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Research Article

Comparison of development trends of Tehran and Isfahan cities and its effects on vegetation, climate and air pollution using GEE, Giovanni

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ABSTRACT

Background and objective: Population growth and industrialization of cities have led to the rapid growth of urbanization and development of cities. Today, the evaluation of urban physical development using modern remote sensing techniques can provide basic information to planners. The purpose of this study is to investigate the trend of urban development and its effects on changes in vegetation, temperature, rainfall, and air pollution in the two metropolises of Tehran and Isfahan.
Materials and methods: In this study, two systems (Google Earth Engine) GEE and Giovanni have been used to analyze indicators such as temperature, vegetation, humidity, and precipitation. NDVI maps and diagrams of two cities in 5- and 10-year periods produced from MODIS satellite (2000 to 2021) and Landsat 8 (2013 to 2021).
Results and conclusion: Urban development and population growth in Tehran have led to an increase in heat islands (LST) and temperature in the region, which has a direct effect on the reduction of snow and rain and, as a result, the reduction of runoff, vegetation, and soil moisture. Due to the development of industrial towns and residential constructions around Isfahan, destructive environmental effects related to vegetation, weather, and pollution in Mashhad, and the increase in urbanization and industry have led to a decrease in the level of vegetation and NDVI in this area. This conclusion was obtained that the obtained results confirm that the development of the cities of Tehran and Isfahan has destructive environmental effects on the weather and vegetation in all directions.

1. Introduction

Urban development is the result of physical and human effects over time, which in the prevailing urban life and its rapid growth, especially in an uneven way in developing societies and the need for sustainable planning, has faced significant challenges today (Bibri et al., 2020; He et al., 2021). Rapid population growth and increased human economic activity lead to unsustainable resource utilization and rapid depletion of land natural reserves, and the study of land use change and land use helps to analyze the various environmental and development implications over time (Mittal & Mittal, 2013; Jamali et al., 2021).

Urban development is a type of land cover change that has a great impact on the environment. In the process of urbanization, natural vegetation cover is largely replaced by impervious surfaces such as

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buildings, roads, parking lots, sidewalks, factories, industrial estates, and other built surfaces (Schueler, 1994; Arnold & Gibbons, 1996; Bowles, 2002; Ghorbani Kalkhajeh and Jamali, 2019)

Urbanization has an important impact on the environment. Considering that cities cover small parts of the world, urban areas with more than 50% of the world's population and 7-90% of economic activity are the circle of human activities (Schneider et al., 2009). Urbanization threatens biodiversity and changes climatic systems, and affects ecosystem productivity by disturbing energy balance and habitats and the loss of carbon storage and biomass (Cui et al., 2012).

Land surface and urbanization cause a modified climate that is warmer than surrounding and non-urban areas. In addition to land cover, urban change also affects urban climate change, Land surface and Climate due to urbanization cause a modified climate that is warmer than the surrounding, non-urbanized areas (Thi Van & Duong Xuan Bao, 2010). While the urbanization process has important consequences for demographic change and physical transformation, unsystematic and rapid urbanization can have profound effects on various environmental components, especially land and water. Therefore, understanding the change in urban-induced land cover change is essential to counteract environmental change and facilitate sustainability. This is because most of the world's urban areas have undergone significant land cover changes over the years. In addition, these urban areas consume more global energy and cause serious environmental problems and the destruction of ecosystems through air, water, and land pollution (Yan et al., 2016; Battista & de Lieto Vollaro, 2017).

Many studies have used satellite imagery and various systems to study urban development and changes in land cover and temperature. Alberti et al. (2003), Andersson (2006), Lundholm and Richardson (2010) Have shown that human activities significantly affect the urban environment.

Gui et al. (2019) showed the urbanization process and its impact on vegetation change and urban heat islands in Wuhan, China. their results showed that rapid urbanization significantly alters vegetation and heat distribution, threatening sustainable development and quality of life. The study Sensitivity of multi-temporal NOAA AVHRR data of an urbanizing region to land-use / land-cover changes has concluded that more attention is needed to monitor land use change and land cover in a city (Stow & Chen, 2002). In addition, in the study Urbanization and its environmental effects in Shanghai, China, it was found that some climatic parameters change after vegetation replacement with urban habitat (Cui & Shi, 2012; Voogt & Oke, 2003; Zhao et al., 2006; Kometa & Akoh, 2012). Research on the role of urban land in climate change has shown that the conversion of natural lands, agriculture, and other sparsely populated areas into urban settlements has changed the Climate of the area (Rosenzweig et al., 2011).

In such circumstances, access to accurate maps with knowledge of the physical expansion of cities and their changes over time is one of the most important issues in urban planning and management today to successfully plan and efficiently implement programs, managers and decision-makers need information. Timely and accurate dimensions of urban development and changes under their influence can extract this information from satellite imagery, which are two widely used tools for extracting information from satellite imagery, the Google Earth Engine System (GEE) and the Giovanni system. The purpose of this research is to compare the two cities of Tehran and Isfahan in terms of urban development and its effect on changes in vegetation, temperature, climate, and air pollution in twenty years. The data is extracted from satellite image data from 2000 to 2021.

2. Materials and methods

2.1. Study area

In the present study, the cities of Tehran and Isfahan were evaluated. The city of Tehran is located at 51.25 degrees longitude and 35.43 degrees latitude and the average altitude of this city is 1100 degrees above sea level and the city of Isfahan is 51.61 degrees longitude and latitude. It is located at 32,638 degrees, which is 1575 meters above sea level (Fig. 1).

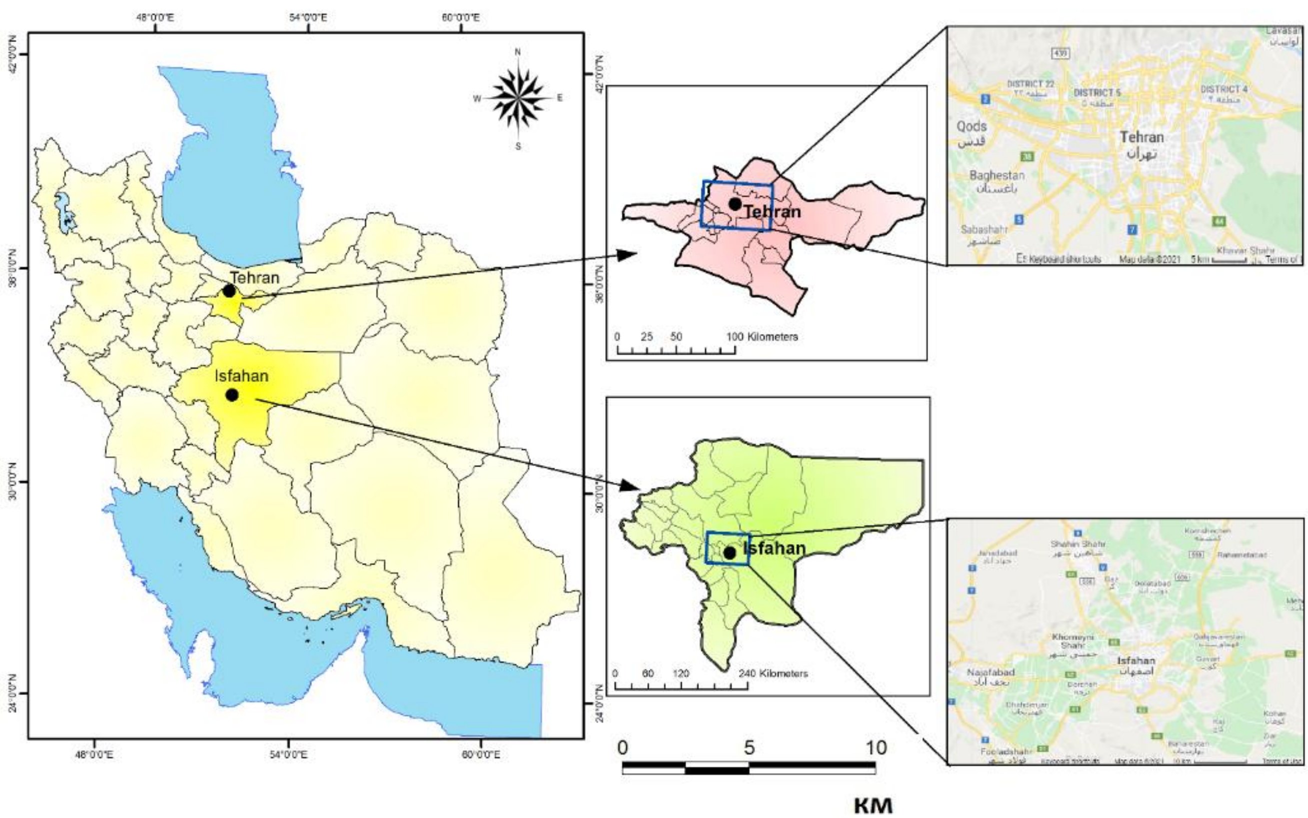


Fig.1- study area

2.2. Methodology

In the present study, satellite data provided by GEE and the Giovanni system have been used. The data do not require preprocessing and modification (geometric, radiometric, etc.) and are easily accessible.

The Google Earth Engine (GEE) system is a web-based, cloud-based system developed by Google to store and analyze large volumes of data in comparison to petabytes (including various satellite imagery, digital elevation models, data Climate and Vector Data) and enables the classification of and processing of high-speed satellite imagery that can be used in land use monitoring and mapping. Free and online to its database (Ghane Ezabadi et al., 2021).

Giovanni is a web-based application developed by Goddard Earth Science Data and Information Services (GES DISC) that provides a simple way to visualize, analyze, and access large volumes of remote sensing data without having to download data. Giovanni stands for Online Geographic Interactive Visualization Infrastructure.

GHSL images from 1975 to 2014 were used to map urban development. GHSL designs and implements new spatial data mining technologies that enable automated processing, analysis, and extraction of knowledge from large amounts of heterogeneous data, including large-scale satellite video data streams, census data, and demographic or voluntary geographic resources. he does. The data sources of this data contain a multidimensional data layer derived from Landsat image collections

(GLS1975, GLS1990, GLS2000, and the ad-hoc Landsat 8 2013/2014 collection) and data using the Global Human Residence Layer method Produced in 2015.

The Iowa Environmental Mesonet (IEM) site was used to calculate wind roses. This system generates a wind rose for a while. Wind roses can quickly show the direction of the prevailing wind.

MODIS images with a resolution of 250 meters have been used to investigate vegetation changes and calculate the NDVI index for different periods from 2000 to 2021. The MOD13Q1 V6 product provides a Vegetation Index (VI) value on a per-pixel basis. There are two primary vegetation layers. The first is the Normalized Difference Vegetation Index (NDVI) which quantifies vegetation and specifies the amount of vegetation in the range of -1 to 1. The second vegetation layer is the Enhanced Vegetation Index (EVI) which minimizes canopy background variations and maintains sensitivity over dense vegetation conditions.

