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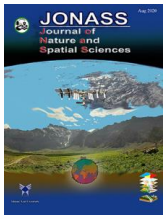

Case Study

An investigation of the relationship between the land surface temperature and changes in the vegetation cover using the Google Earth Engine (Case study: Mashhad and Gorgan cities in Iran)

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ABSTRACT

Background and objective: The research was conducted to the relationship review of LST and NDVI of the Mashhad and Gorgan cities of Iran using the GEE system based on the Landsat 8 OLI and Sentinel 5P images from the period between 1/1/2021 and 1/1/2022. The purpose of this research was to compare the relationship between the temperature of the earth's surface and changes in the vegetation index and its possible relationship with air pollution.

Materials and methods: For this purpose, first, the date of certain images and then the desired bands for calculating three variables, earth surface temperature, vegetation index, and air pollution were introduced to it. In the end, a normalized vegetation difference index or NDVI was obtained to calculate surface emissivity and LST land surface temperature map, and an air pollutants map (So2, No2, HcHo, Co, Aerosol) was prepared and produced.

Results and conclusion: The results showed that the highest average temperature for the cities of Mashhad and Gorgan is 42 and 35 degrees Celsius, and the lowest average temperature is 27 and 17 degrees Celsius, respectively. It can also be seen that the relationship between the temperature of the earth's surface and the amount of vegetation has an inverse relationship. Thus, the lowest temperature is related to the areas with the most vegetation and the highest temperature is related to the barren lands and built areas. By superimposing the surface temperature map and the air pollution map, it was found that high temperature brings more pollution.

1. Introduction

With the development of urbanization, large areas of agricultural areas and forest cover are replaced by built-up areas, including residential and industrial areas and other infrastructures. From the landscape point of view, the city shows the process of transformation of land cover or land use, this process includes the transformation of natural landscapes of water, soil, and plants into artificial landscapes such as chemicals, asphalt, cement, and other elements. As a human-made landscape

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replaces a natural landscape, the change of surface materials causes a series of changes in surface reflection, storage, and heat transfer, or in other words, significant effects on local climate (Zhang et al., 2012). The land surface temperature (LST) is controlled through the energy balance of the land surface and atmosphere as well as surface and subsurface thermal properties and is considered an important parameter in many environmental models (Arianpour and Jamali 2014; Srivastava et al., 2009). The knowledge of the LST level is useful for a wide range of issues related to earth sciences, such as urban climate, global environmental changes, and the study of human-environment interactions (Mallick et al., 2008). Land use types affect the LST level and it is considered an index to check its trend (Dang et al., 2020). Using LST, useful information is obtained about the physical characteristics of the earth's surface and climate, which have a significant impact on environmental processes (Lu & Deng, 2004). LST is an important factor in many fields of study, such as global climate change, hydrology, agriculture, and land use. Due to the heterogeneity of land surface features, such as vegetation, topography, and soil, LST is rapidly changing in scale.

It changes spatially and temporally. Therefore, to achieve LST changes in space and time, this parameter must be measured. Considering the complexity of this variable, the measurements It is not possible to land across large areas. With the development of remote sensing, LST calculation through satellite images is expanding as a method with a high temporal and spatial resolution (Li et al.,ang Li et al, 2013). Thermal infrared data is directly related to LST through radiative transfer. The plant index is one of the most famous and simple plant indices used. As its name suggests, this index has normal values in the range of -1 and +1, which makes it easy to check and display the values. Different NDVI values represent different covers. So that NDVI values are between 0.05 and 0.1 for thin vegetation areas, values between 0.1 and 0.5 for normal vegetation areas, and 0.5 and above for very dense and rich vegetation areas. Water, snow, and ice have negative NDVI values and soils have values less than 0.05, and clouds usually have values around zero (Yaghobi et al.,, 2019). Excessive extraction of underground water sources and a decrease in rainfall are among the factors that have caused an increase in temperature and a decrease in vegetation cover and ultimately a change in land use.

It seems that there is a significant relationship between the temperature of the earth's surface and vegetation and the amount of pollutants. This has prompted the researcher to look for the relationship between the temperature of the earth's surface, the amount of pollution, and changes in vegetation index in the emerging Google Earth Engine system, which features include: Being a free system, the ability to transfer data and processes without the need for hardware, high processing power and support for time series. But its biggest limitation is the lack of access to commercial satellites with high spatial resolution to increase research accuracy. Also, this research intends to solve the shortcomings of previous research by using the Google Earth Engine system and provide a new approach to the future in accessing satellite data.

Ghane Ezabadia et al. 2021 in a study showed that during the 40 years especially from 2020 to 2010, the volume of dust and wind stress in the study area has increased significantly. Also, dust, vegetation, and wind stress have had related changes over 40 years, so wind stress is directly related to the amount of dust and increases its effects. Also, in areas with more vegetation, there is less dust. (Hadipour et al., 2020) investigated urban heat islands and their relationship with air pollution and NDVI and NDBI indices in Arak city. and 8 investigated the variables of the research, and the obtained results indicate that there is a significant difference in all land uses, except for residential land use and salt lake, in LST and NDVI indices, and also there is a significant difference in all existing land uses. It was within the studied range for the NDBI index.Also, the results of the paired t-test for air temperature and LST variables showed that there is no significant difference between all uses and residential use and the correlation between air temperature and LST and air quality data including suspended particles is less than 2.5 Micron was significant at the 99% level (Arvin, 20172018). In this research, which was conducted under the title of investigating heat islands in connection with air pollution in Isfahan City, the researcher believes that one of the causes of creating heat islands is air pollution, therefore, using Landsat 8 images with Subrino's discrete window

algorithm has calculated the surface temperature of the earth and compared the obtained results with the data collected in meteorological stations. The results show that the difference between the temperature of the heat island of urban air and the surrounding temperature of the city is greater at the time of the occurrence of maximum pollution, and it was confirmed that there is a stronger correlation coefficient between these two variables on days with high pollution. (Jamlai and Raeesi, 2015; Khoshnam et al., 2015; Liu et al., 2021) stated that land cover classification obtained from multi-year NDVI performs better than multi-spectral data. An accurate classification based on the time series of plant clusters in seasonal forests allows for the seasonal variation of land cover classes in rainy and dry seasons as well as the transition between seasons.

