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RESEARCH ARTICLE

The effect of vegetation cover on dust concentration: Case study (Constantine, Algeria)

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Abstract. Urban greenery plays a crucial role in preserving a healthy and pollution-free climate for our planet. However, metropolitan areas are facing a significant threat from pollution, specifically dust particles. This study focuses on exploring the connection between dust concentration and vegetation cover in Constantine, Algeria, using advanced remote sensing techniques. As urban development continues to encroach upon green spaces, the issue of pollution, particularly dust particles, has become a pressing concern in metropolitan areas. To conduct the study, data from USGS and GLOvis were utilized for climate analysis, while Landsat images from GEE were employed for accurate mapping. Over the course of multiple years, comprehensive datasets including land cover maps, Aridity Index (AI), precipitation data, and Normalized Difference Vegetation Index (NDVI) maps were collected and subjected to thorough analysis. The NDVI and Dust Index (DI) were employed to evaluate the impact of vegetation on dust concentration. The findings of the study indicate that the presence of vegetation directly affects dust levels, and the Dust Index (DI) exhibits variations over time in relation to the values of NDVI. This study underscores the critical importance of preserving and enhancing urban greenery as a means to mitigate dust pollution and create a healthier environment.

1. Introduction

Air quality is a significant subject that involves various epidemiological disciplines, as well as specialists in transport modeling, pollutant emissions and transformations, geographic systems, and remote sensing, along with local authorities and industrial experts. A conducive planet for a better quality of life relies on a healthy natural environment. Urban vegetation plays a catalytic role in providing clean air for humans, impacting their physical and psychological health (Liang et al., 2020). The presence of green spaces is a major criterion for improving the quality of the living environment. Trees and plants, as essential components of the Earth system, help regulate the urban climate and mitigate the urban heat island effect by providing cooling effects, oxygen production, carbon dioxide absorption, shade generation, and radiation interception (Aram, García, Solgi, & Mansournia, 2019). Several studies have examined the impact of vegetation cover on particulate matter (PM) concentrations in metropolitan areas such as Beijing, China, using remote sensing data. Tian et al. (2014) reported that air quality was worst in spring, improved in summer, and tended to worsen again in autumn and winter (Zhang, Wang, Hu, Ying, & Hu, 2015). Other research has explored the relationship between vegetation cover and dust concentration in arid regions such as the Taklimakan Desert in China and the Mu Us Sandy Land region.

Numerous studies have demonstrated that the impact of dust on air quality can be influenced by meteorological conditions (Haddad & Vizakos, 2021). Dust-induced climate change, especially in arid areas, can increase the frequency, duration, and intensity of droughts. In Algeria, there have been few research studies conducted in this field, which prompted us to carry out additional research to better understand how vegetation influences dust concentration in Constantine, Algeria, and how conservation efforts can be enhanced to reduce the adverse effects of dust on human health and the environment. Rapid urbanization reduces green coverage, resulting in increased land surface temperature and degraded air quality, causing imbalances in surface temperature homogeneity (Tariq, Shu, Siddiqui, Imran, & Farhan, 2021). Urban and industrial expansions improve our lives and luxuries; however, they also lead to growing environmental problems for humans, such as climate change and industrial air pollution(El-Hattab, Amany, & Lamia, 2018). Land use and land cover changes are one of the major drivers of environmental changes at spatio-temporal scales (Mishra, Rai, Kumar, & Prasad, 2016). Most studies on desert aerosols have focused on arid regions in Sahelian and West African countries (including only the extreme south of Algeria). However, studies on semi-arid areas, such as the Algerian steppe zone, are highly valuable in monitoring phenomena, particularly drought and desertification (Nakes, Legrand, Francois, & Mokhnache, 2007).

Studies have also focused on the impact of urban vegetation on land surface temperature regulation (Jabbar & Yusoff, 2022), and consequently, on air quality regulation. They have shown that land surface temperature can be reduced by increasing green space and water mass fraction (Musy, 2014), leading to a decrease in aerosol levels. While many studies highlight the benefits of urban tree evapotranspiration, it is important to note that trees also affect wind patterns in cities. By modifying wind patterns, trees can alter the effectiveness of cooling breezes and play a significant role in dispersion processes and pollutant removal through deposition.

Researchers from the Global Modeling and Assimilation Office at NASA have captured wind patterns carrying aerosols around the world. Assessing exposure involves cross-referencing urban expansion data with pollution data and analyzing the NDVI and its relationship with pollution. A simulation produced by the Goddard Earth Observing System Model Version 5 (GEOS-5) shows clouds (white), dust (brown shades), sulfates (purple shades), and organic black carbon (green shades) at a resolution of 7 kilometers from September 1, 2005, to December 31, 2005 (hourly). Simulations like these enable scientists to better understand how different types of aerosols move in the atmosphere, impact cloud formation, and influence weather, climate, environment, and the living environment. The concentration and properties of these aerosols exhibit significant spatial and temporal variability. The possibility offered by satellite remote sensing to continuously observe the Earth's surface has led to the creation of large databases whose analysis provides information on the status and evolution of natural resources and local ecosystems (Benabou et al., 2022).

This research aimed to examine the links between atmospheric dust concentration, meteorological factors, and land cover, conducting a time series evaluation of dust concentration and its relationship with NDVI and LST in the city of Constantine.