Also, the MOD13C2 v006 satellite images of the Giovanni system have been used to prepare the NDVI index diagrams of the two cities.

The mathematical formula for NDVI is: NDVI = (NIR - VIS)/(NIR + VIS), where NIR is near-infrared radiation and VIS is visible wavelength radiation. To compare the NDVI values of the two cities, we use Sentinel-2 images.

NASA images have been used to calculate monthly precipitation. Global Precipitation Measure (GPM) reports every three hours the data related to the amount of rainfall in the coming years around the world. NASA satellite STRM images were used to calculate Dew point, DEM, And Hill shade. The Shuttle Radar Topography Mission digital elevation data is an international research effort that obtained digital elevation models on a near-global scale. This NASA product is SRTM V3 with a resolution of 30 meters.

ERA5-Land images were used to calculate Runoff AND Snow Depth. ERA5-Land is superior to ERA5 for analyzing land variables for a long period with better quality. ERA5-Land is produced by recasting the land component of the ECMWF ERA5 climate reanalysis. The reanalysis data is old, which provides accurate information on past climate conditions.

ERA5 images were used to calculate the temperature. ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. ERA5 data is available from 1979 to three months in real-time. ERA5 MONTHLY provides aggregated values for each month for seven ERA5 climate reanalysis parameters: 2m air temperature, 2m Dew point temperature, total precipitation, mean sea level pressure, surface pressure, 10m u-component of wind, and 10m v-component of wind (Jamali et al., 2018).

Giovanni system has been used to calculate air pollution. The number of NO2 molecules in an atmospheric column (from the Earth's surface to the top of the atmosphere) above one square centimeter of the surface. NO2 data are used in L2G Giovanni when their cloud cover is less than 30%.

Landsat 8 satellite images were used to calculate the land surface temperature. Satellite images from Landsat 8 OLI/TIRS sensors are atmospherically corrected, covering the visible, near-infrared (VNIR), and thermal bands.

Sentinel-2 satellite imagery was used to map the three indices NDBI, MSAVI, and NDMI. Sentinel-2 images are widely used in the analysis of environmental changes, including water, soil, and vegetation, and it also has the ability to detect land cover changes and environmental pollution.

2.3. Tehran City:

The development process of Tehran metropolis, like most metropolises of the developing world, has had a rapid and wide physical expansion. The expansion of Tehran in different directions was not the same in terms of quantity and quality, and the movement towards external development took place in Tehran, and the north, south, east, and west of Tehran met the needs of development.

As you can see in Fig. 2 (a), the development of constructions in Tehran from 2000 to 2014 has taken place in the western, eastern, southern, and a little in the northern part of Tehran.

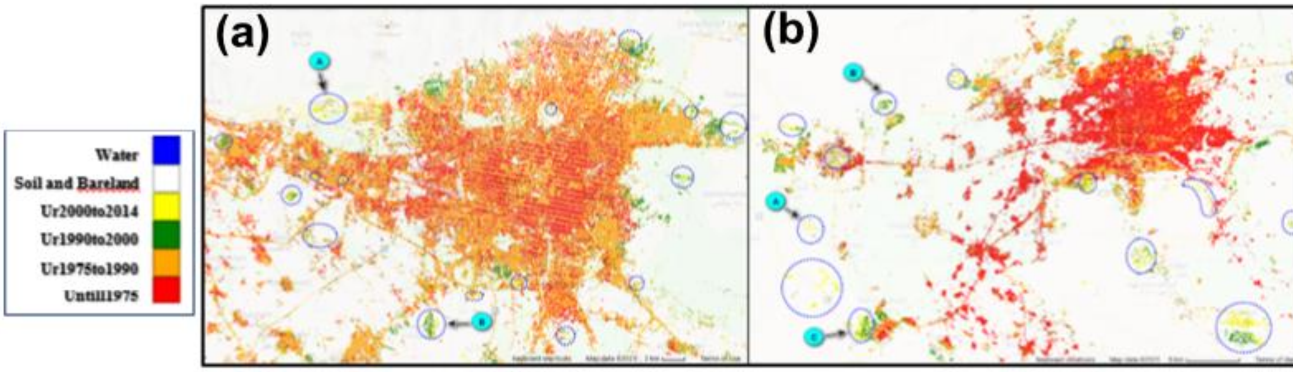


Fig.2 - (a): Urban development map of Tehran (b): Urban development map of ISFAHAN

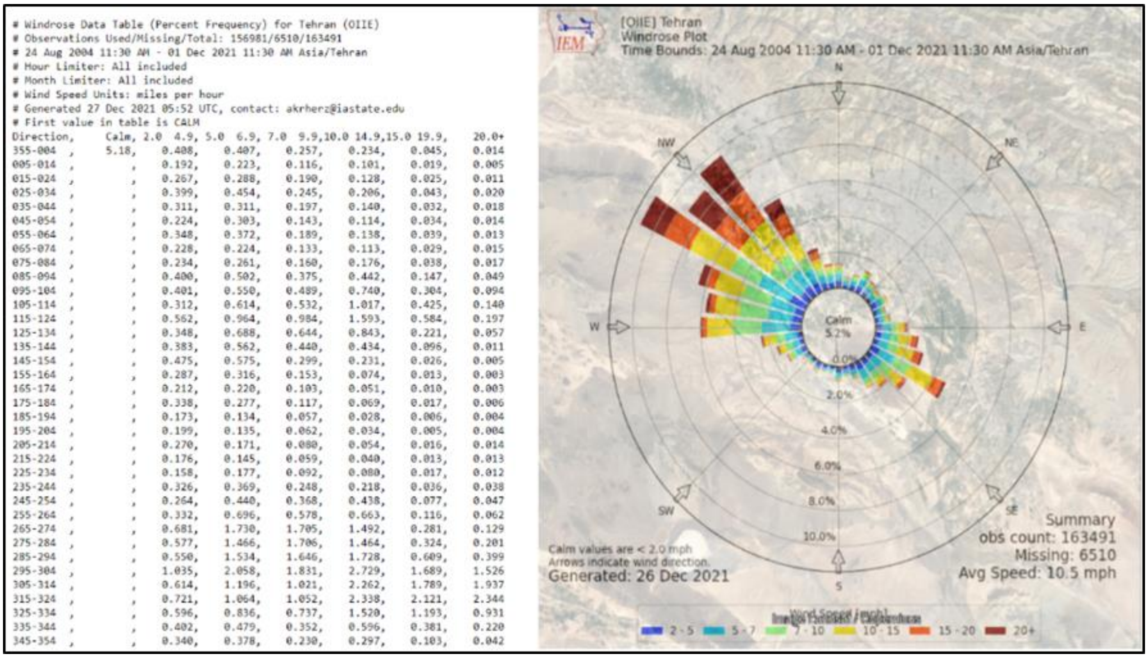
2.3.1. The impact of creating industry and tourism on urban development

In this section, we examine the impact of Chitgar Lake and Chahardangeh Industrial Town on urban development:

A. Chitgarh Lake

Chitgar Lake or Martyrs Lake of the Persian Gulf is an artificial lake located in the northwest of Tehran and the 22nd district of Tehran Municipality. The area of this lake is 130 hectares and in the vicinity of it, 120 hectares of the recreational complex has been created in the land area. The construction of this lake has had a significant impact on the environmental and climatic conditions of the region and urban and economic development in the region.

Due to the location of the lake and the direction of the prevailing wind in Tehran, which is according to the plan of Windrose (northwest-southeast), the role of Chitgar Lake in softening the air and raising the humidity of Tehran, especially in its western region, is important. (Fig. 3).



```
# Windrose Data Table (Percent Frequency) for Tehran (OIIE)
# Observations Used/Missing/Total: 156981/6510/163491
# 24 Aug 2004 11:30 AM - 01 Dec 2021 11:30 AM Asia/Tehran
# Hour Limiter: All included
# Month Limiter: All included
# Wind Speed Units: miles per hour
# Generated 27 Dec 2021 05:52 UTC, contact: akrherz@iastate.edu
# First value in table is CALM
```

Direction,	Calm,	2.0 4.9,	5.0 6.9,	7.0 9.9,	10.0 14.9,	15.0 19.9,	20.0+
355-004 ,	5.18,	0.408,	0.407,	0.257,	0.234,	0.045,	0.014
005-014 ,	,	0.192,	0.223,	0.116,	0.101,	0.019,	0.005
015-024 ,	,	0.267,	0.288,	0.190,	0.128,	0.025,	0.011
025-034 ,	,	0.399,	0.454,	0.245,	0.206,	0.043,	0.020
035-044 ,	,	0.311,	0.311,	0.197,	0.140,	0.032,	0.018
045-054 ,	,	0.224,	0.303,	0.143,	0.114,	0.034,	0.014
055-064 ,	,	0.348,	0.372,	0.189,	0.138,	0.039,	0.013
065-074 ,	,	0.228,	0.224,	0.133,	0.113,	0.029,	0.015
075-084 ,	,	0.234,	0.261,	0.160,	0.176,	0.038,	0.017
085-094 ,	,	0.400,	0.502,	0.375,	0.442,	0.147,	0.049
095-104 ,	,	0.401,	0.550,	0.489,	0.740,	0.304,	0.094
105-114 ,	,	0.312,	0.614,	0.532,	1.017,	0.425,	0.140
115-124 ,	,	0.562,	0.964,	0.984,	1.593,	0.584,	0.197
125-134 ,	,	0.348,	0.688,	0.644,	0.843,	0.221,	0.057
135-144 ,	,	0.383,	0.562,	0.440,	0.434,	0.096,	0.011
145-154 ,	,	0.475,	0.575,	0.299,	0.231,	0.026,	0.005
155-164 ,	,	0.287,	0.316,	0.153,	0.074,	0.013,	0.003
165-174 ,	,	0.212,	0.220,	0.103,	0.051,	0.010,	0.003
175-184 ,	,	0.338,	0.277,	0.117,	0.069,	0.017,	0.006
185-194 ,	,	0.173,	0.134,	0.057,	0.028,	0.006,	0.004
195-204 ,	,	0.199,	0.135,	0.062,	0.034,	0.005,	0.004
205-214 ,	,	0.270,	0.171,	0.080,	0.054,	0.016,	0.014
215-224 ,	,	0.176,	0.145,	0.059,	0.040,	0.013,	0.013
225-234 ,	,	0.158,	0.177,	0.092,	0.080,	0.017,	0.012
235-244 ,	,	0.326,	0.369,	0.248,	0.218,	0.036,	0.038
245-254 ,	,	0.264,	0.440,	0.368,	0.438,	0.077,	0.047
255-264 ,	,	0.332,	0.696,	0.578,	0.663,	0.116,	0.062
265-274 ,	,	0.681,	1.730,	1.705,	1.492,	0.281,	0.129
275-284 ,	,	0.577,	1.466,	1.706,	1.464,	0.324,	0.201
285-294 ,	,	0.550,	1.534,	1.646,	1.728,	0.609,	0.399
295-304 ,	,	1.035,	2.058,	1.831,	2.729,	1.689,	1.526
305-314 ,	,	0.614,	1.196,	1.021,	2.262,	1.789,	1.937
315-324 ,	,	0.721,	1.064,	1.052,	2.338,	2.121,	2.344
325-334 ,	,	0.596,	0.836,	0.737,	1.520,	1.193,	0.931
335-344 ,	,	0.402,	0.479,	0.352,	0.596,	0.381,	0.220
345-354 ,	,	0.340,	0.378,	0.230,	0.297,	0.103,	0.042

Fig. 3 - Map of Windrose, Tehran

B. Chahar Dangeh industrial town

Chahardangeh is a city with a population of about 50,000 in the southwest of Tehran. The existence of an industrial town near this city has caused urban and economic growth in the region and therefore has made this city one of the poles of Tehran province in terms of production.