The most important variables that helped accurately were the red, near-infrared (NIR), and short infrared (SWIR) bands in the multispectral classification of the same dates and the months of the dry season most related to multi-year NDVI classification. (Ebrahimi et al., 2020) This research was conducted to investigate the relationship between land surface temperature and land use changes and its relationship with the vegetation cover index in Arsanjan city, Fars province, in which out of 11 images related to the data Level_1 Landsat satellite was used, which was studied in the period from 2003 to 2018, and the final result was that with the change of land use, the amount of vegetation index decreased from 2003 to 2018 (from 0.25 to 0.18), but the temperature changes increased. (from Co29 to Co49.7) which shows the inverse relationship between these two variables. (Anjomshoa et al., 2021) This study investigated the effect of the existing vegetation in Kerman city in the form of green space, on the temperature of the earth's surface and also identified thermal islands using Landsat images in the Google Earth Engine systemThe temperature measured as the average of two images in the middle months of the seasons for the years 2012, 2015, and 2019 were used using a separate window method. The results obtained from this research prove that the larger the green spaces, the lower the temperature, and the greater the distance from the green space, the temperature will increase so that at a distance of 200 meters from the vegetated areas, the temperature increases by 3 degrees (Niliyeh Borojni & Ahmadi Nadushan, 2019). This research investigated the relationship between urban vegetation and surface temperature using 3 Landsat satellites, TM, ETM, and OLI and LST measurements in Isfahan City in 1985, 2010, and 2016 (USGS, 2013). TerrSet software was used to conduct this research, and the results indicate that the temperature is increasing during the mentioned years. Vegetation has been decreasing, which indicates the inverse relationship between these two variables.Study Areas

The Areas of study are Gorgan and Mashhad cities located in the north and northeast of Iran. The city of Mashhad, the capital of Razavi Khorasan province, with an area of 351 square kilometres, is located at the coordinates of 36°,17′ and 50″ north latitude and 59°,36′ and 24″ longitude in the area of Kashf River and between Binalud and Hezar Masjid mountains. The height of this city is 1050 meters above sea level and its average rainfall from 1345 to 1396 is equal to 22.93 mm. According to the general population and housing census of 2015, the population of this city is 3,001,184 people, which is also known as one of the metropolises of Iran. The city of Gorgan is located in the geographical position of 36°, 50′ and 30″ north latitude and 54°, 26′ and 01″ longitude in the north of the Alborz mountain range and the southeast of the Caspian Sea. The height of this city is 176 meters above sea level and its average rainfall from 1345 to 1396 is 45.01 mm. Among the neighbours of this city, it can mention Kurdkoy in the west, Aqqla in the north, and Shahroud and Semnan in the south. In terms of the political situation, both provinces are next to each other. Figures (1 and 2) shows the map of the geographical location of the Area of study in Iran.

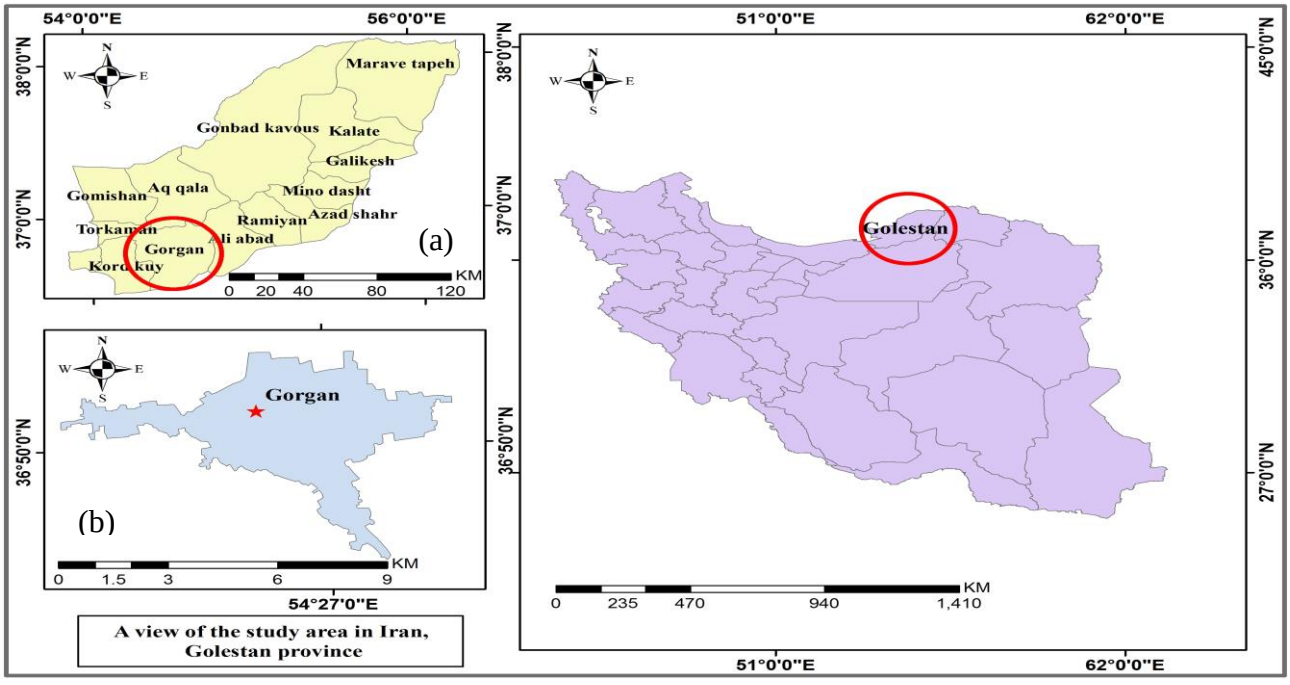


Fig 1: Geographical location of the Area of study in Iran. a) Golestan, b) Gorgan

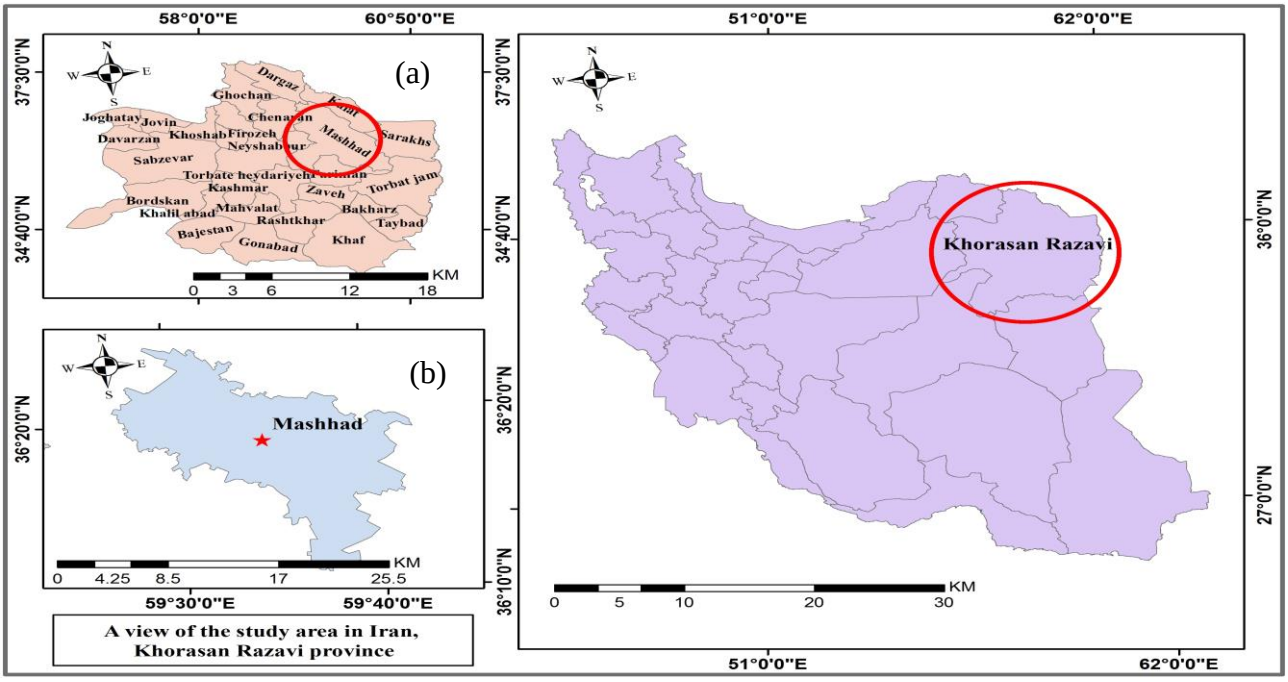


Fig 2: Geographical location of the Area of study in Iran. a) Khorasan Razavi, b) Mashhad