2. Methods

Study area

Constantine, the capital of eastern Algeria, located approximately 431 kilometers from Algiers. It is one of the country's most important city, covering an area of around 2,297.20 km², and is located equidistant between the coastline to the north and the Aurès massif to the south, forming a link between the cities of the south and the coastal cities. It is located in latitude 36° 17' and longitude 6° 37', between 350m and 1100m above sea level. The city's overall population is predicted to be 836977 people, with a population density of 400 people per Km2 and an annual growth rate of -0.68.

The city of Constantine is situated between the Sahara in the south, which has a continental climate, and the Mediterranean climate in the north, which has variable rainfall and a lengthy period of summer drought. As a result, the city's climate is cool semi-arid, with two distinct seasons (Gherraz, 2021)

Data processing & analysis

The primary goal of this study was to look at the relationship between the normalized difference vegetation index (NDVI), land cover, and particulate matter concentration throughout various years, including 2001, 2010, and 2022. We employed a variety of technologies and reliable data sources to conduct this investigation.

To access the relevant data, we used Google Earth Engine (GEE), USGS Earth Explorer, and USGS Earth Map. The data used for our analysis comes mostly from the Landsat and MODIS satellites, which provide wide spatial and temporal coverage. We augmented this information with weather data collected from POWER LARC NAZA. (power.larc.nasa.gov/data-Access), to take account of relevant environmental elements.

We used ArcGIS software, a well-known tool in the field of geospatial analysis, to analyze these data. We were able to use ArcGIS to combine NDVI, land cover, and particle concentration data, allowing us to identify the correlations

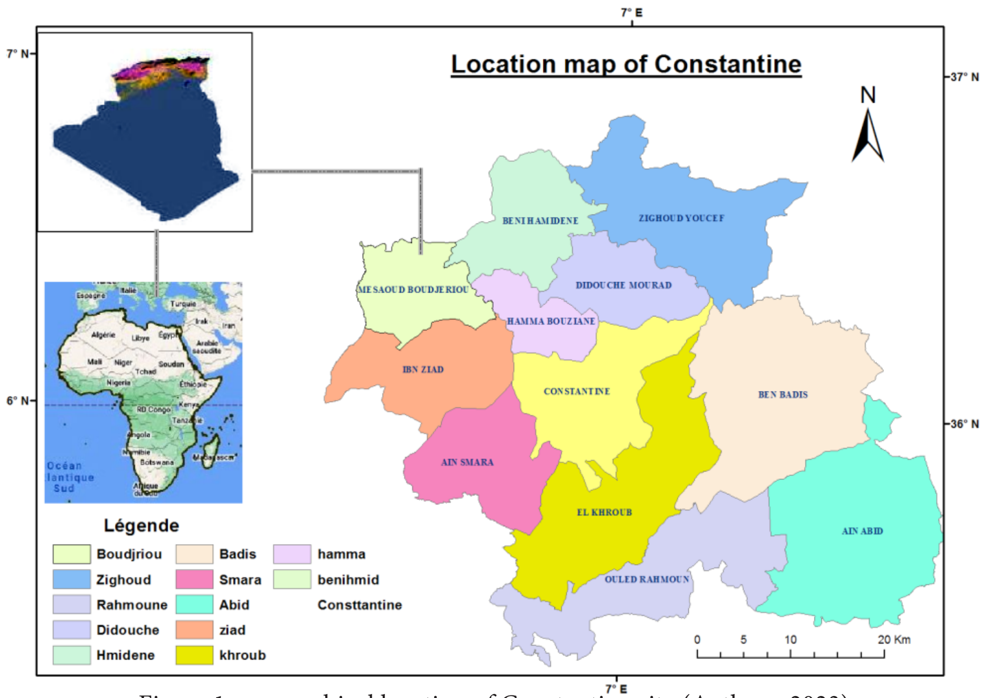

Figure 1. geographical location of Constantine city (Authors, 2023)

between these variables and build maps and graphs to visualize the results. It should be mentioned that having access to these data and tools was critical for carrying out our research and producing reliable and robust results. We were able to give comprehensive information on the relationship between NDVI, land cover, and particle concentration by utilizing an integrated approach that capitalized on the advantages of each data source and instrument.

The aridity index

Aridity index (AI), which is used to categorize climate regimes and track drought episodes, is defined as the ratio of annual potential evapotranspiration to annual precipitation. Looking into AI variation (Nakes et al., 2007)

$$\text{Aridity index} = \frac{\text{average annual precipitation}}{\text{potential evaporation}}$$

We downloaded and used climate data for the city of Constantine from 2001 to 2022 using the power data access viewer site and the Geojson plugin.In terms of rainfall, the highest cumulative averages were over 10mm/day in 2003, 8mm/day in 2004, 6.5mm/day in 2009, nearly 6mm/day in 2014, 4mm/day in 2018, and nearly 5mm/day in 2021. (Figure 2).

The normalized difference vegetation index (NDVI)

The NDVI quantifies vegetation by measuring the difference between near infrared light (which vegetation strongly reflects) and red light (which vegetation absorbs). The NDVI value is always between -1 and +1. When the readings are negative, it is almost certainly water. When an NDVI value is close to +1, it indicates that there are lush green foliage or irrigated crops nearby. The NDVI was defined by this formula:

NDVI = (NIR – Red) / (NIR + Red)

NDVI = (Band 5 - Band 4) / (Band 5 + Band 4) for Landsat 8.
NDVI = (Band 4 - Band 3) / (Band 4 + Band 3) for Landsat 5.