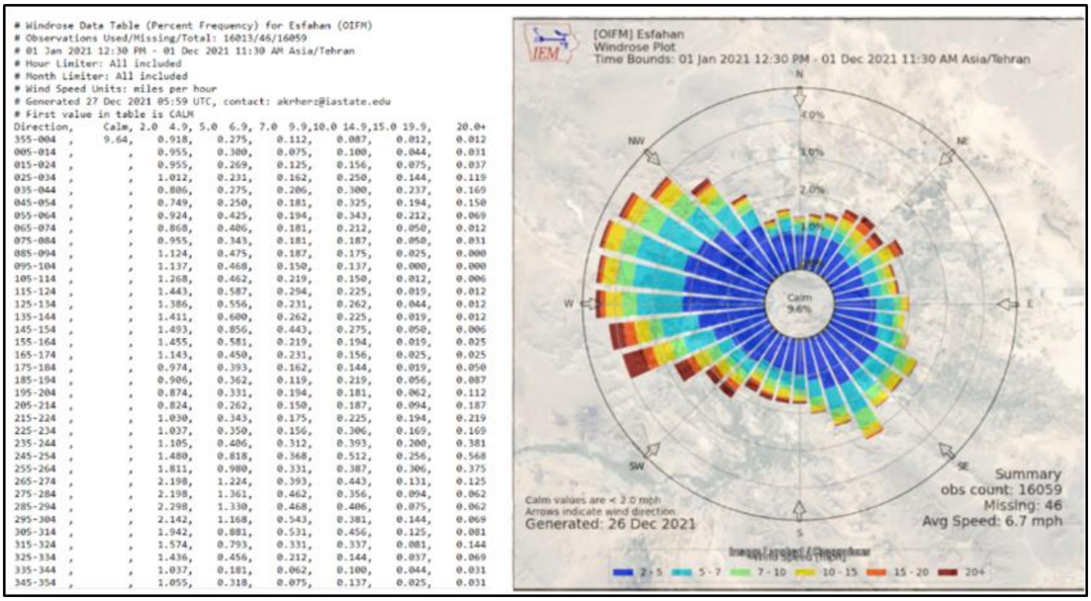
2.4. Isfahan City:

The city of Isfahan in recent years compared to other major cities in the country has grown rapidly and unbridled, and due to population growth, migration, and expansion of services, has had significant social, economic, and physical changes.

This is seen in the form of scattered urban growth and excitement with the integration of cities and villages and agricultural lands around the city.

Fig. 2 (b) shows urban development and construction in Isfahan the most urban development has been in the western, southwestern, and southeastern parts, the main reason being steel factories and industrial towns.

Due to the prevailing wind direction of Isfahan, which according to Windrose map is from the west and southwest, the location of industrial towns and steel plant is not a suitable place and therefore the west wind blows all the pollution of these industries into the city (Fig. 4).



Windrose Data Table (Percent Frequency) for Esfahan (OIFM)
Observations Used/Missing/Total: 16013/46/16059
01 Jan 2021 12:30 PM - 01 Dec 2021 11:30 AM Asia/Tehran
Hour Limiter: All included
Month Limiter: All included
Wind Speed Units: miles per hour
Generated 27 Dec 2021 05:59 UTC, contact: akrherz@iastate.edu
First value in table is CALM

Direction,	Calm,	2.0 4.9,	5.0 6.9,	7.0 9.9,	10.0 14.9,	15.0 19.9,	20.0+
355-004 ,	9.64,	0.918,	0.275,	0.112,	0.087,	0.012,	0.012
005-014 ,	,	0.955,	0.300,	0.075,	0.100,	0.044,	0.031
015-024 ,	,	0.955,	0.269,	0.125,	0.156,	0.075,	0.037
025-034 ,	,	1.012,	0.231,	0.162,	0.250,	0.144,	0.119
035-044 ,	,	0.806,	0.275,	0.206,	0.300,	0.237,	0.169
045-054 ,	,	0.749,	0.250,	0.181,	0.325,	0.194,	0.150
055-064 ,	,	0.924,	0.425,	0.194,	0.343,	0.212,	0.069
065-074 ,	,	0.868,	0.406,	0.181,	0.212,	0.050,	0.012
075-084 ,	,	0.955,	0.343,	0.181,	0.187,	0.050,	0.031
085-094 ,	,	1.124,	0.475,	0.187,	0.175,	0.025,	0.000
095-104 ,	,	1.137,	0.468,	0.150,	0.137,	0.000,	0.000
105-114 ,	,	1.268,	0.462,	0.219,	0.150,	0.012,	0.006
115-124 ,	,	1.443,	0.587,	0.294,	0.225,	0.019,	0.012
125-134 ,	,	1.386,	0.556,	0.231,	0.262,	0.044,	0.012
135-144 ,	,	1.411,	0.600,	0.262,	0.225,	0.019,	0.012
145-154 ,	,	1.493,	0.856,	0.443,	0.275,	0.050,	0.006
155-164 ,	,	1.455,	0.581,	0.219,	0.194,	0.019,	0.025
165-174 ,	,	1.143,	0.450,	0.231,	0.156,	0.025,	0.025
175-184 ,	,	0.974,	0.393,	0.162,	0.144,	0.019,	0.050
185-194 ,	,	0.906,	0.362,	0.119,	0.219,	0.056,	0.087
195-204 ,	,	0.874,	0.331,	0.194,	0.181,	0.062,	0.112
205-214 ,	,	0.824,	0.262,	0.150,	0.187,	0.094,	0.187
215-224 ,	,	1.030,	0.343,	0.175,	0.225,	0.194,	0.219
225-234 ,	,	1.037,	0.350,	0.156,	0.306,	0.169,	0.169
235-244 ,	,	1.105,	0.406,	0.312,	0.393,	0.200,	0.381
245-254 ,	,	1.480,	0.818,	0.368,	0.512,	0.256,	0.568
255-264 ,	,	1.811,	0.980,	0.331,	0.387,	0.306,	0.375
265-274 ,	,	2.198,	1.224,	0.393,	0.443,	0.131,	0.125
275-284 ,	,	2.198,	1.361,	0.462,	0.356,	0.094,	0.062
285-294 ,	,	2.298,	1.330,	0.468,	0.406,	0.075,	0.062
295-304 ,	,	2.142,	1.168,	0.543,	0.381,	0.144,	0.069
305-314 ,	,	1.942,	0.881,	0.531,	0.456,	0.125,	0.081
315-324 ,	,	1.574,	0.793,	0.331,	0.337,	0.081,	0.144
325-334 ,	,	1.436,	0.456,	0.212,	0.144,	0.037,	0.069
335-344 ,	,	1.037,	0.181,	0.062,	0.100,	0.044,	0.031
345-354 ,	,	1.055,	0.318,	0.075,	0.137,	0.025,	0.031

Fig. 4 - Map of Windrose, Isfahan

2.4.1. The following refers to the development of these settlements from 2000 to 2021:

A. Najafabad Industrial Town

Najafabad industrial town in 2000 on the 4th kilometer of Najafabad to Fooladshahr axis and has an area of 240 hectares, of which 160 hectares have industrial use and 140 hectares have been handed over so far. It also has 17.5 hectares of green space.

B. Montazerieh Industrial Town

Villashahr or Montazerieh industrial town in Isfahan province is one of the prominent industrial towns in Najafabad city. The area of this industrial town is about 87 hectares. Of these 87 hectares, 72 hectares are dedicated to industrial areas.

C. Isfahan Fooladshahr

The new city of Fooladshahr is located in the central part of Lenjan city, 25 km southwest of Isfahan, in the communication axis of Isfahan and Shahrekord. The city has an area of 7700 hectares. Fooladshahr was established in 1964 to house steelworkers and began operating as a new city in 1985.

Due to its proximity to the center of the province and also easy access to large industries such as Isfahan Steel, Mobarakeh Steel and Sepahan Cement Factory, this city has become a suitable place for housing.

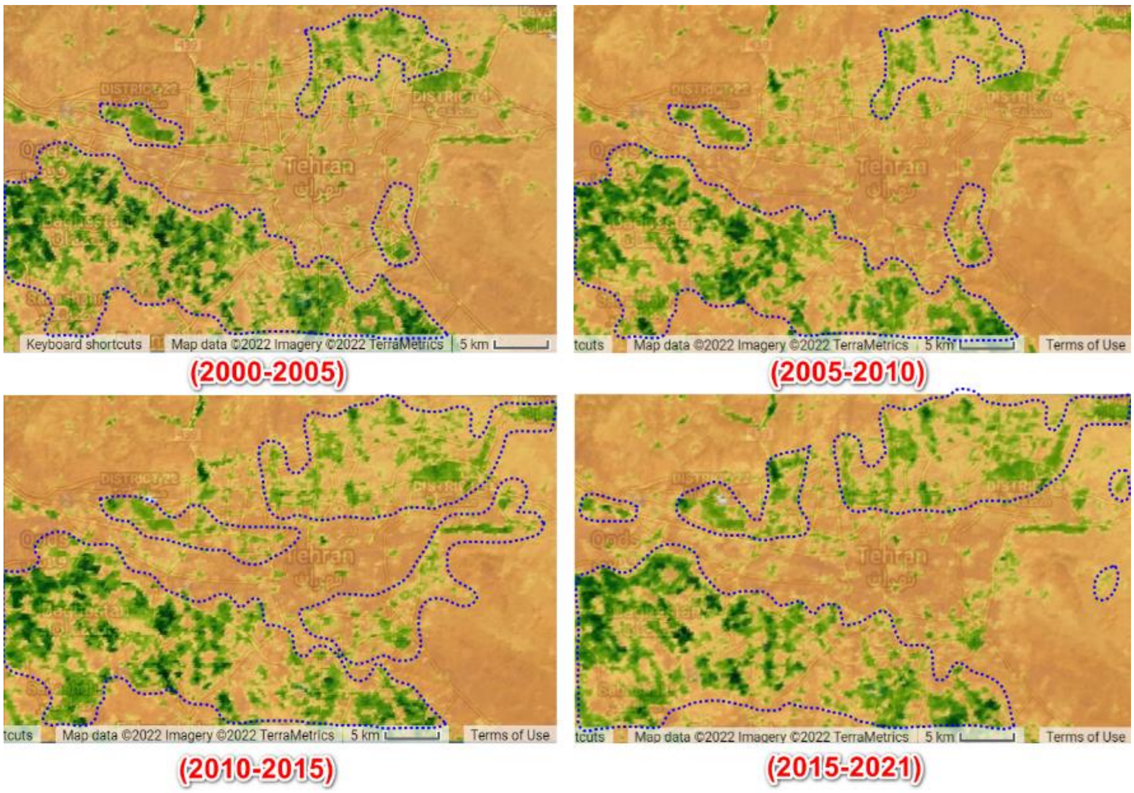
3. Results and discussion

3.1. Comparison of vegetation in four five-year periods from 2000 to 2021

According to the Fig. 5 NDVI index in 5-year periods, you can see that the vegetation of Tehran has decreased in the second 5 years compared to the first 5 years, and in the third 5 years compared to the previous 5 years, the vegetation has increased and in the fourth 5 years the vegetation Has increased, but in the city of Isfahan, vegetation in the second 5 years has decreased slightly compared to the first 5 years, and in the third 5 years, compared to the previous 5 years, vegetation has decreased and in the fourth 5 years, a significant decrease in vegetation in Isfahan Shows that these changes in vegetation during this period indicate drought in this area.