2. Methods

To calculate and compare the surface temperature of the two cities of Mashhad and Gorgan, the range

was determined and selected in the Google Earth Engine system in a specific dimension; The method of selection was done so that the area in question used such as forest cover, agricultural and garden lands, barren lands, mountainous areas, water areas and built-up lands for both cities. Then, the Landsat images from 1/1/2021 to 1/1/2022 were coded as variables, and variables such as NDVI, BT, and EM were defined and coded to calculate the temperature of the earth's surface. In the following, more details of the LST algorithm are provided.

In the following relation, there is a variable called BT, which is explained.

$$Ts = \frac{BT}{\left\{1 + \left[\frac{\lambda . BT}{\rho}\right] Ln\epsilon\right\}} \quad (1)$$

$$\rho(h * c/a) = 1.438.10^{-2}$$

Where TS is the temperature of the earth's surface in Kelvin. BT equals brightness temperature, emissivity ϵ, ρ is a numerical constant value and λ is the wavelength. By calling LST, the temperature of the earth's surface will be calculated in Kelvin.

To calculate NDVI, the near-infrared bands and the red band were used, in Landsat 8, these bands are located in bands 5 and 4, respectively. Also, band 10 of this satellite was used to calculate the brightness temperature, and the result obtained to convert Kelvin to degrees Celsius is 273.15. - became. The final result is the average surface temperature map during the year 2021, which can be seen in Figures (4, 5, and 6.) The above-mentioned cases have been done for both the cities of Mashhad and Gorgan.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (2)$$

Where the RED band is 4 and the NIR band is 5 for the Landsat 8 satellite. (Weng et al., 2004; Zha et al., 2003). In this research, to discover the possible relationship between the temperature of the earth's surface and the level of pollution in the Areas of study, 5 variables (So2, No2, HcHo, Co, Aerosol) were investigated, and Sentinel 5P images were used to calculate these pollutants.

3. Results and Discussion

Investigations have shown that the average maximum temperature of the earth's surface in the period from 1/1/2021 to 1/1/2022 in the city of Mashhad was equal to 45 degrees Celsius, which corresponds to barren and mountainous lands without vegetation. The fallow lands are around the city of Mashhad, which is scattered on the west side of the city, where the green color can be seen in Figure 3. It can also be seen that the urban and man-made areas are in the second place of the ranking of the hottest areas scattered in the above-mentioned figure and marked in white and yellow colors, and finally, the coldest areas are related to agricultural and garden lands and sometimes green valleys in the mountains. And green spaces are a city whose average temperature reaches 27 degrees Celsius. It is worth mentioning that the findings show the average temperature of the earth's surface for the city of Gorgan is up to a maximum of 35 degrees and a minimum of 17 degrees. According to the figure below, the highest temperature obtained for the city of Gorgan belongs to the lands in the northwest of the range and the lowest temperature corresponds to the forest areas in the southern half of the

range.

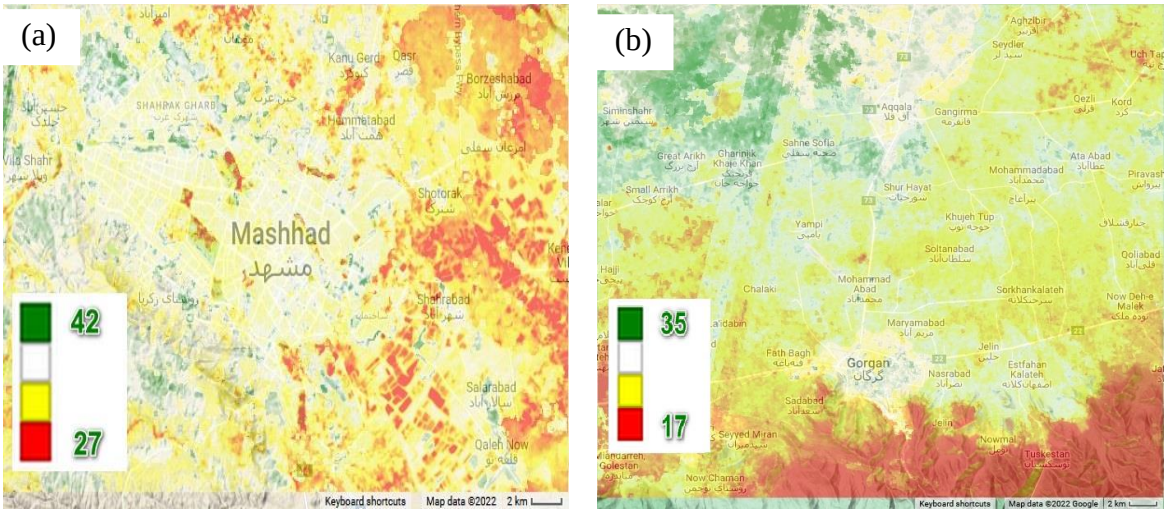


Fig 3: Comparison of the LST map of a) Gorgan and b) Mashhad in Landsat images dated 01-01-2021 to 01-01-2022

In the continuation of the research, the results of the NDVI vegetation cover index have been investigated. What is clear is the significant difference in the amount of this index in the two cities of Gorgan and Mashhad, so the highest amount of this index for the city of Gorgan is 0.76; Areas with this amount of vegetation can be identified as green spots in the area, which are the forests of the northern slopes of the Alborz mountain range, while the highest index for Mashhad city is 0.43 and the location is The capture of these areas can be seen scattered in green in the limits of Mashhad city in Figure 4. Further, the lowest value of this index for the two cities of Mashhad and Gorgan was equal to 0.094 and 0.21, respectively. In Figure 4, the lowest NDVI vegetation index can be seen in red in different areas. Other areas marked in white or yellow show the minimum and maximum temperatures.