Landsat imagery is the main data source to calculate NDVI. Landsat imagery data include Landsat Thematic Mapper (TM) and OLI/TIRS geo-referenced scenes for the years 2001, 2010 and 2022 respectively in the same season; these datasets were acquired from the National Aeronautics and Space Administration (NASA) through their USGS (Earth Explorer) Data Gateway Database. The pre-processing and the processing were performed using ArcMap 10.5 software. The details of Landsat images were incorporated in the study given in Table 1.

The dust index

We worked with 'MODIS/006/MCD19A2 in google earth engine. The MCD19A2 V6.1 data product is a MODIS Terra and Aqua combined Multi-angle Implementation of Atmospheric Correction (MAIAC) Land Aerosol Optical Depth (AOD) gridded Level 2 product produced daily at 1 km resolution.

The evaluation of the impact of green space on the improvement of air quality and the reduction of pollutant deposits (aerosols; dust) through remote sensing, for which we proceeded to detect the relationship between the NDVI and the surface of the ground cover and the concentration of dust through the years 2001, 2010, and 2022), thanks to Google Earth Engine (GEE), USGS and Earth map (USGS), and Earth explorer (USGS), with maps of Latitude and Longitude. (POWER LARC NAZA (Power.larc.nasa.gov/data-Access).

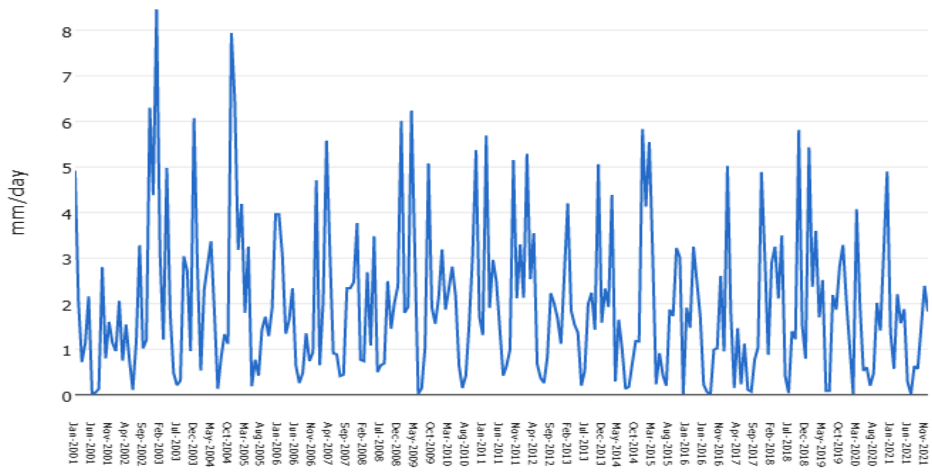

Figure 2. Precipitation sum average

Table 1. Data used to calculate NDVI

ID	Date Acquired	Path	Row
• LT05_L2SP_194035_20010426_20200906_02_T2	2001/04/26	• 194	• 035
• LT05_L2SP_193035_20100311_20200824_02_T1	2010/03/11	193	• 035
LC08_L2SP_193035_20220515_20220519_02_T1	2022/05/15	193	• 035

Source :(usgs.gov, 2019)

(Figure 3) depicts a flow chart outlining the stages taken in our research to acquire the results.

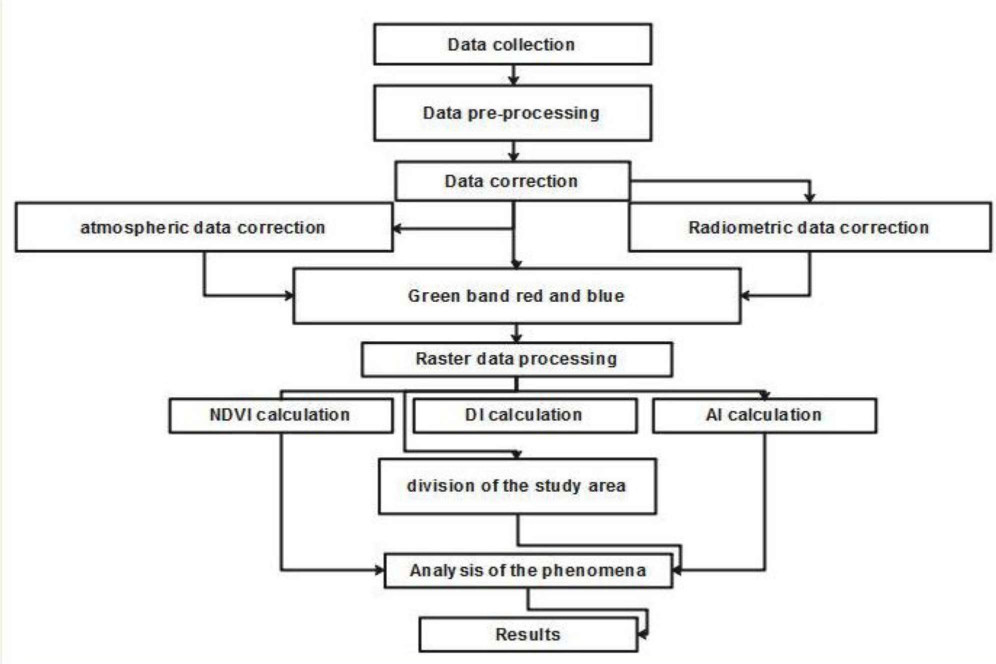

Figure 3. Flowchart of research methodology incorporated in the study (Authors, 2023)