NDVI
Image Collection : MODIS/006/MOD13Q1
Resolution : 250 meters

TEHRAN



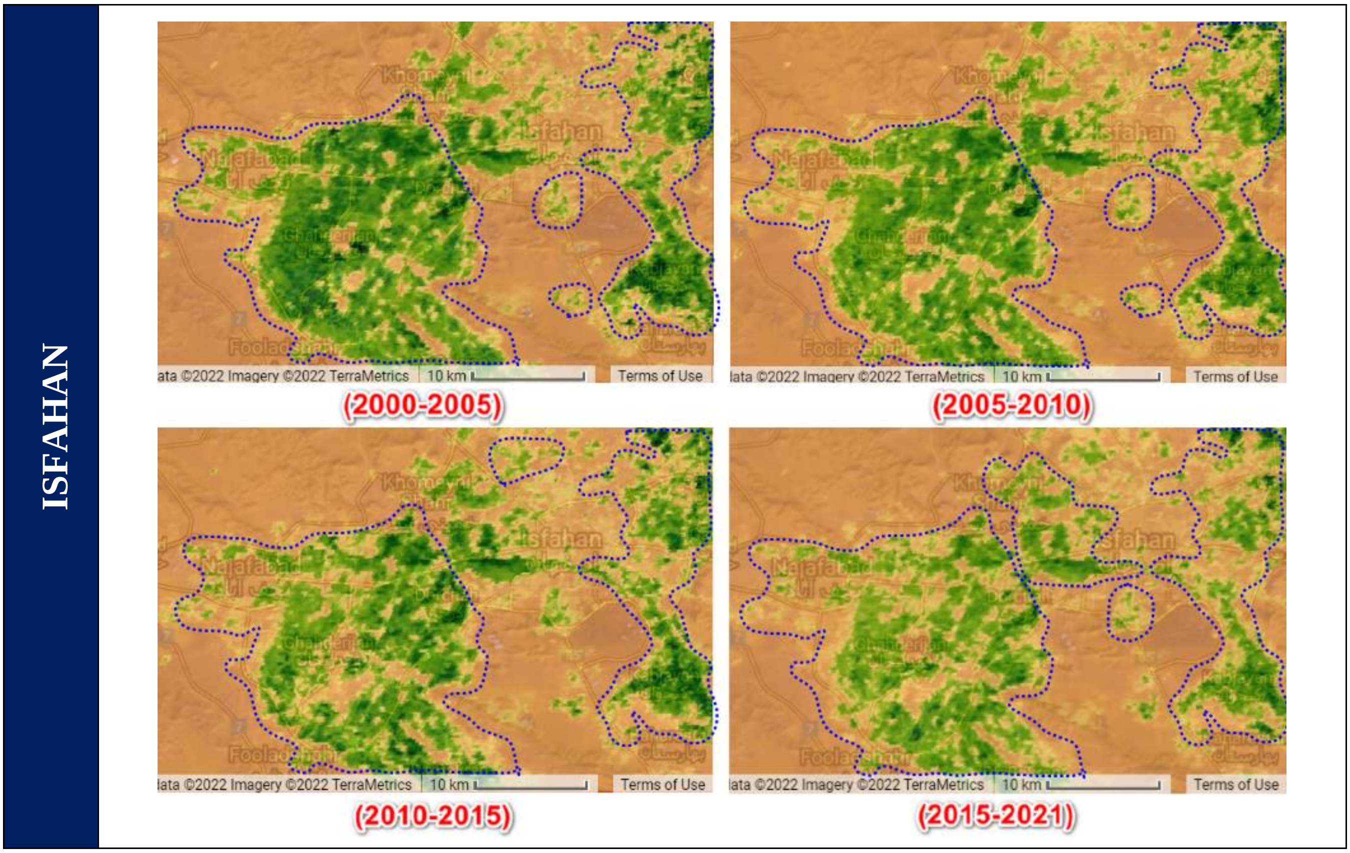


Fig.5 – NDVI of Tehran and Isfahan

As can be seen in Fig. 6 the 20-year time series diagram in different periods, the vegetation status of Tehran has been increasing from 2000 to 2020 due to environmental reasons and in 2021 the vegetation has been decreasing, but the vegetation status of Isfahan from 2000 to 2021, there was a decreasing trend and vegetation has decreased. In the continuation of this study, the cause of this increasing and the decreasing trend has been investigated.

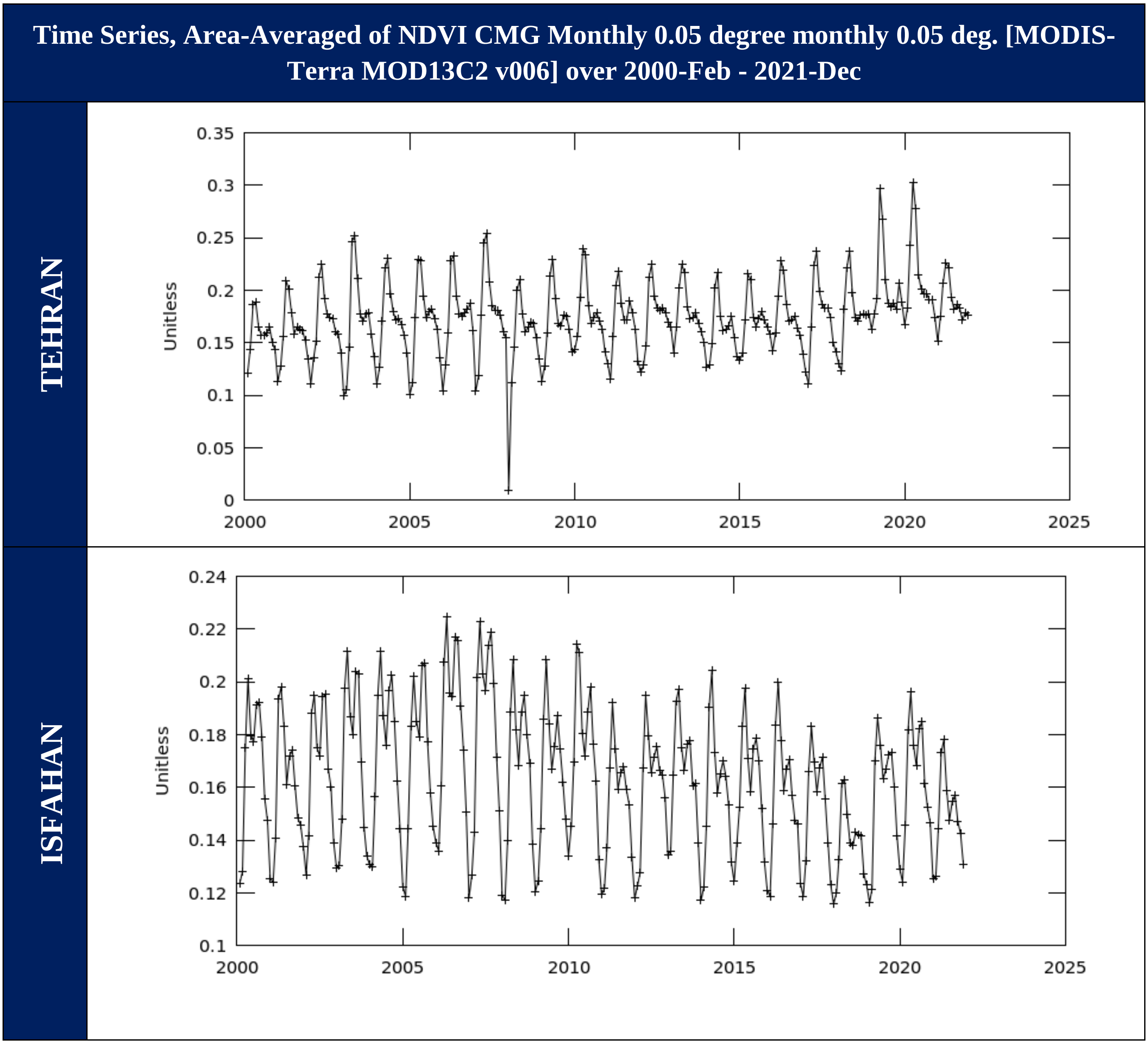


Fig.6 – Diagram of Vegetation Status (NDVI) of Tehran and Isfahan

According to the rainfall chart for the city of Tehran, from 2000 to 2007 the amount of rainfall had a favorable trend, but from 2008 to 2011 the amount of rainfall had a decreasing trend and then for a year in 2012 the amount of rainfall increased and again from 2013 By 2018, rainfall has decreased and from 2019 to 2020, rainfall has increased significantly, which in 2020 shows the highest rainfall in the last 20 years, and from 2021 onwards, the amount of rainfall has decreased.

According to the rainfall chart for the city of Isfahan, from 2000 to 2007, the amount of rainfall was favorable, but from 2008 to 2011 shows the lowest amount of rainfall, which caused drought in the region, and then for a year, i.e. in 2012, rainfall. It has increased and since then, from 2013 to 2018, the rainfall has had a decreasing trend, until 2019, the amount of rainfall increased significantly, but since then, it has decreased. The lowest rainfall in the last 20 years in the city of Isfahan belongs to 2008, which has caused drought in the region.