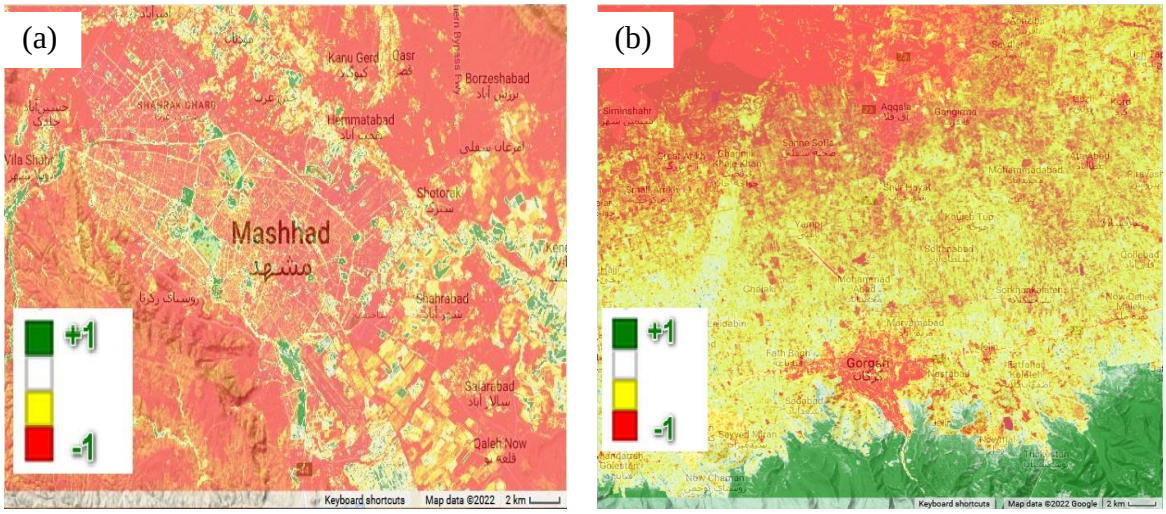


Fig 4: Comparison of NDVI map of a) Gorgan and b) Mashhad in Landsat images dated 01-01-2021 to 01-01-2022

The graphs obtained from the number of changes in the vegetation index can be interpreted in such a way that it has changed according to the Areas of study and its prevailing climate; These changes in the city of Gorgan indicate that the highest level of greenness was recorded in April and the lowest level was recorded in November 2021. which can be seen in Figure 5.

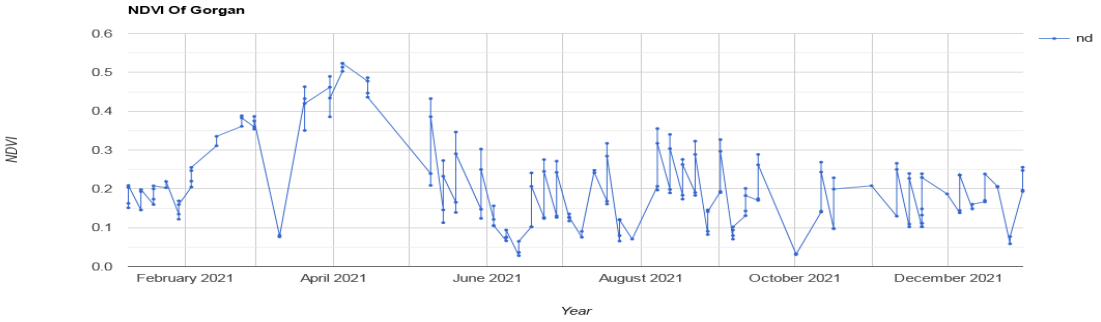


Fig 5: Chart of NDVI values of Gorgan city in Landsat images dated 2021-01-01 to 2022-01-01

The graph obtained from the amount of vegetation index in Mashhad city shows the changes that indicate the change in the amount of this index in the range. The highest amount is related to April and June and the lowest is related to February. The range of these changes is depicted in Figure 6.

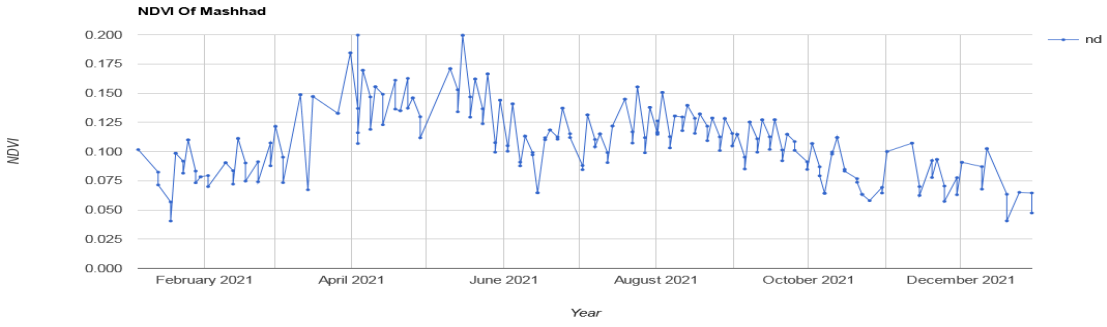
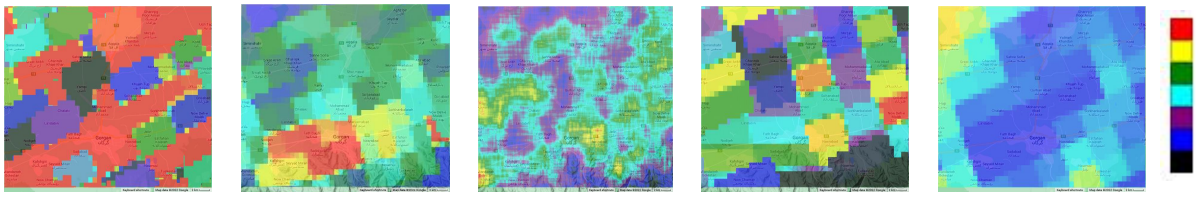


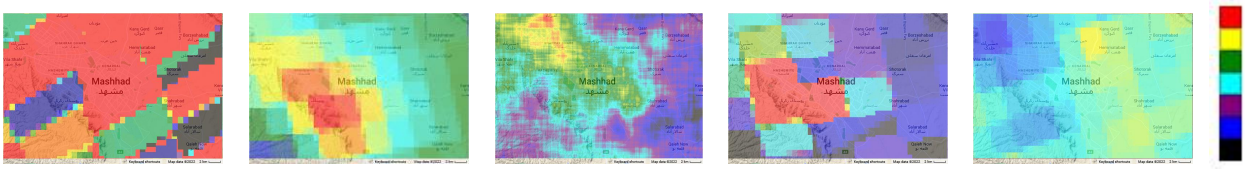
Fig 6: Chart of NDVI values of Mashhad city in Landsat images dated 2021-01-01 to 2022-01-01

After calculating the surface temperature and vegetation index, pollution indices were prepared in the Areas of study using Sentinel 5P images, and 5 indices were examined. According to the map guide in Figures 7 and 8, the lowest amount for each index is shown in the dark, and the highest amount is shown in red. In most of the obtained results, the highest values of each pollutant correspond to the cities and industrial centers in the Areas of study, or they were aligned in the direction of the prevailing wind of that area.



SO_2 NO_2 HCHO CO AEROSOL

Fig 7: Air pollution indicators of Gorgan city in Sentinel 5P images from 2019-01-01 to 2020-01-01



SO_2 NO_2 HCHO CO AEROSOL

Fig 8: Mashhad air pollution indicators in Sentinel 5P images from 2019-01-01 to 2020-01-01

Charts are telling facts in the form of numbers and figures. Here, to increase the accuracy of the work and ensure the obtained results, help is taken from the charts. And for a better understanding, each pollutant index is listed separately and compared between the two areas of Mashhad and Gorgan. In figures number (9-11), the amount of So2 pollutant for the two cities of Mashhad and Gorgan can be seen that the amount of this index in both areas follows a general trend, so that on most days of the year, the amount is between 0 and 0.001, But the range of changes at the beginning of the period is greater in Gorgan compared to Mashhad.