3. Results and Discussion

Land cover

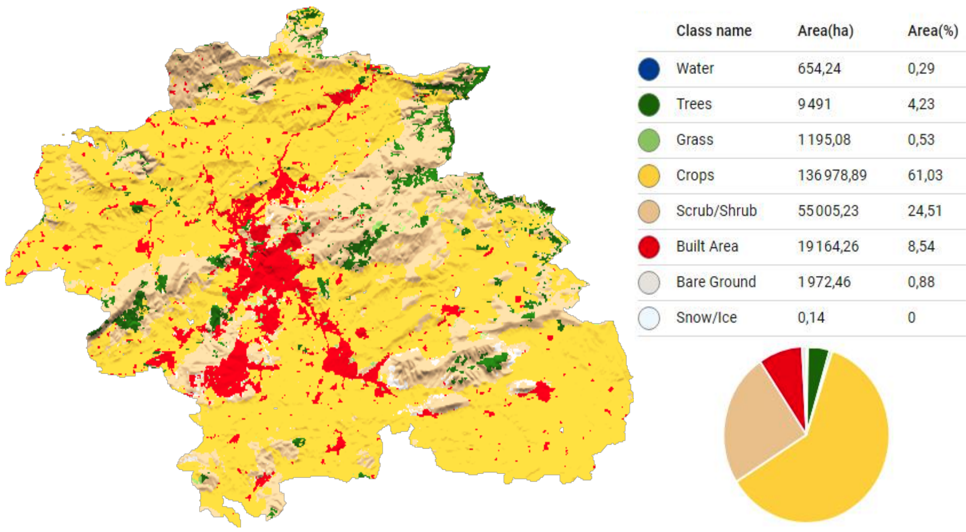

Figure 4. Constantine's land cover (authors, 2023)

We worked with GEE on the land cover, utilizing a pre-existing script and an ArcGis update. The map is created using Sentinel-2 imagery with a resolution of 10m that was retrieved from Earth Engine (GEE). It is a combination of LULC projections for ten courses that run throughout the year. The underlying deep learning model employs Sentinel-2 surface reflectance data from six bands: visible blue, green, red, near infrared, and two short-wave infrared bands (Figure 4).

Forest trees, tall-stemmed plants, and ornamental plants are among the species planted in the city (Gherraz, 2021). The type of the plants has a direct influence on the vegetation cover, with agricultural land primarily utilized for arable farming (dry and irrigated crops) predominating, as evidenced by NDVI maps, which indicate an increase in values above 0.35 and 0.4. Plantations are worth 62% of the total value, which includes cereals, grasses, and planted crops such as maize, wheat, and soya.

AI (Aridity Index)

We extracted the aridity indices for 10 years (2001-2010 and 2010-2020) and obtained convincing results, with the index lying between (1-3): This indicates moderate aridity, with the region experiencing times of drought or periodic water deficiency but generally retaining viable plant growth conditions.(Figure 5)

The graphic below compares movements in the aridity index (AI) for the median values from 2001 to 2010 to 2011 to 2021. The move to drier conditions is depicted in red, and the shift to wetter conditions is shown in blue.

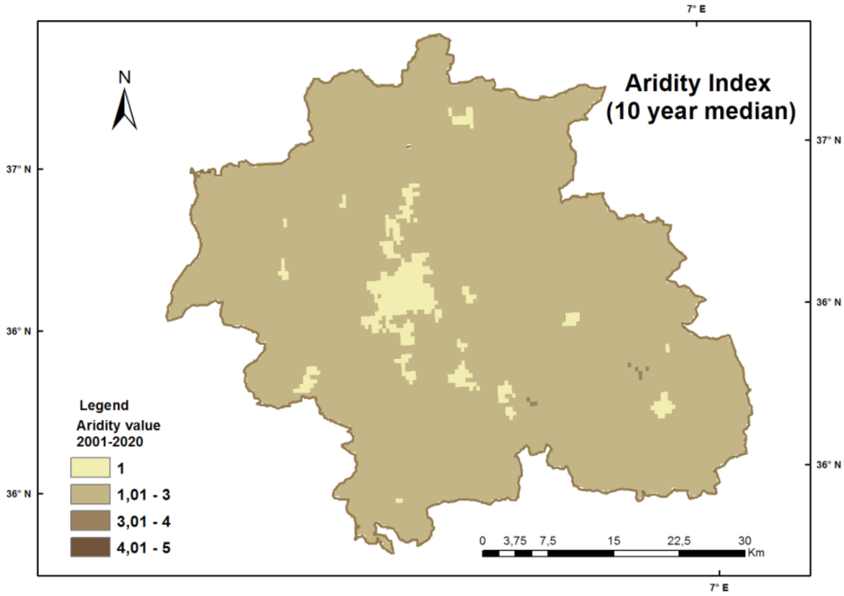

Figure 5. Aridity index 2001-2010 and 2010-2020 (authors, 2023)