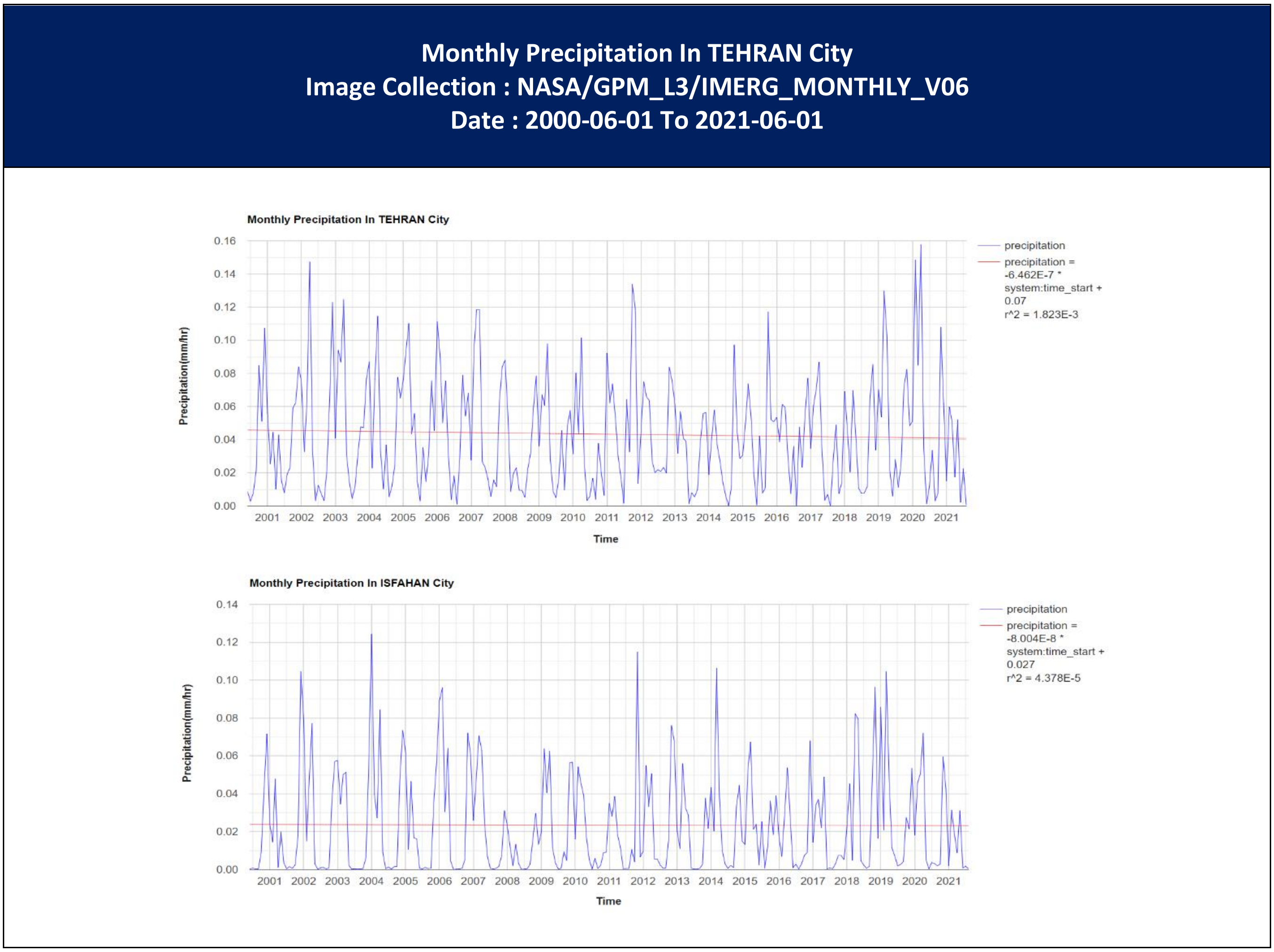


Fig.7 – Monthly rainfall in Tehran and Isfahan

Fig. 8 below shows the average monthly rainfall from 2000 to 2021 in four seasons: winter, spring, summer, and autumn in Tehran and Isfahan. According to the chart below, on average, the highest amount of rainfall in Tehran and Isfahan is related to the years 2007-2002 and 2020-2019 and the lowest amount of rainfall is related to the years 2000, 2008, and 2021.

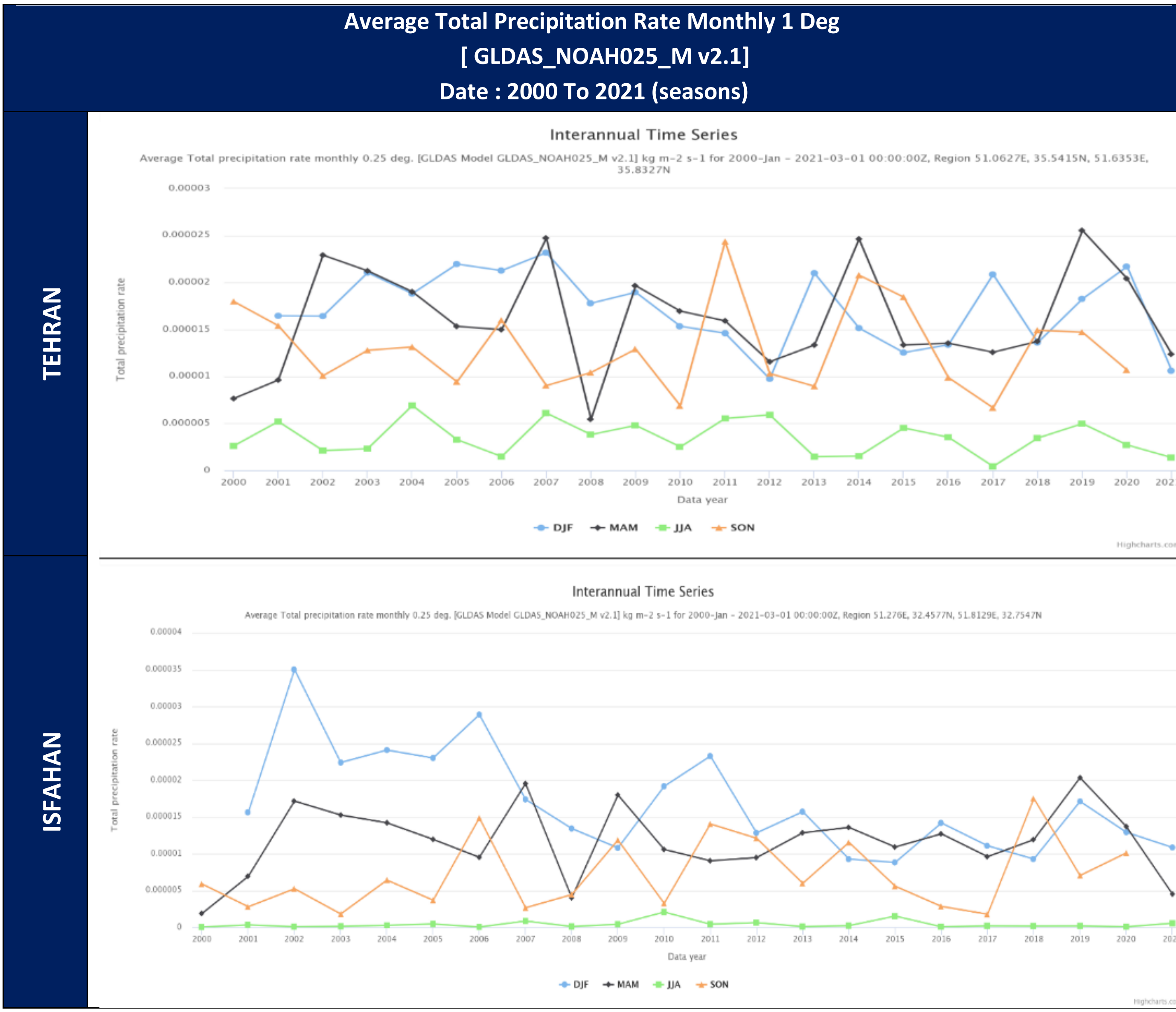


Fig. 8 – Average total rainfall in Tehran and Isfahan

Fig. 9 below shows the amount of dew point in the period 2000 to 2021 when Dew Point refers to the temperature at which air is saturated. As you can see in the chart below, the dew point temperature of Tehran and Isfahan reached its lowest level in 2008 and 2021, while the amount of rainfall in these two years has decreased significantly, which has led to a drought.

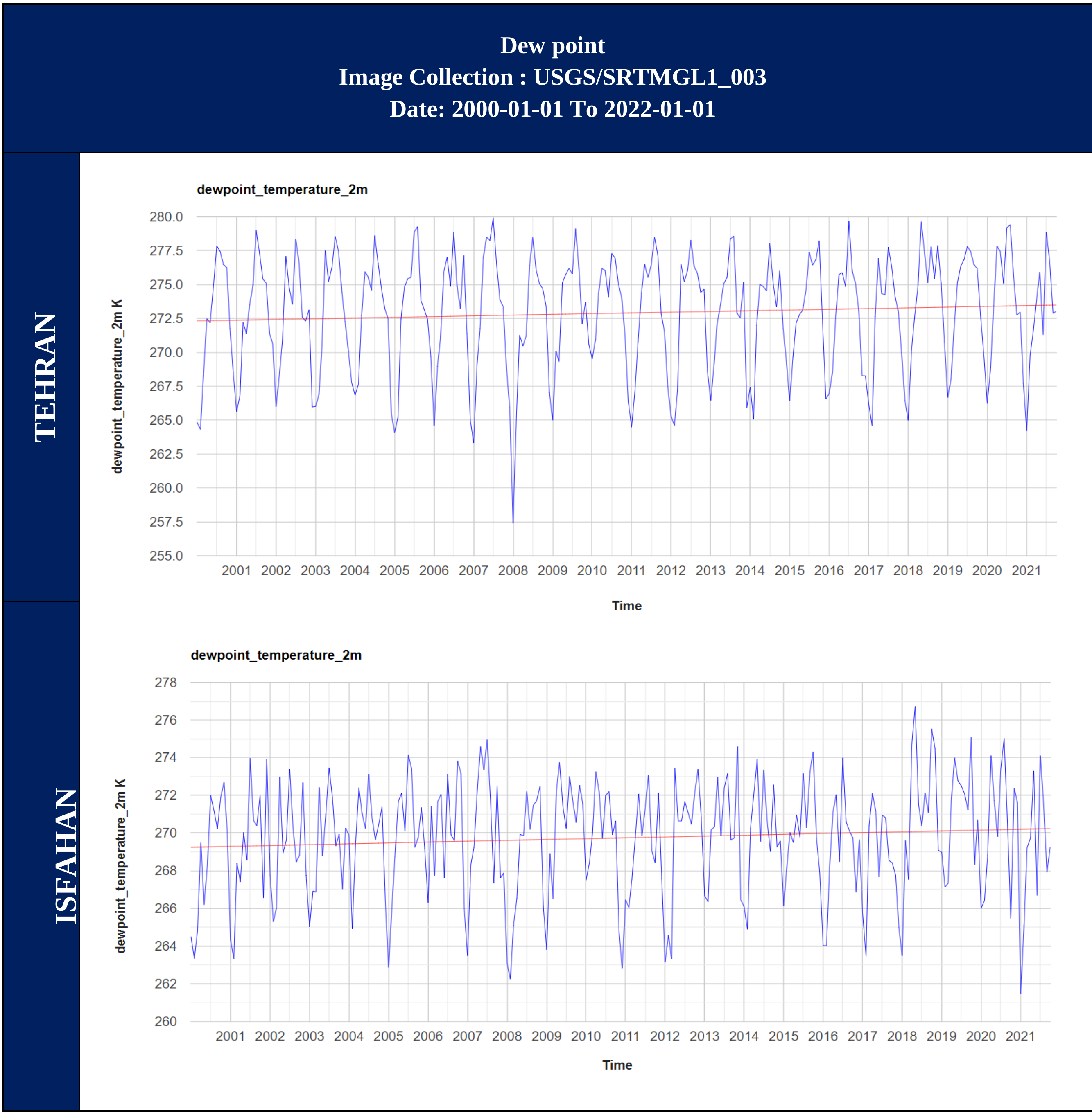


Fig. 9 – Dew point of Tehran and Isfahan

Some water from rainfall, melting snow, or deep in the soil, stays stored in the soil. According to Fig. 10 below, runoff in Tehran has increased in years when the average rainfall or snowfall was high, and in years of low rainfall and drought, such as 2008 to 2011 and 2014 to 2018, the lowest surface and non-surface runoff was shown. And in the city of Isfahan, except in 2006, when runoff reached its highest level, the rest of the years due to drought has been at its lowest level.