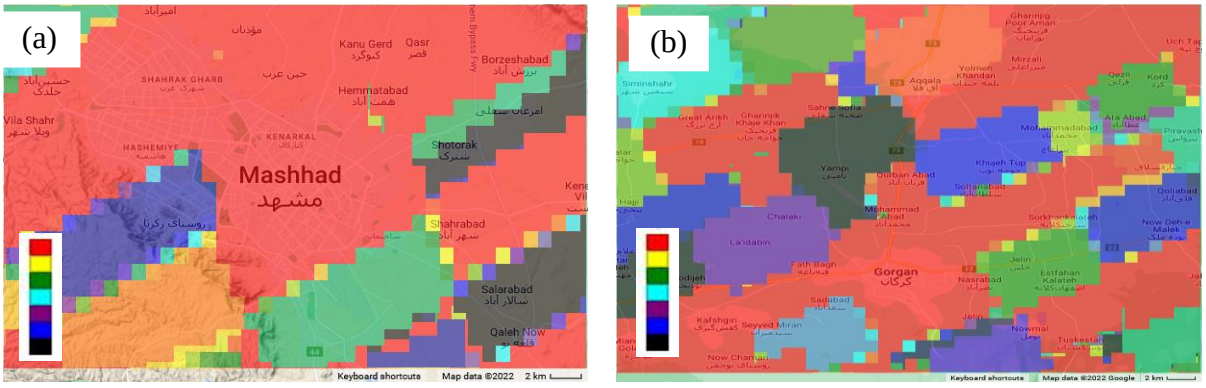


Fig 9: Maps of So2 index of a) Mashhad and b) Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

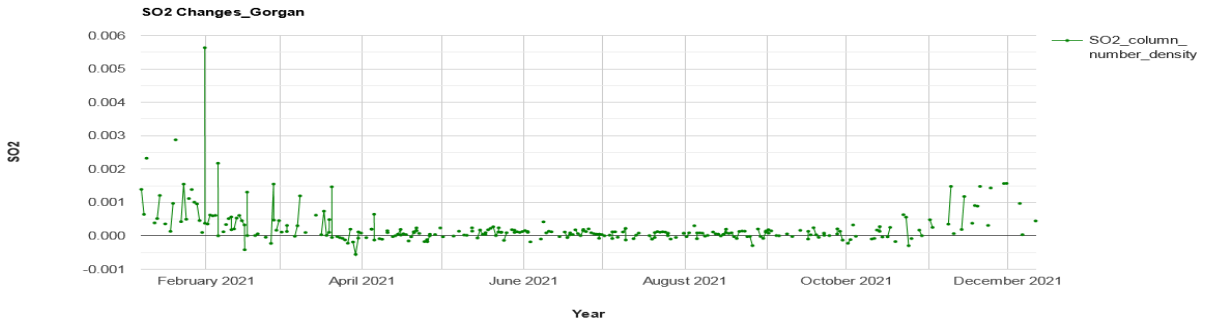


Fig 10: Chart of So2 Index of Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

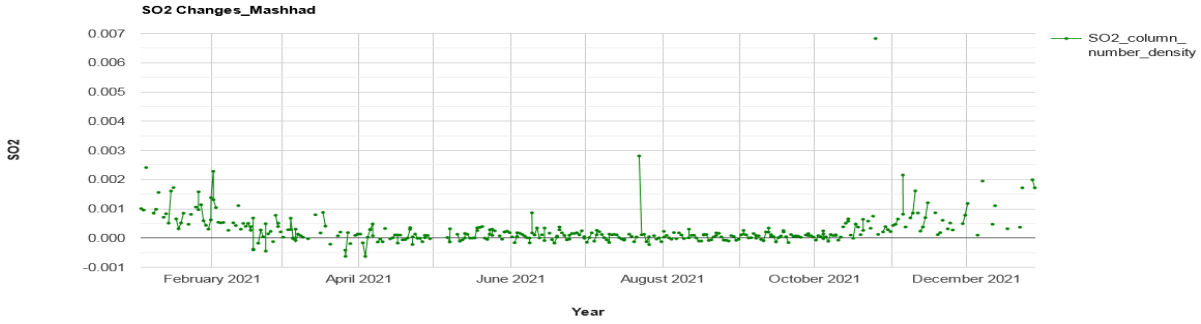


Fig 11: Chart of So2 Index of Mashhad in Sentinel 5P images from 2019-01-01 to 2020-01-01

In Figures number (12-14), the amount of pollutant No2 for the two cities of Mashhad and Gorgan is indicated, and the amount of this index in Mashhad is twice as much as in Gorgan. In Gorgan, this index is between 0 and 0.9, but in Mashhad, the same index is between 0 and 2.2, and the range of changes of this pollutant in both cities is greater in spring and winter than in other seasons.

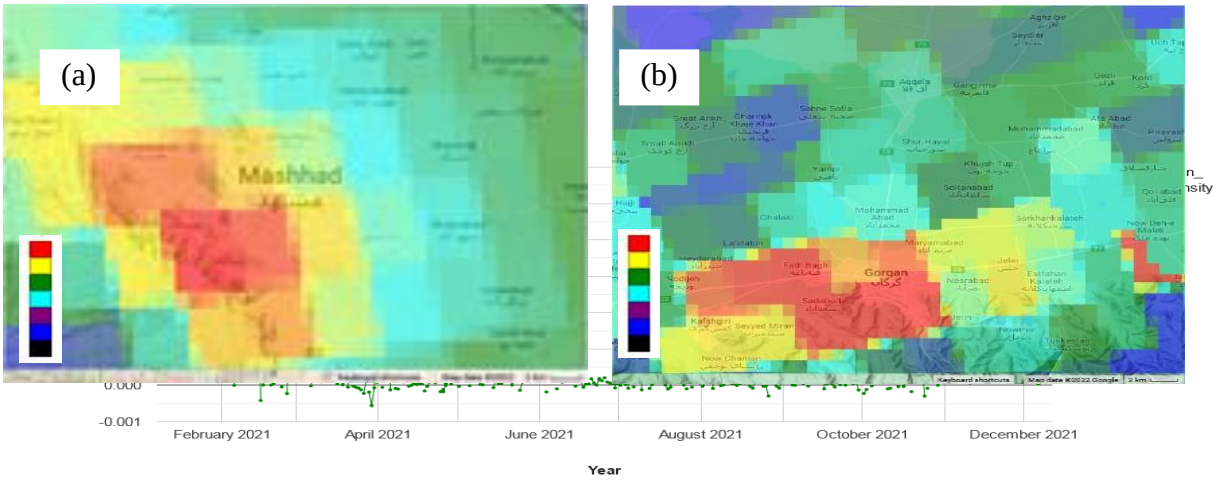


Fig 12: Maps of No2 index of a) Mashhad and b) Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