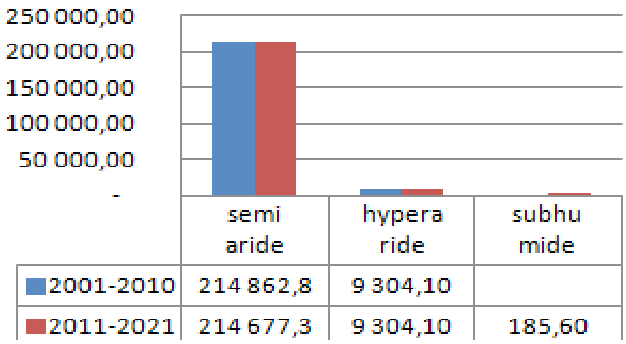

Figure 6. Change in aridity over 10 years.(Power.larc.nasa.gov)

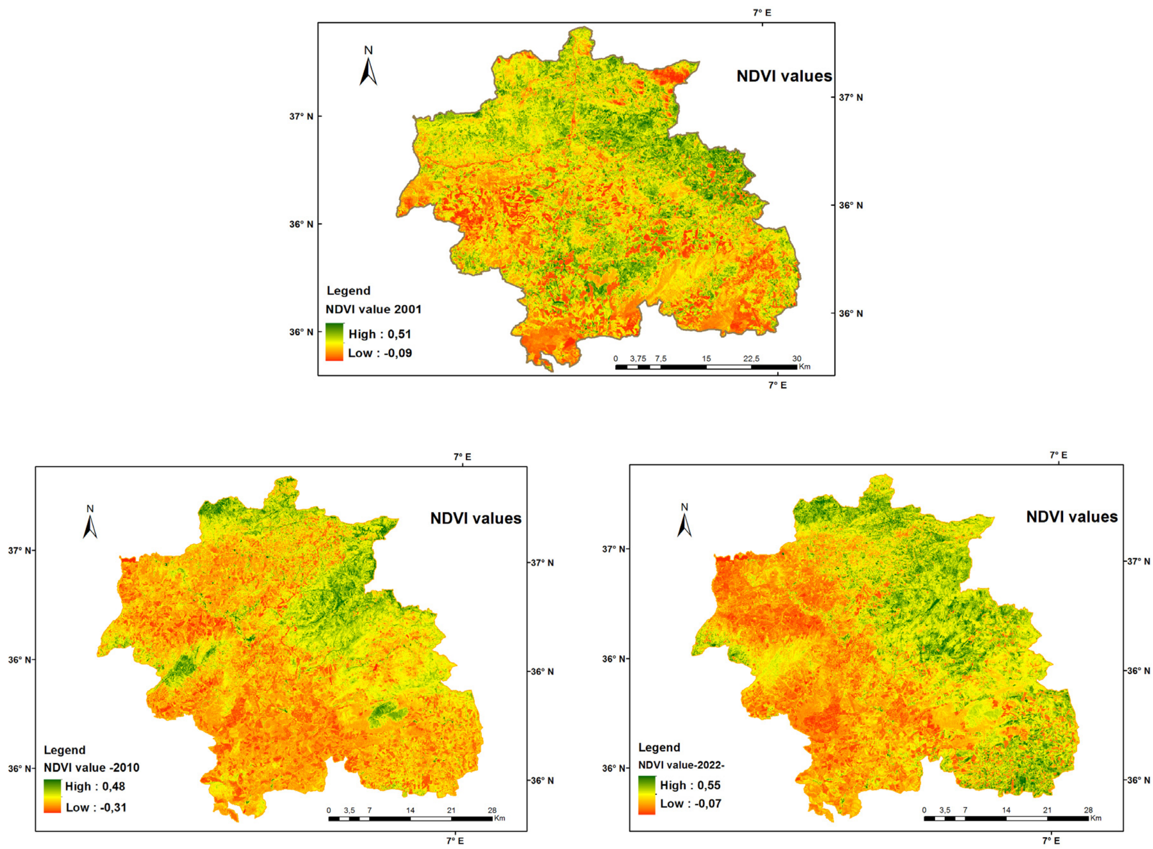

Figure 7. NDVI of Constantine city for 2001 and 2022 respectively

The persuasive findings from the analysis of the 10-year aridity indices (2001–2010 and 2010–2020) show that moderate aridity is present, with an index between 1 and 3. This indicates that although there are occasionally dry spells or water shortages in the region (see Figure 6), overall circumstances are still favorable for plant development. According to the rainfall graph, these findings point to a gradual evolution of drier circumstances over time, which may have effects on the research area's vegetation and water supply.

The normalized difference vegetation index (NDVI)

Vegetation indices have long been utilized in a variety of applications, including vegetation monitoring, aerosol and dust concentration, climate and hydrological modeling, agricultural operations, and drought studies, among others... (Didan, 2015)

The NDVI values observed in 2001 range from (0.51 to -0.09), with an average of 0.23, and the higher rate exceeding 0.35 is in the majority. The NDVI readings reported in 2010 range between (0.48 to -0.31) with an average of 0.16 and a higher rate exceeding 0.28 in the majority. The NDVI readings reported in 2022 range between (0.55 to -0.07) with an average of 0.23 and a higher rate exceeding 0.38 in the majority. Precipitation, temperature, land use, natural disturbances, and human activities are only a few examples of the variables that might cause variation in NDVI. Changes in precipitation patterns, such as droughts or times of excessive rain, can directly affect the amount of water available to plants, as seen by NDVI values. Similar to how temperature changes, especially significant ones, can harm plants by impairing photosynthesis and causing heat stress.

