat island of Delhi, India. Geomatics, Natural Hazards and Risk, 13:1, 1762-79.DOI: 10.1080/19475705.2022.2097452

[20]Andronis V., Karathanassi V., Tsalapati V., Kolokoussis P., MiltiadouM.,DanezisC., 2022.Time Series Analysis of Landsat Data for Investigating the Relationship between Land Surface Temperature and Forest Changes in Paphos Forest, Cyprus.Remote Sens., 14(4): 1010. https://doi.org/10.3390/rs14041010

[21]Guha S., Govil H., 2020. Land surface temperature and normalized difference vegetation index relationship: a seasonal study on a tropical city. SN Appl. Sci. 2: 1661. https://doi.org/10.1007/s42452-020-03458-8

[22]Hussain S., Karuppannan S., 2023. Land use/land cover changes and their impact on land surface temperature using remote sensing technique in district Khanewal, Punjab Pakistan, Geology, Ecology, and Landscapes, 7:1, 46-58.DOI: 10.1080/24749508.2021.1923272

[23]Yu Y., Shibo Fang S., ZhuoW.,2023. Revealing the Driving Mechanisms of Land Surface Temperature Spatial Heterogeneity and Its Sensitive Regions in China Based on GeoDetector.Remote Sens, 15(11):2814. https://doi.org/10.3390/rs15112814

[24] Seeberg G.,Hostlowsky A.,Huber J., Kamm J., Lincke L., SchwingshacklC., 2022. Evaluating the Potential of Landsat Satellite Data to Monitor the Effectiveness of Measures to Mitigate Urban Heat Islands: A Case Study for Stuttgart (Germany). Urban Science. MDPI, 6(4): 82.https://doi.org/10.3390/urbansci6040082

[25]Guha S.,Govil H., Diwan P., 2020. Monitoring LST-NDVI Relationship UsingPremonsoon Landsat Datasets. Advances in Meteorology, Article ID 4539684, 15 pages.https://doi.org/10.1155/2020/4539684

[26]Guha S., Govil H., 2021. A long-term monthly analytical study on the relationship of LST with normalized difference spectral indices. European Journal of Remote Sensing, 54(1): 487-512.DOI: 10.1080/22797254.2021.1965496

[27]Thanabalan P., Vidhya R., Kankara R., 2023. Time-series analysis of MODIS (LST and NDVI) and TRMM rainfall for drought assessment over India. ApplGeomat, 15: 383-405.https://doi.org/10.1007/s12518-023-00505-y

[28] Ermida S.L., Soares P., Mantas V., Göttsche F. M., Trigo I. F., 2020. Google earth engine open-source code for land surface temperature estimation from the landsat series. Remote Sensing, 12(9):1-21.https://doi.org/10.3390/RS12091471