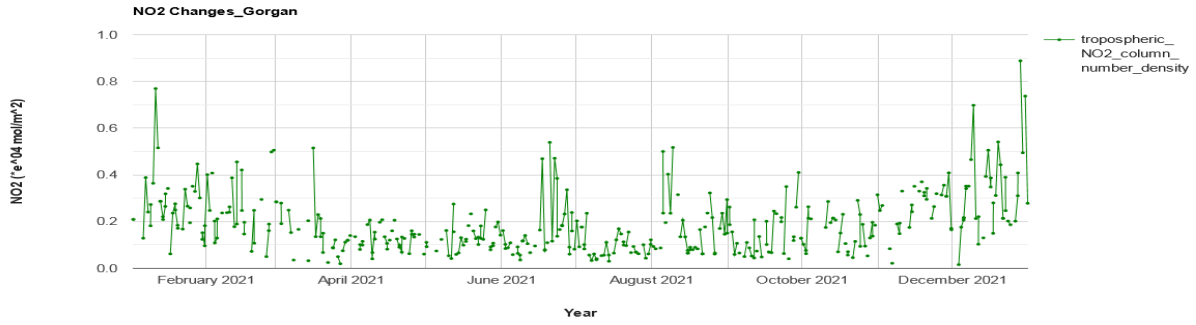


Fig 13: Chart of No2 Index of Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

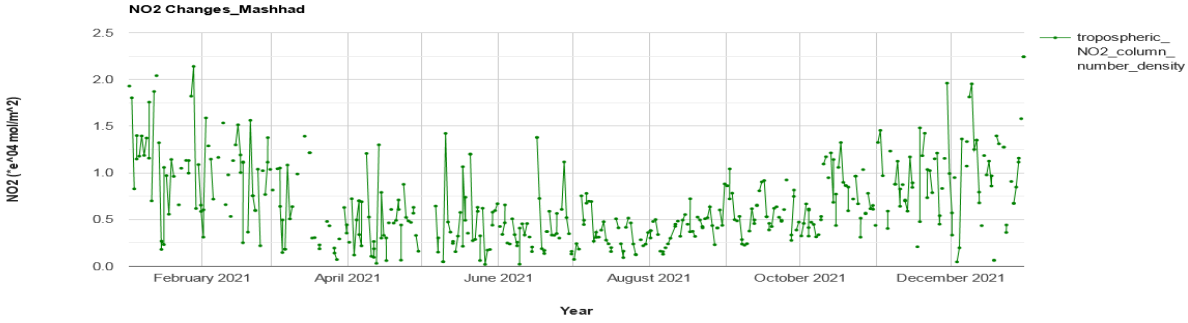


Fig 14: Chart of No2 Index of Mashhad in Sentinel 5P images from 2019-01-01 to 2020-01-01

In figures number (15-17), the amount of HcHo pollutant for the two cities of Mashhad and Gorgan is indicated, and in both study areas, the values of this index are recorded between -0.0004 and 0.0005. The obtained values show that there is a range of changes throughout the year, but the highest and lowest amount of this air pollutant was recorded for the city of Gorgan.

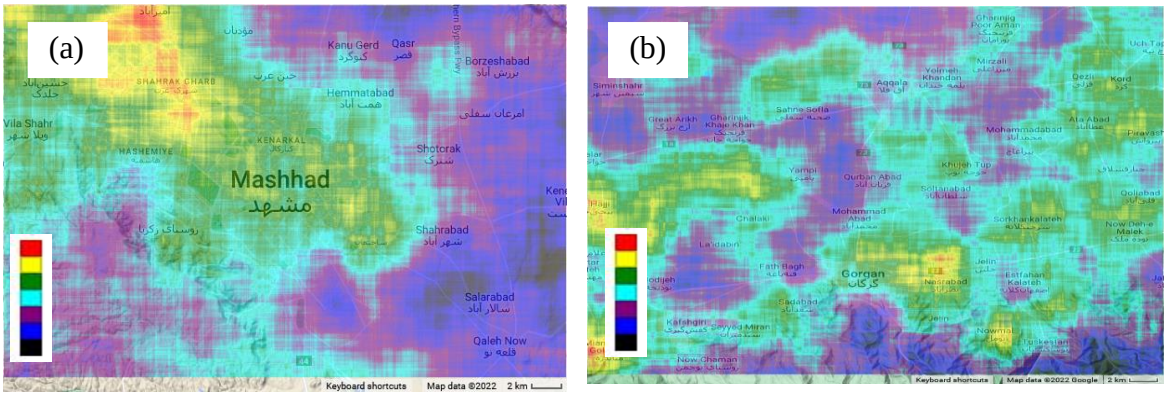


Fig15: Maps of HcHo index of a) Mashhad and b) Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

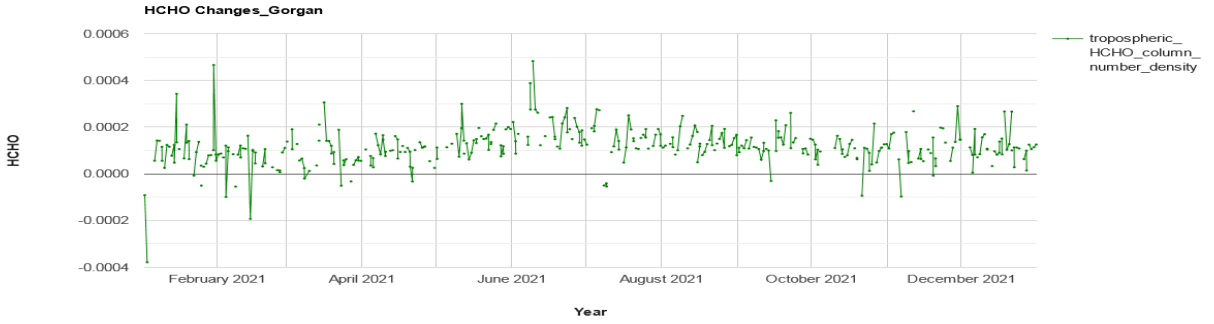


Fig 16: Chart of HcHo Index of Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

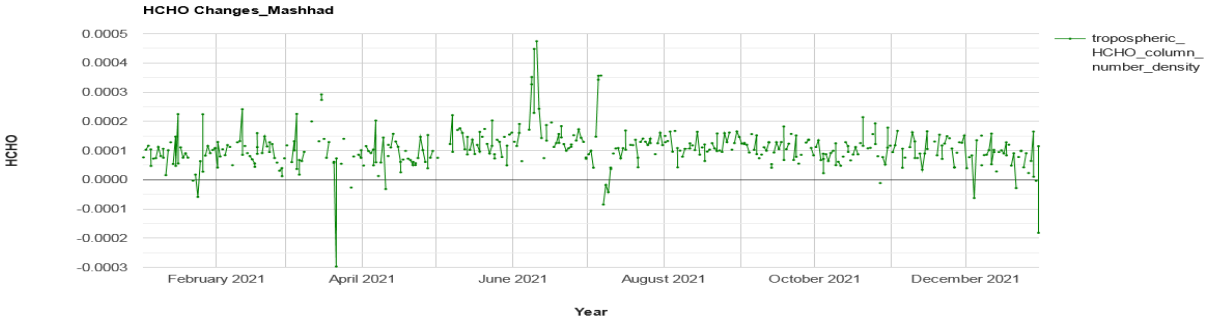


Fig 17: Chart of HcHo Index of Mashhad in Sentinel 5P images from 2019-01-01 to 2020-01-01

In Figure number (18-20), the amount of Co pollutant for the two cities of Mashhad and Gorgan is mentioned, and this index follows the general trend throughout the year, just like indices such as HcHo and So2. But the range of recorded changes is different from the mentioned indicators. These changes are more noticeable in the city of Mashhad, but the highest and the lowest amount of this pollutant, which is equal to 0.02 and 0.05 respectively, were recorded in the city of Gorgan. The noteworthy point is that the amount of this pollutant in both cities has reached its highest level in autumn.