The quantity and quality of vegetation existing in this area can be modified by changes in land use, such as deforestation for the building of the tramway, the transrhumel, urban growth for the construction of social and subsidised housing, and intensive agriculture, which can then affect NDVI values. Natural disturbances like the recent forest fires can also result in sudden changes in vegetation cover, which can modify the NDVI.

The ecology and the health of ecosystems can also be impacted by human activities, which are reflected in NDVI levels, such as excessive irrigation and pesticide use.

Dust index (DI)

Dust index (DI) values observed in 2001 range from (166.27 to 25.75), with an average of around 69 and a higher rate exceeding 70 in the majority of cases. The DUST values reported in 2010 range from (220.5 to 47.16) , with an average of 130 and a higher rate exceeding 98,5 in the majority of cases. The DUST values reported in 2022 are between (164.7 and 28.25) , with an average of 82 and a higher rate exceeding 75 in the majority of cases. Through the modification of radiative forcings, which can affect climate variables like precipitation and temperature, dust aerosols have a substantial impact on regional climate. According to studies, determining how human activities affect dust phenomena requires an understanding of the relationship between local climatic elements such wind speed and precipitation and dust aerosols (Kamal, wu, & Lin, 2019).

Assessing the impact of dust aerosols on climate requires a precise description of dust source regions and an