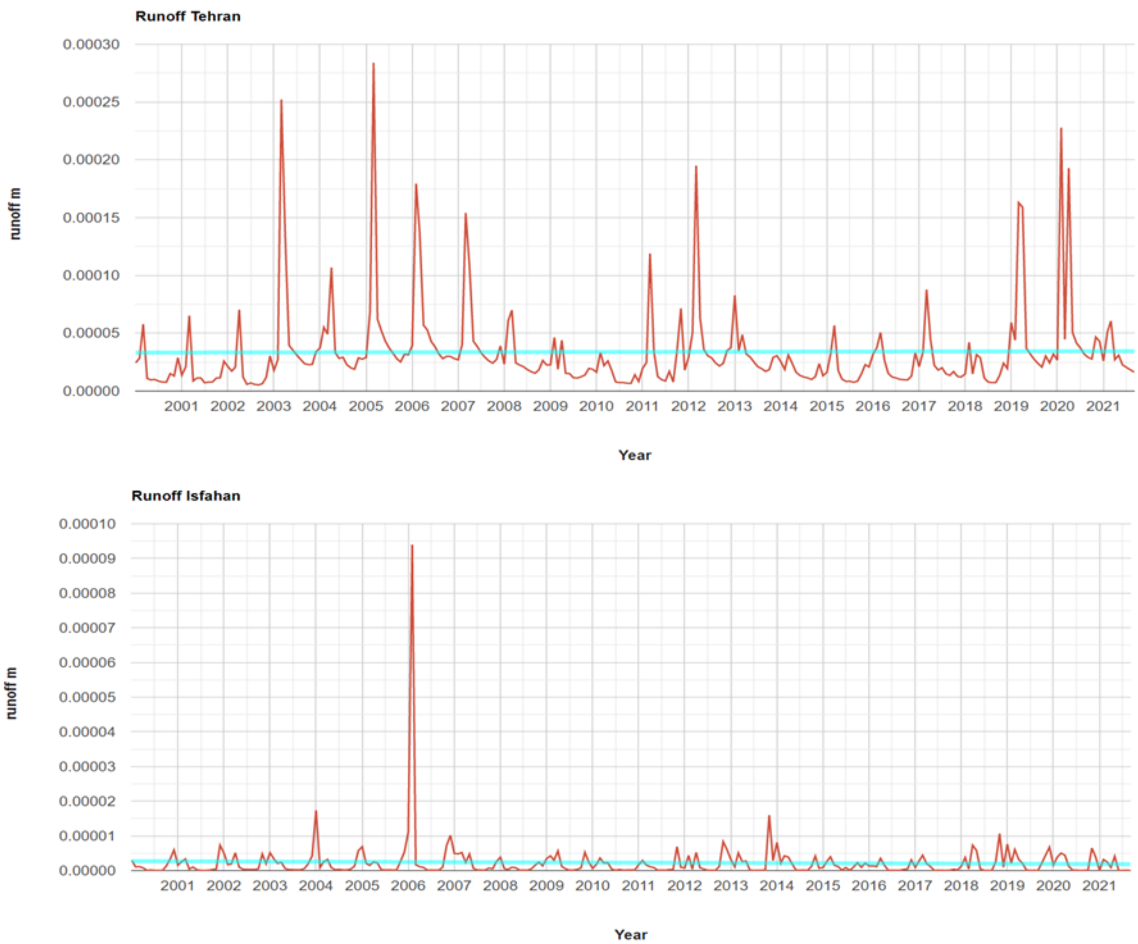


Fig. 10 – Runoff from Tehran and Isfahan

According to Fig. 11 the snow depth chart, the amount of snowfall in Tehran has generally decreased from 2000 to 2021, and in 2005 it had the most snowfall, with a snow depth of 28 cm. In the city of Isfahan, the depth of snow in 2007 reached its maximum, i.e. 6 cm, but in times of drought, the depth of snow and consequently snowfall was zero.

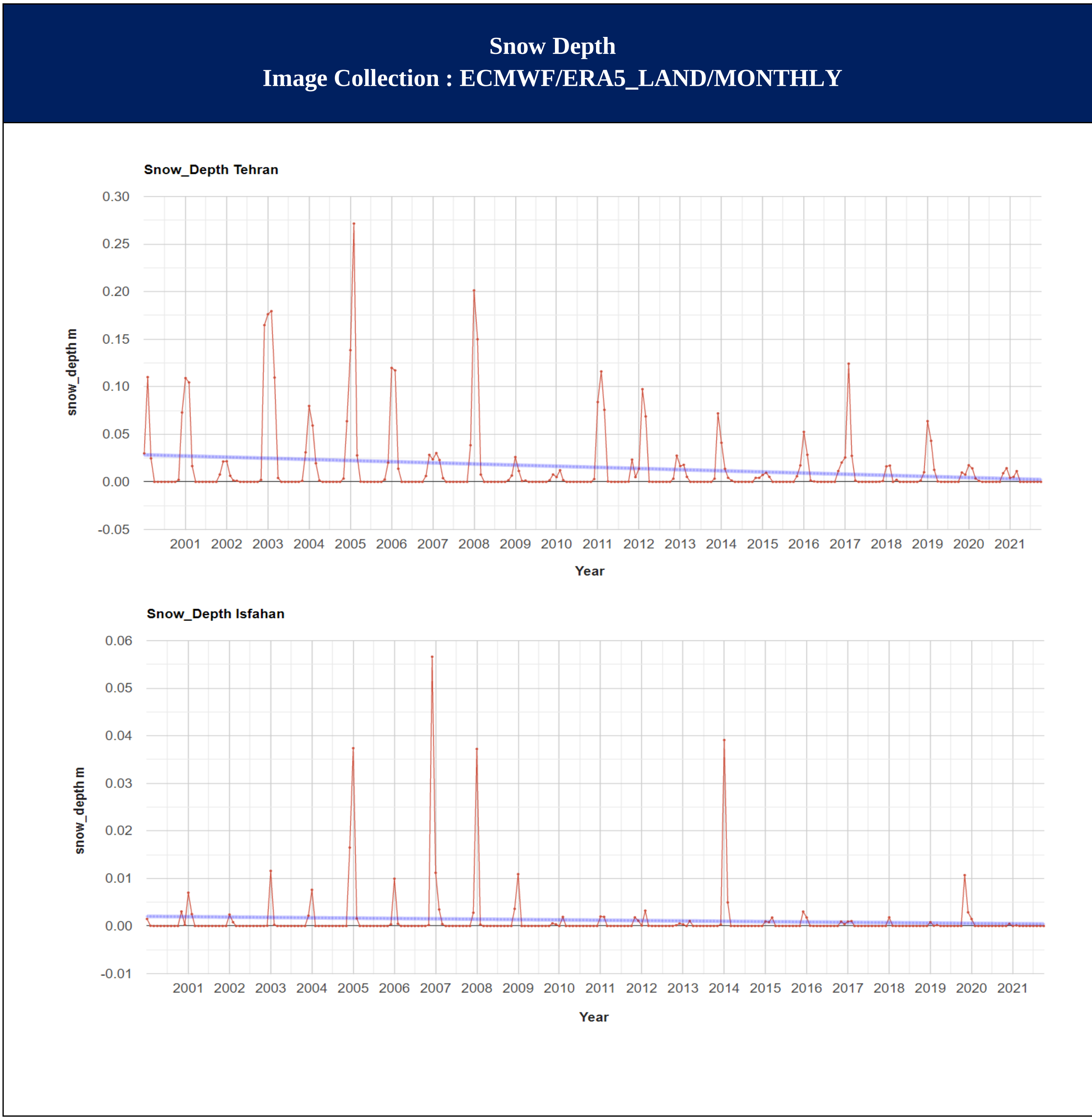


Fig. 11 – snow depth of Tehran and Isfahan

In Fig. 12 below, which shows the average day and night temperature of the region, the average temperature in Tehran in the period 2000 to 2021 has been facing small and increasing changes, and only in 2008 the temperature has decreased significantly in Isfahan, temperature changes were low and positive, and in 2005, 2008 and 2014, when the temperature reached its lowest level.