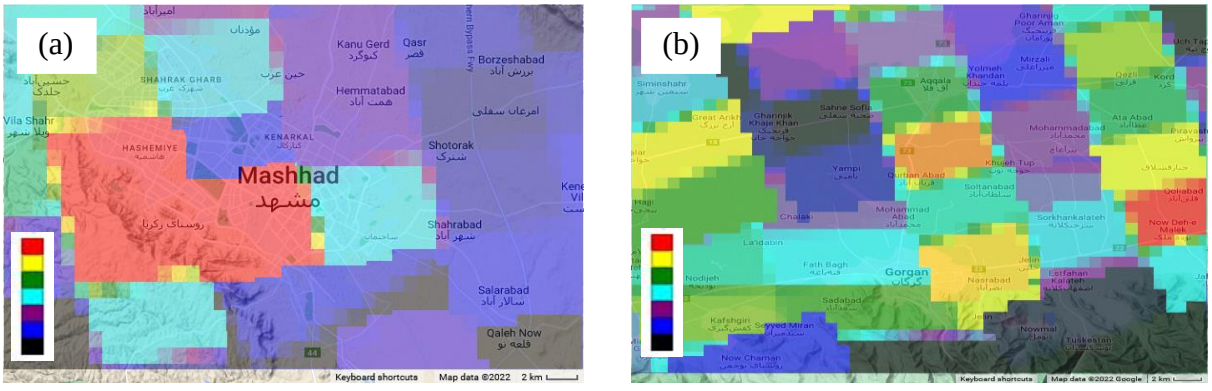


Fig18: Maps of Co index of a) Mashhad and b) Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

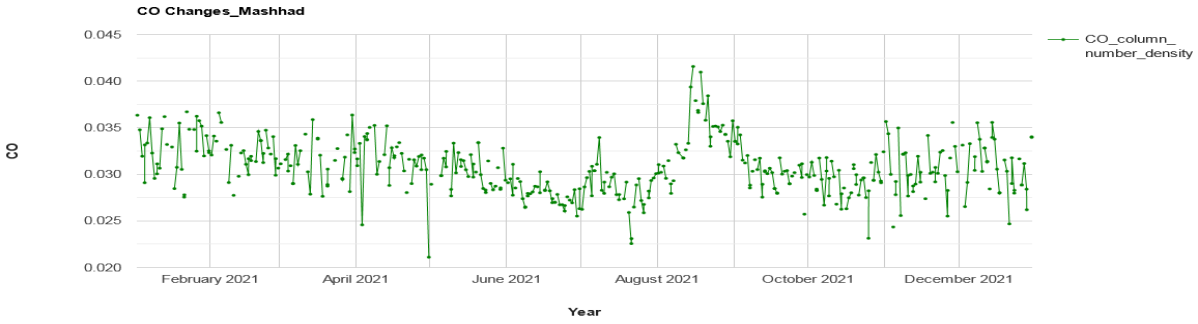


Fig 19: Chart of Co Index of Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

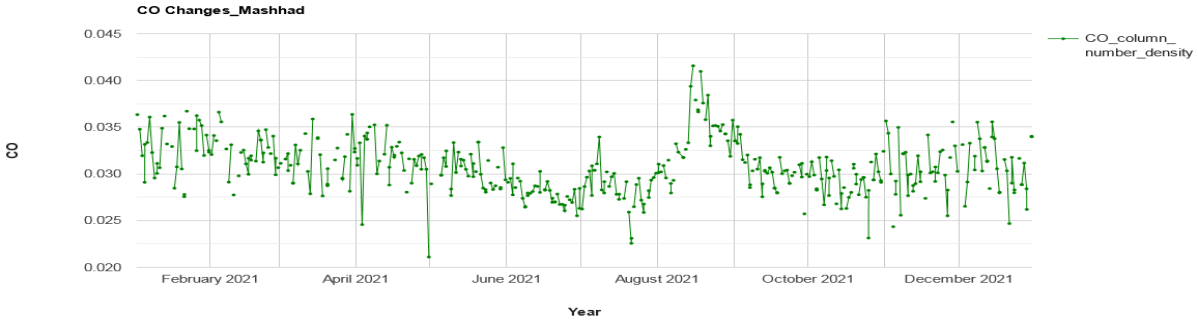


Fig 20: Chart of Co Index of Mashhad in Sentinel 5P images from 2019-01-01 to 2020-01-01

In Figure number (21-23), the number of aerosol pollutants is given for the two limits under study. This index can be divided into two general parts based on the values recorded in the chart according to the season because its trend changes accordingly. Based on what is visible in the diagram, the range of changes in both cities is accompanied by many changes. The highest and lowest value of this index is between -2.5 and 2. The lowest value is recorded in Gorgan and the highest value is in Mashhad.

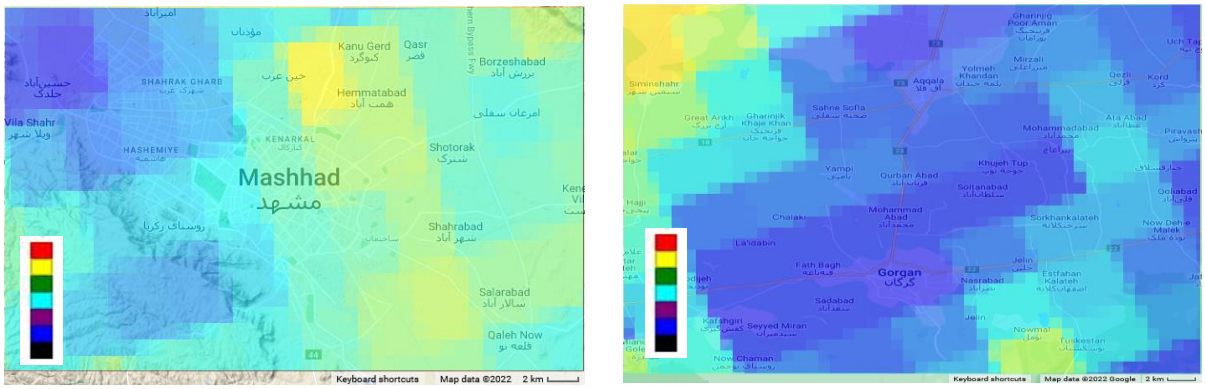


Fig 21: Maps of Co index of a) Mashhad and b) Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