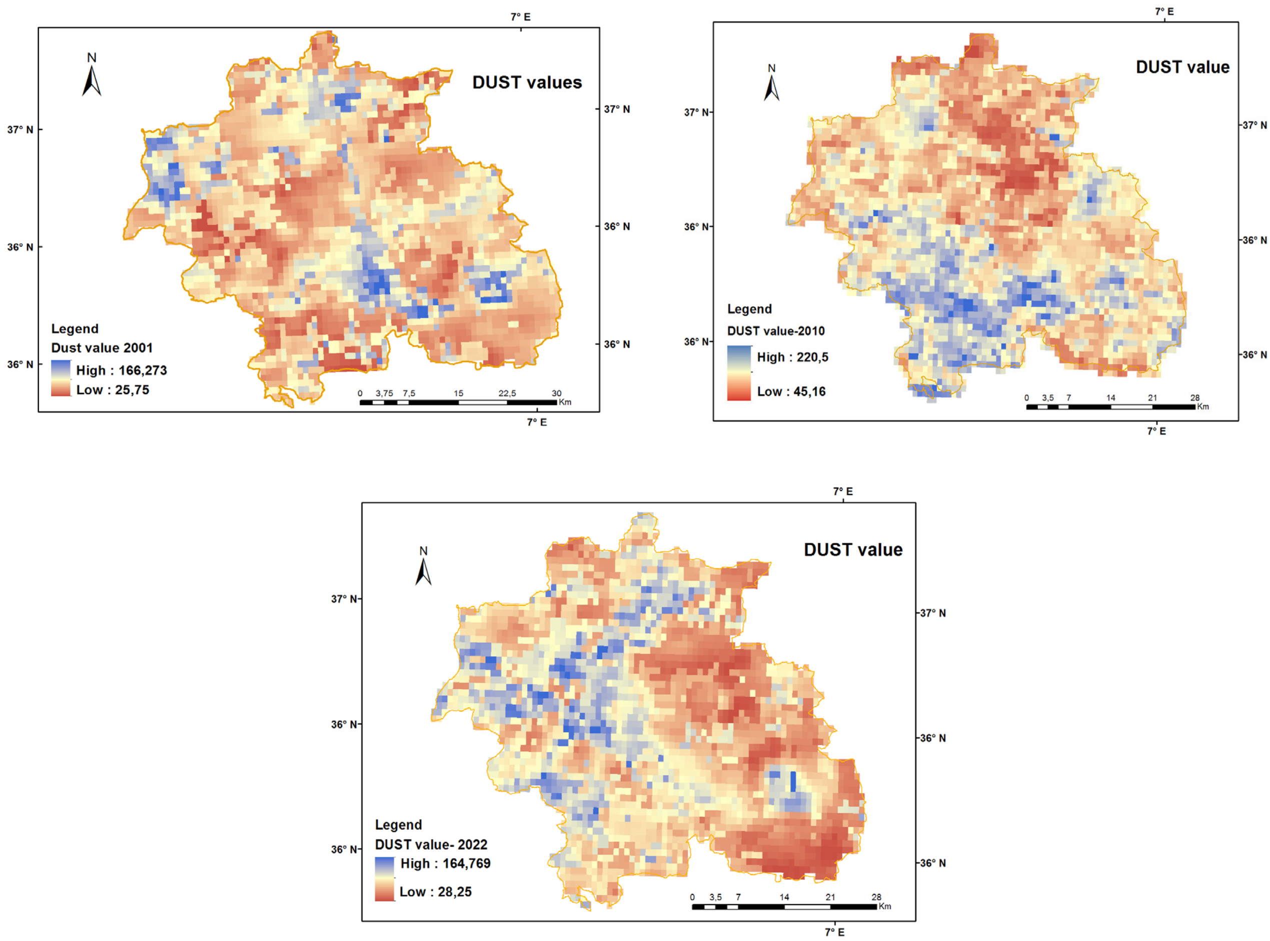

Figure 8. Constantine dust's map of 2001,2010 and 2022

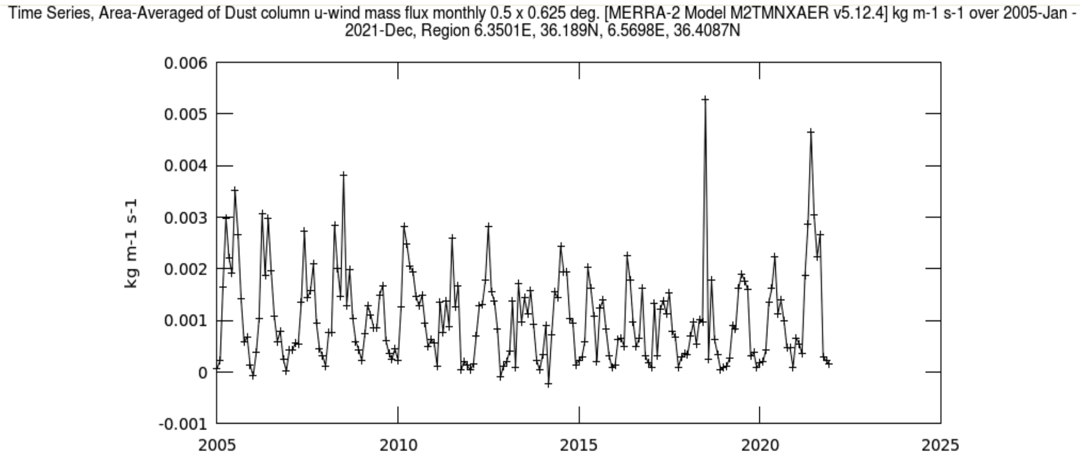

Figure 9. Time serie, area average of dust column u wind mass monthly over2005 -2022-

understanding of the meteorological processes leading to dust emission. Scientists may more accurately predict and project the effects of dust particles on local climate using this information.

Many industries, including agriculture, transportation, construction, and emergency preparedness, depend on precise and timely weather forecasting. For making wise selections, it offers useful information. Furthermore,we can more accurately predict how dust distributions will vary in response to climate change by studying dust source regions and associated meteorological processes. In Constantine, a number of things can affect the amount of dust in the air. Dust is formed as a result of the region's rugged topography, high winds, dry spells, and human activity like building, particularly the massive housing program, and industrial activities. Dust is also produced as a result of agricultural operations and soil degradation.

Correlation between NDVI index and Dust index:

We ran correlation analyses with SIGMA plot 15 software, using the t-test and the Kruskal-Wallis One Way Analysis of Variance on Ranks, and the following findings were obtained:

Correlation between NDVI and dust in 2001

Kruskal-Wallis One Way Analysis of Variance on Ranks

The variations in median values across treatment groups are bigger than would be predicted by chance; the difference is statistically significant. (Sig = 0,001 lower than 0,05)

A Pearson correlation coefficient (r= -0.43)a moderate negative correlation

Correlation between NDVI and dust in 2022

Kruskal-Wallis One Way Analysis of Variance on Ranks

The variations in median values across treatment groups are bigger than would be predicted by chance; the difference is statistically significant. (Sig = 0,006 lower than 0,05)

A Pearson correlation coefficient (r= -0.39)a moderate negative correlation.

The relationship between NDVI and the dust index (IDDI) is inverse. Because vegetation lessens the accentuation of dust and NDVI in locations with high NDVI values and low dust index values.