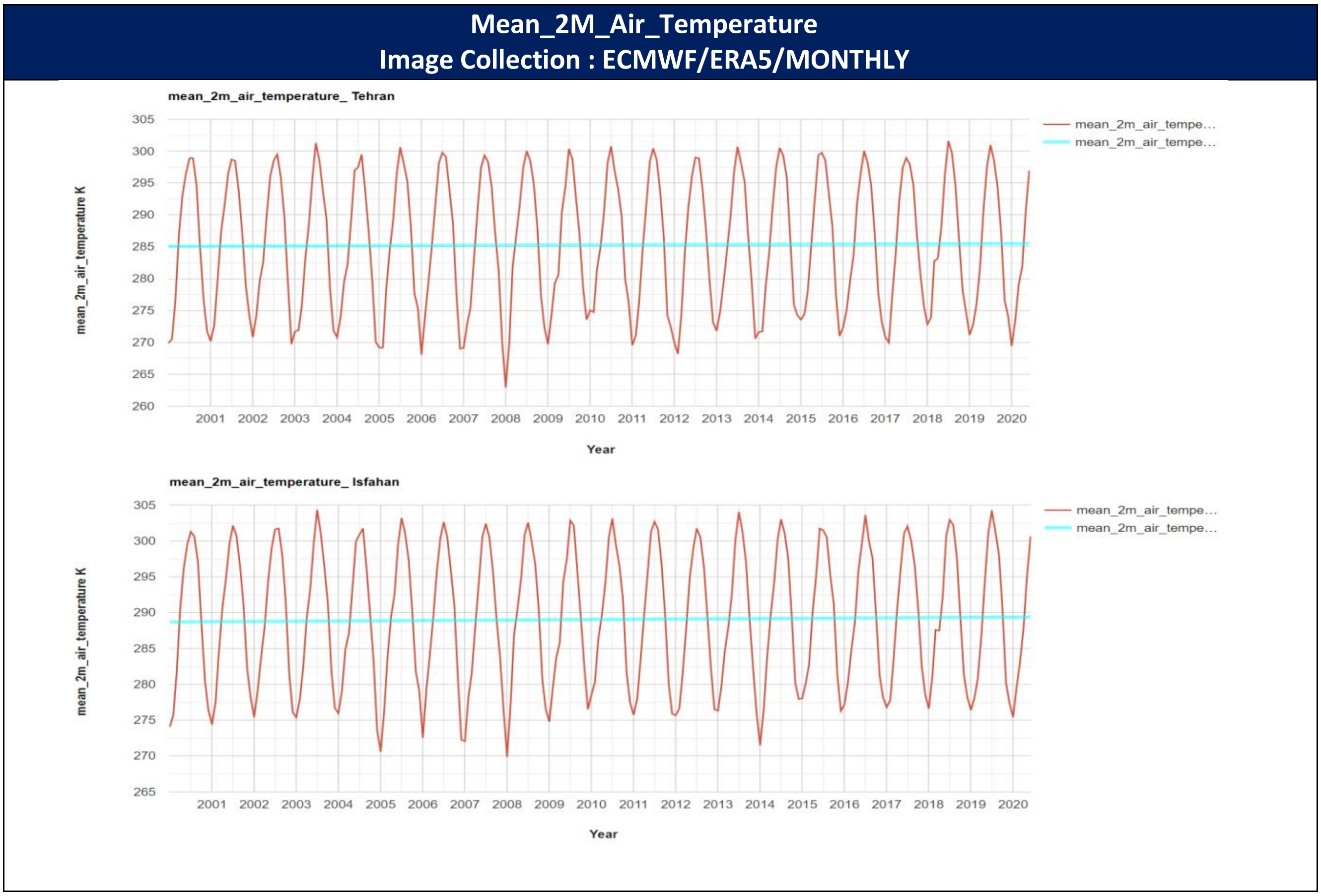


Fig. 12 – Average day and night temperature of the region

Fig. 13 below shows the temperature changes in the period 2000 to 2021 in 4 chapters. As you can see, in 2008 we see the most temperature changes and temperature differences.

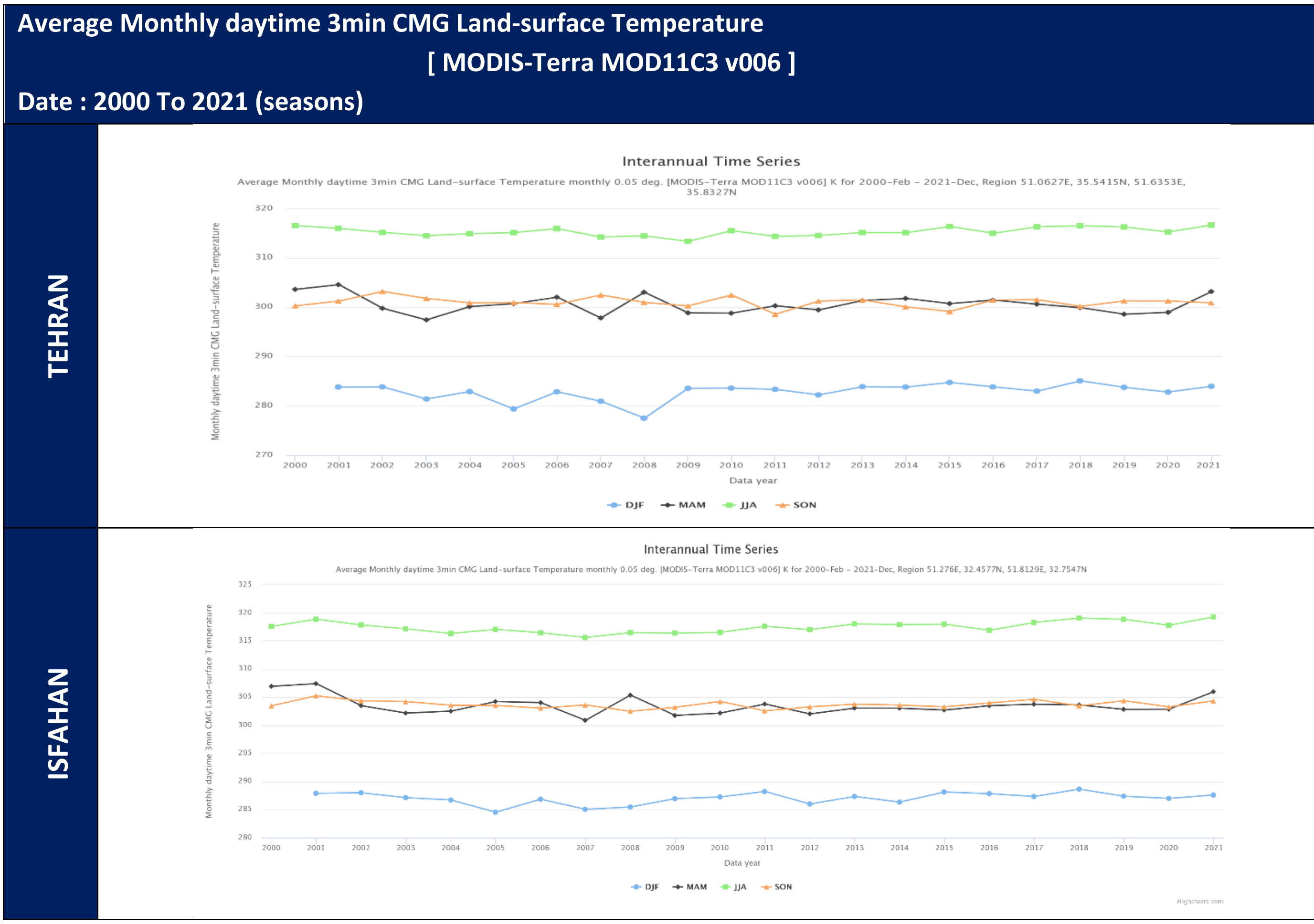


Fig. 13 – Land surface temperature of the region

Fig. 14 below examines the level of air pollution and the presence of NO2 pollutants in the air. Air pollution in Tehran in 2007, 2014, and 2021 had the highest rate and in 2020 had the lowest rate of air pollution that air pollution can be directly related to the monthly rainfall and in years when rainfall was very low, the rate of air pollution is higher and the years of high rainfall, such as 2019 to 2020, air pollution has reached its lowest level.

In Isfahan, air pollution reached its peak in 2014, and in 2020 and 2019, due to increased rainfall, air pollution reached its lowest level.

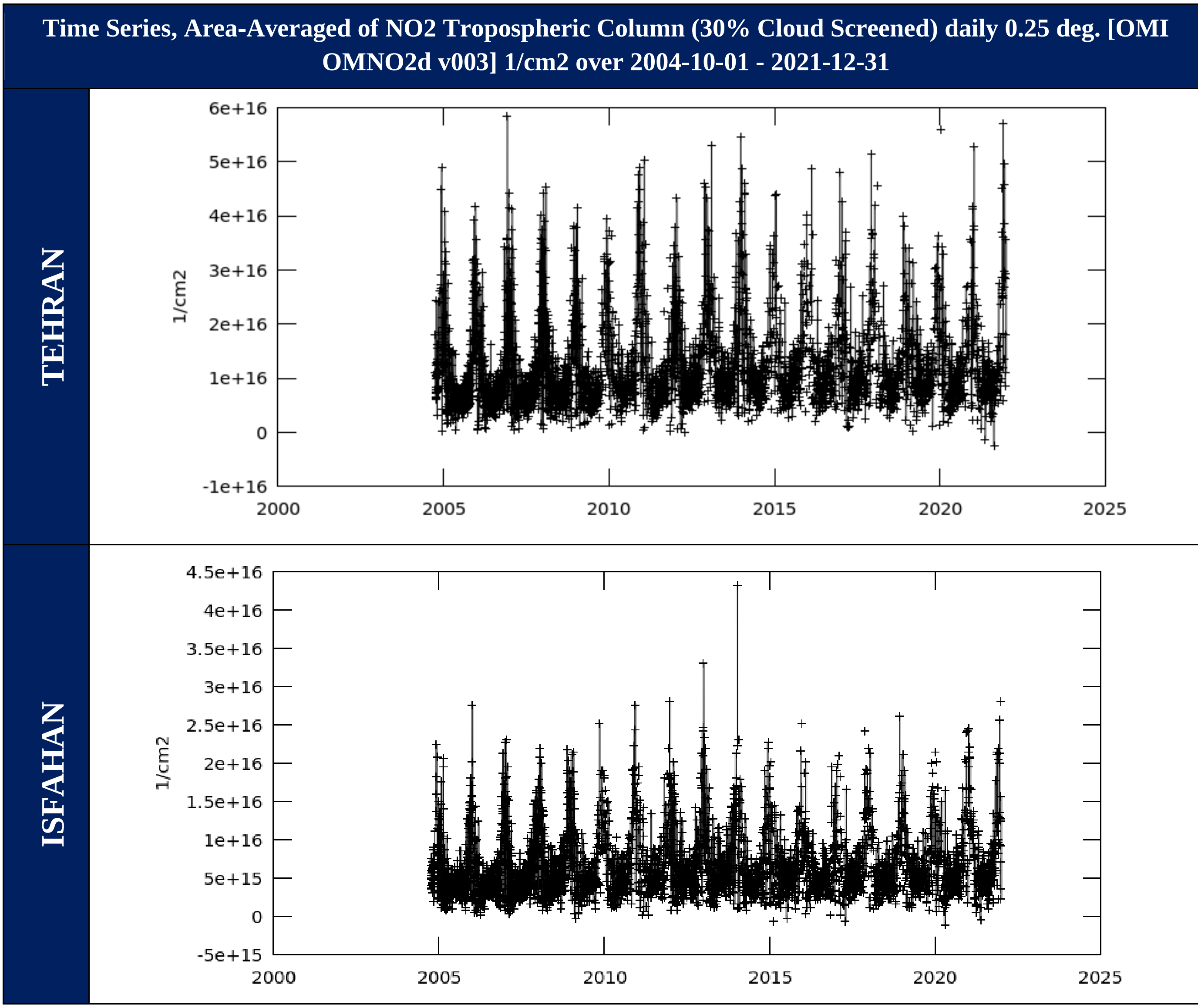
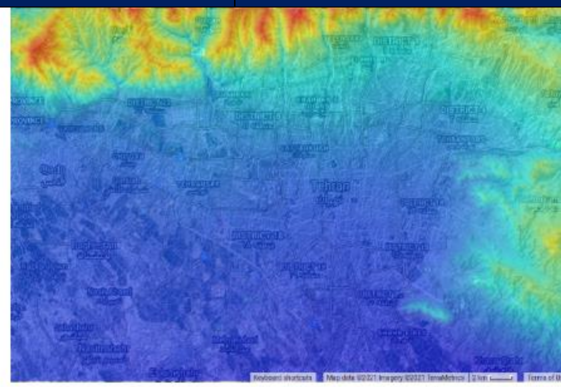
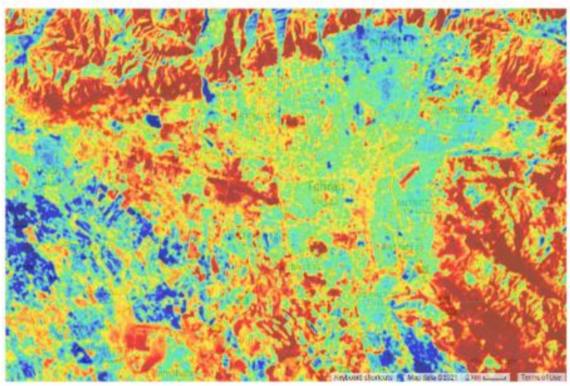
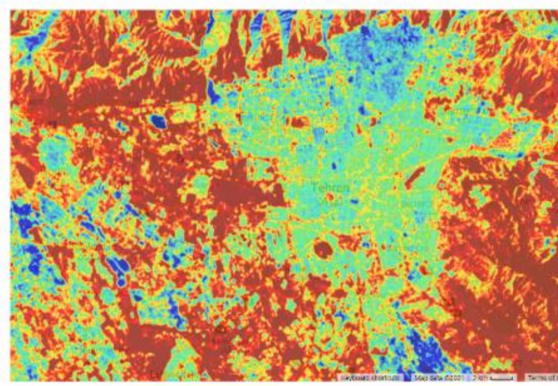
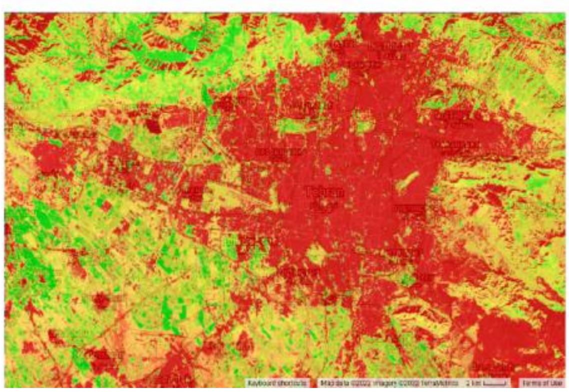
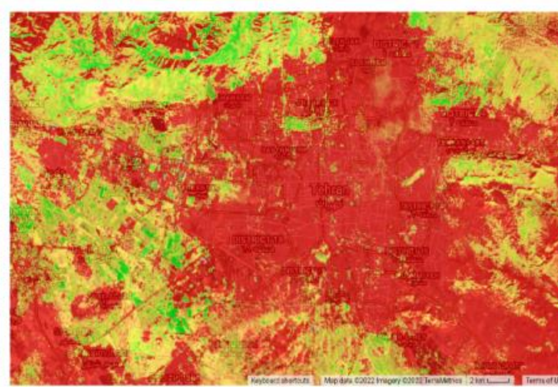