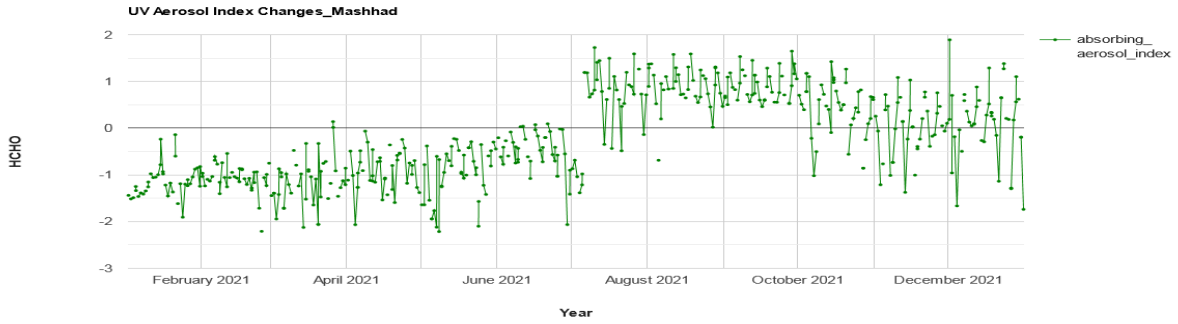


Fig 22: Chart of Co Index of Gorgan in Sentinel 5P images from 2019-01-01 to 2020-01-01

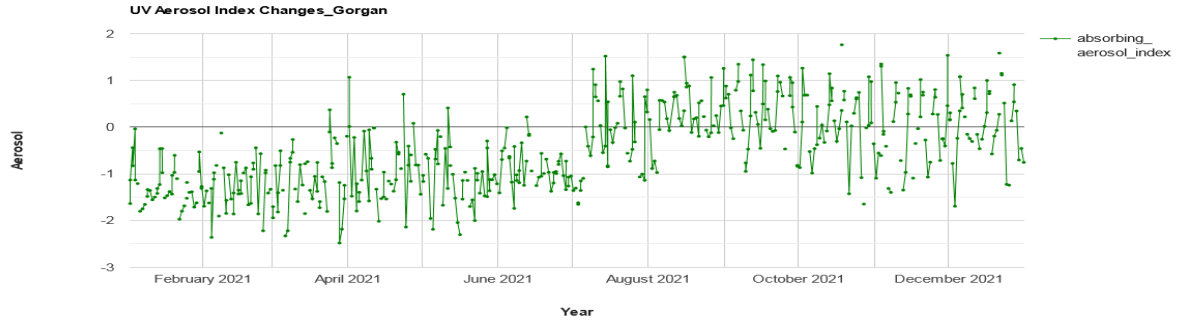


Fig 23: Chart of Co Index of Mashhad in Sentinel 5P images from 2019-01-01 to 2020-01-01

As mentioned, the comparison of the two variables of land surface temperature and vegetation cover index for the area of Mashhad city showed an inverse relationship; The city of Gorgan also followed this relationship and the areas with high average temperature correspond to barren lands with a vegetation cover index of 0.21 and forest cover with the lowest average temperature with a vegetation cover index of 0.76. It should be noted that according to the range obtained from the vegetation index, the blue zone has not been registered in this area. From the comparison of the produced maps, it can be concluded that the average temperature of the ground surface in Mashhad city is higher than in Gorgan city, and subsequently, this value is inverse for the vegetation cover index, and the value of this index in Gorgan city is significantly higher than in Mashhad city. and the reason for that is the presence of forest cover and high-quality agricultural lands in the city of Gorgan.

The results of various studies using different methods and software are consistent with this study (Jie et al., 2021; Ghane Ezabadia et al., 2021; Soltani & Mohammadnejad, 2021; Ebrahimi et al., 2020; Anjam al-Shaaa, Maruti, Anjomshoa, et al., 2021; Niliyeh Borojni & Ahmadi Nadushan, 2019). Therefore, the temperature of the earth's surface varies according to the percentage of vegetation, and the higher its value, the lower the temperature of the earth's surface (Areffian et al., 2020; Panda & Jain, 2017; Sun & Kafatos, 2007; Yuan & Beaver, 2007).

4. Conclusion

By comparing the average temperature of the earth's surface and the NDVI vegetation index, it can be concluded that the relationship between these two variables is inverse because the places with

higher average temperatures also have less vegetation so the value of the NDVI index in these areas is reached 0.094, this amount indicates the soil, on the other hand, the areas with lower average temperature have more vegetation, so the NDVI index in these areas reaches 0.43, which indicates green space.

It is interesting to note that In the studied area (Mashhad) the blue zone is registered. Also, the conclusion of the research shows that the average temperature of the ground surface in Gorgan city is lower than that of Mashhad city so the maximum average temperature of the ground surface in this area reaches a maximum of 35 degrees Celsius, which is higher than the maximum average temperature of the ground surface in the area of Mashhad city. 7 degrees Celsius is lower, this temperature is shown in green in the northwest of the specified range; In the second rank of this temperature classification are urban and man-made areas, which are displayed in white and yellow colors, and in the last rank is the average lowest temperature of the earth's surface, which is classified in red color and with an average temperature of 17 degrees Celsius in figure no 3 is visible.

Now that the relationship between the temperature of the earth's surface and the vegetation index has been determined, the next step is to discuss the relationship between the temperature of the earth's surface and the amount of pollution. The So2 index follows a general trend in both Areas of study and its level is higher in winter than in other seasons. Index No. 2 has intermittent changes throughout the year, but overall its amount is higher in winter. Another index that has been studied is the Co index; This index was at its highest level in December and the highest value was recorded in Mashhad. Another index studied in this research is the HcHo index; This index also goes through a constant trend, which is in the range of 0 to 0.0002.

And finally, the Aerosol index is the last of the investigated indices, which follows a similar trend in both areas, so that in the first 6 months of the year, its value is less than 0, and in the second 6 months of the year, its value is more than 0. according to the researches of (Hadipour et al., 2020) and (Arvin, 2018) which investigated the relationship between pollution and the temperature of the earth's surface; It can be said that the obtained results are also consistent with the research of these two researchers and the results of this research have confirmed the existence of a relationship between these two variables. What can be inferred from this research is that remote sensing technology is very efficient in detecting changes during different periods, and if complete data and multi-time images are available, useful results can be reached, which in combination with intelligent algorithms can provide solutions. Presented to predict and prevent issues. Using this fan reduces costs and saves time and money.

The correspondence of past studies and the obtained results and graphs confirm that with the change of land use and climate changes; It will face the reduction of vegetation and the subsequent increase in the temperature of the earth's surface. Based on this, the following suggestions are presented.

· Using satellite images with high spatial resolution such as SPOT and IRS to achieve more accurate results

· Using forecasting models to predict changes in the coming years

- Continuous monitoring of temperature changes and using them for management

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Code availability (Yes, in GEE https://code.earthengine.google.com/68b0e8eb9927722806977d1818bdd6f7)
Code availability (Yes, in GEE https://code.earthengine.google.com/306078139ab6172c0cd16a29fa937730)

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