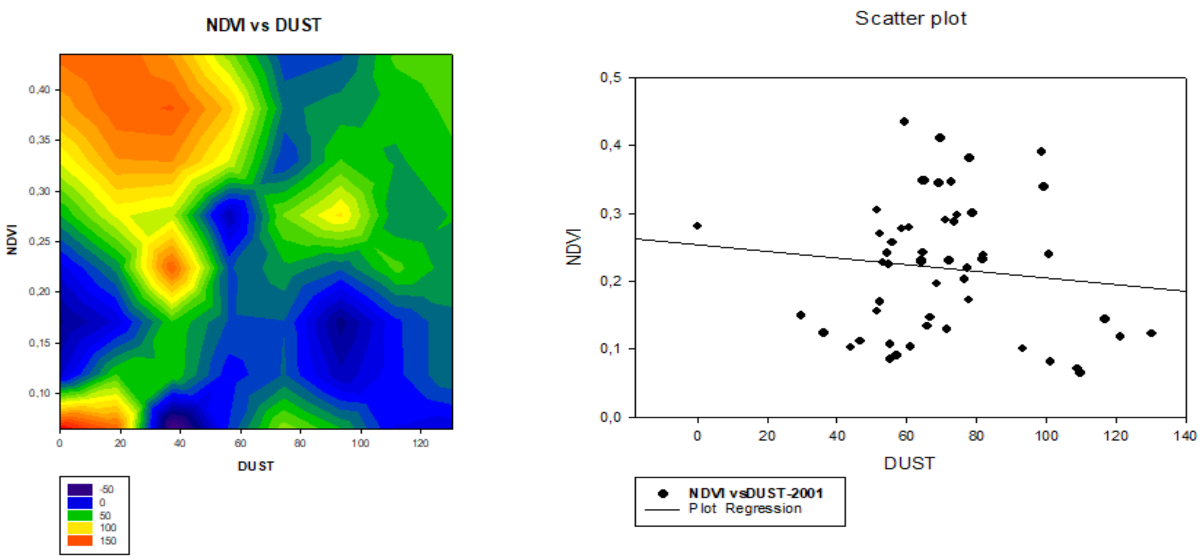

Figure 10. NDVI-DUST correlation -2001

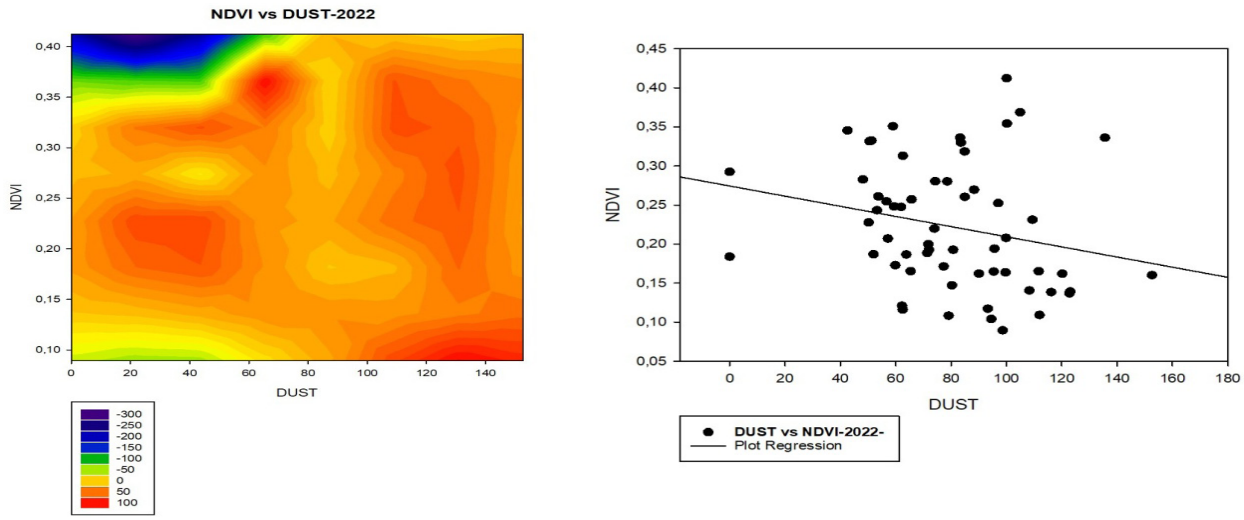

Figure 11. NDVI-DUST correlation in 2022

The findings of the correlation studies showed a moderately negative association between plant cover and the presence of aerosols (dust), which was statistically significant. Although the association is not particularly strong, this correlation suggests a potential cause-and-effect relationship. The protective function of thick vegetation is a tenable explanation for this negative association. Dense vegetation minimizes soil exposure to wind erosion, which stops dust particles from being released into the atmosphere. Additionally, vegetation serves as a filtration system by catching and holding onto dust particles, so reducing the spread of those particles. It is crucial to emphasize that, despite the correlation's importance, this complex relationship may also be influenced by other factors. To better comprehend the underlying mechanisms and the relationship between vegetation cover and the presence of aerosols, more factors and in-depth research may be necessary. To better characterize this link and its ramifications, a multidisciplinary approach integrating environmental data, in situ observations, and modeling may be helpful.

4. Conclusion

The optical depth of the aerosols and their kind (background, biomass combustion, or dust) are initially retrieved (and reported) in the MODIS blue B3 band (0.47), as is their optical depth in the "green" band (B4). Based on the spectral features of the regional aerosol model used in the retrievals, it is computed from 0.47. Validation demonstrates that the AOD quality at 0.55 is often close to, if slightly lower than, the initial recovery quality at 0.47. AOD is currently not retrieved at high altitudes more than 4.2km, except when Smoke/Dust aerosol is observed.

Meteorological variability has a significant impact on ambient air pollution, influencing emissions, movement, production, and deposition of pollutants and dust both directly and indirectly. Vegetation (62% of total soil cover) boosts relative humidity, lowers air temperature, and limits air velocity (250 kg/m2) through its evapotranspiration effect, indicating its ability to reduce pollutant and dust deposition.

Aerosols (dust) are important to scientists because they have the potential to influence climate, weather, and human health. Aerosols have an impact on climate by dispersing sunlight into space and cooling the earth's surface.

Due to a dearth of previous research in this area, it was required to investigate the relationship between the concentration of ambient air pollutants (dust) and variations in NDVI over time in the city of Constantine. Data for 2001, 2019, and 2022 demonstrate that the amounts of several air pollutants in Constantine are decreasing.

Dust is produced by a combination of climate processes and human actions, and unsustainable land use can increase global dust emissions.

The findings of this study, which cover a wide range of environments throughout Constantine, also provide valuable, freely available, and simple-to-use support to the modeling community for model comparison and validation in terms of dust concentration, particle number and size distribution, and so on.

A future description of aerosol (dust) properties is a critical step toward a better depiction of aerosol-cloud interactions in models and, as a result, a more accurate assessment of their impact on climate for future research.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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