Fig. 14 – Air pollution and the presence of NO2 of the region

Land surface temperature (LST) occurs when the surface temperature and air temperature in urban areas are higher than in the surrounding areas. These temperature differences are reflected in temperature maps as islands known as urban heat islands.

NDBI is one of the indicators used to identify urban areas. In this index, two bands, SWIR and NIR, are used. This index has a good ability in identifying urban areas and makes constructions more prominent and usually in areas with vegetation, this index is negative due to the high radiant energy of the near-infrared band, but in urban areas where the radiant energy of the middle infrared band is higher, this index is positive.

Fig. 15 shows the NDBI index is directly related to the LST index, and in areas of the city where construction has taken place from 2015 to 2021, leading to urban or industrial development, the NDBI index has increased and is shown in red, and as a result, the LST index has also increased and turned into dark red.

LST & NDBI			
		2015	2021
TEHRAN	DEM & Hillshade		
	LST		
	NDBI		

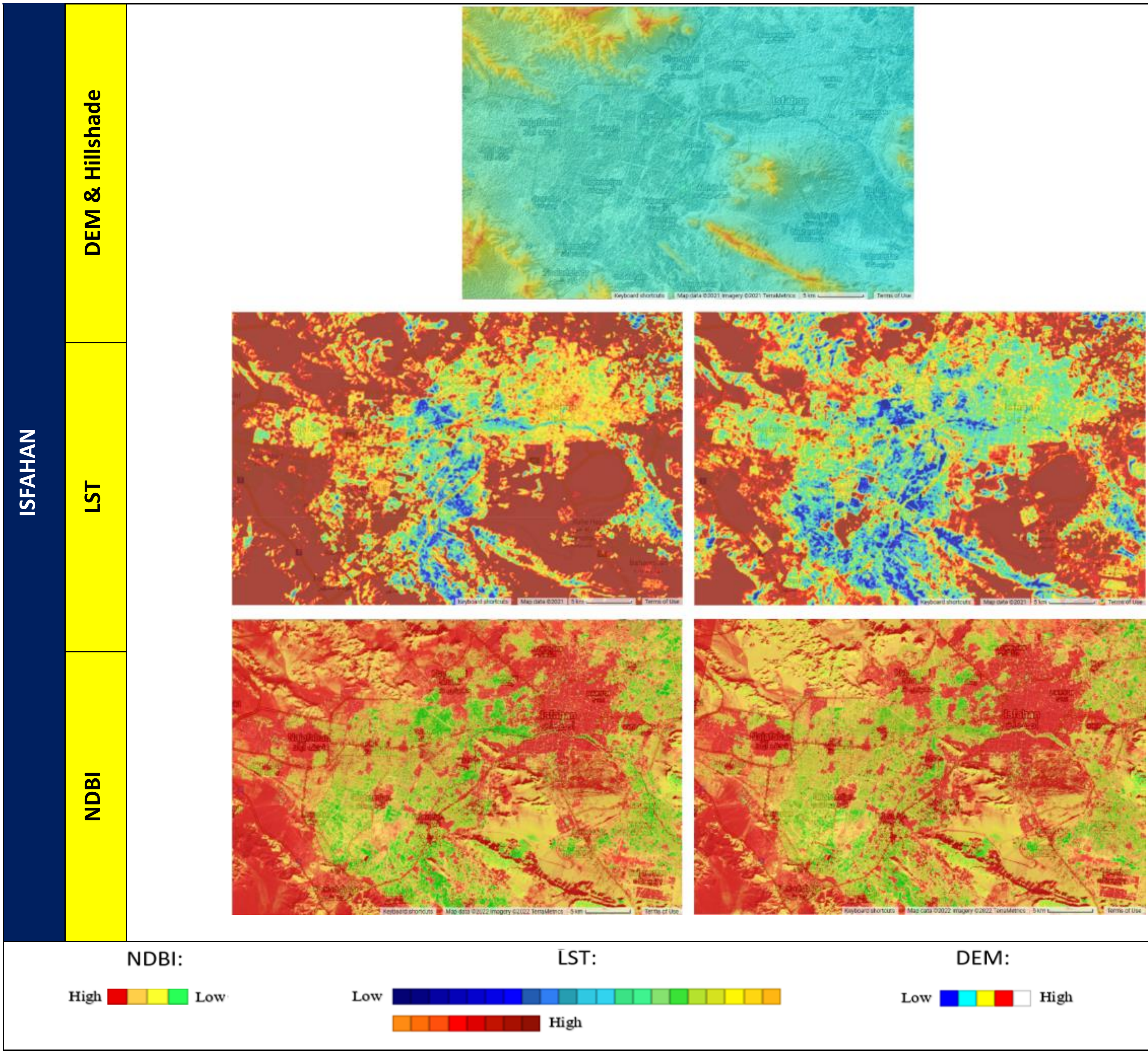


Fig. 15 – Correlation of NDBI with LST index

4. Conclusion

In the present study, the trend of urban development and its effects on vegetation, air pollution, and climate in the two cities of Tehran and Isfahan were investigated. For this purpose, the data available in the online system of satellite image processing of Google Earth Engine (GEE) and the GIOVANI system were used. After processing images of various satellites such as Landsat 8, Modis, Sentinel 2, and NASA and extracting information and indicators from them, important results of the relationship between urban development and residential and industrial towns, with temperature and thermal islands, vegetation, rainfall, and air pollution was obtained. These results suggest that uncontrolled development has led to unplanned construction, which results in rising temperatures, climate change, and dangerous environmental impacts.

As you can see, these systems have been able to show information about the physical development of cities in different periods, for which a GEE model from the GHSL images from 1975 to 2014 was prepared and after reviewing the maps obtained from this model, it was obtained that the growth of urbanization and urban development in Tehran during the last 20 years in various directions has been done quantitatively and qualitatively and external development that this urban development and population growth in Tehran has led to an increase in thermal islands (LST) and temperature in the region. Increasing these two parameters has a direct impact on reducing snow and rain and thus reducing runoff, vegetation, and soil moisture. Changing these parameters has an effective role in air pollution.

According to studies conducted on vegetation in 4 periods of 5 years (NDVI index) in Tehran, the results showed that in periods of high rainfall vegetation had a favorable and growing trend and in periods of rainfall as in 2008, soil moisture, dew point, and runoff temperatures have also decreased, resulting in severe vegetation decline and drought in the area.

Furthermore, according to the studies conducted on the urban development of Isfahan, the results were obtained in such a way that urban development in Isfahan is mostly due to the development of industrial towns and residential constructions around these industries, which have devastating environmental effects on the city has vegetation, climate and pollution and the increase in urbanization and industry has led to a decrease in vegetation and NDVI levels in this area and an increase in thermal islands and temperatures during these 20 years, which has caused climate change and reduced rainfall and runoff levels in this area, resulting in humidity. Soil and plants have decreased and the region has suffered from drought.

Since most of the new industrial towns of the province are located in the west and southwest and the prevailing wind direction of the province is also west and southwest; Pollution and pollutants from these industries are moving toward the city and increasing the air pollution in the city.

The results of the graphs also show that the increase in NDBI (urban construction) index increases the thermal island (LST) and temperature, and as the thermal islands increase, the amount of rain and snow in the region and consequently the level of runoff, Soil moisture (NDMI) and dew point temperature decreases. These parameters have a direct impact on the reduction of vegetation and NDVI and MSAVI indices in the region. In the end, changing all these parameters plays a significant role in increasing air pollution. There was more rain or snow, and air pollution was significantly reduced.

Declarations

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Consent to Publish (Authors consent to publishing)

Authors Contributions (All co-authors contributed to the manuscript)

Code availability (Not applicable)

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