A Novel Viewpoint to the Green City Concept Based on Vegetation Area Changes and Contributions to Healthy Days: A Case Study of Mashhad, Iran

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Abstract

One of the significant challenges in urbanization is the air pollution. This highlights the need of the green city concept with reconsideration of houses, factories and traffics in a green viewpoint. The literature review confirms that this reconsideration for green space, has a positive effect on the air quality of large cities and to remove the air pollution. The purpose of this study is to evaluate the annual vegetation changes in the green space of Mashhad, Iran as a very populated city in the middle east to study the air pollution. To investigate the relationship between the air pollution and vegetation, the Landsat 8 satellite images for summers of 2013-2019 were used to extract changes in vegetation by calculating the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and the Optimized Soil Adjusted Vegetation Index (OSAVI). The main contribution in comparison with the relevant studies is to study the relationship between clean, healthy and unhealthy days with the green space area for the first time in Mashhad, Iran. The results show that the implementation of green city concept in Mashhad, Iran has been increased by 64%, 81% and 53% by NDVI, EVI and OSAVI, respectively during the study period. The vegetation area of this city is positively correlated to clean and healthy days and has a negative correlation to unhealthy days, in which the greatest values for NDVI, EVI and OSAVI are 0.33, 0.52 and -0.53, respectively.

1. Introduction

Industrialization and urbanization are the main reasons to burn more fossil fuels in developing countries like Iran to face with a high rate of air pollution (Atkinson et al., 2012; Fathollahi-Fard et al., 2020a). There is no doubt that this high rate is the greatest environmental hazard to mankind health (Barwise and Kumar, 2020). Moreover, it damages the people’s health and is associated to the cardiopulmonary, morbidity and mortality (Calderón-Garcidueñas et al., 2002; Pope and Dockery, 2006). This motivates the concept of green city as it can contribute to a healthier air and air pollution removal (Nowak and Heisler, 2010; Nowak et al., 2006).

As an introduction to the green city, recognition of vegetation characteristics and their relationships to environmental impacts are two of the several factors leading to a great reduction in the air pollutions (Klingberg et al., 2017; Magee et al., 2008; Xing and Brimblecombe, 2019). It goes without saying that urbanization and industrialization are two main green space and ecosystems (Wan et al., 2015; White and Greer, 2006; Zhou et al., 2016; Fathollahi-Fard et al., 2020b). Therefore, they have a direct impact on the life quality in large cities like Mashhad in Iran. Since vegetation and urban greening absorb sun radiations and affecting heat islands, they are able to reduce air pollution and to clean the air (Dimoudi and Nikolopoulou, 2003; Perini and Magliocco, 2014; Susca et al., 2011, Yu et al., 2021). This highlights the need of detection of change values and direction to determine their effects on human lives (Pettorelli et al., 2005). Satellite imagery and remote sensing technology provide the data on a region past. They present many changes which can be detected and compared to determination of changes and their effect on environment (Gao et al., 2020; Mojtahedi et al., 2021).

Vegetation indexes are of important algorithms which are able to extract canopy conditions by means of remote sensing (Salas and Henebry, 2014). Reflective spectrum of sun radiation is used to measure vegetation conditions, as some wavelength are adsorbed and others are reflected (Berger et al., 2019). The most common used index in this research area is the Normalized Difference Vegetation Index (NDVI) (Ren et al., 2018). This metric is an important spatial indicator of vegetation quality (Thenkabail and Lyon, 2016) and is derived from the Red and near-infrared reflectance caused by leaves that is associated to canopy greenness (Brantley et al., 2011). The NDVI is linearly correlated to the canopy and is related to the vegetation photosynthesis and energy adsorption (García-Gómez and Maestre, 2011). The NDVI is sensitive to soil properties and may be influenced in sparse vegetation and dark backgrounds like dry sandy soils (Fern et al., 2018).

In order to diminish NDVI deficiency, there are some other metrics to improve the evaluation. One of them is the Enhanced Vegetation Index (EVI) which was developed to improve NDVI by increasing sensitivity to canopy variation and reducing atmospheric and soil reflectance impacts (Huete et al., 2002). As indicated in the literature review, the EVI is used in most crop-mapping studies (Wardlow and Egbert, 2010). Another metric is the Optimized Soil-Adjusted Vegetation Index (OSAVI) which was developed to decrease the background effect. This metric is an extension to the Soil-Adjusted Vegetation Index (SAVI) and Transformed Soil-Adjusted Vegetation Index (TSAVI). One merit of OSAVI in comparison with SAVI and TSAVI is that it is simpler and doesn't require prior knowledge about soil (Rondeaux et al., 1996; Steven, 1998). In addition, it has been found that it is more efficient than NDVI in reduction of background effects of soil type and to further determine the vegetation (Fern et al., 2018; Liu et al., 2012). However, the EVI is more efficient to reduce the aerosols disorder (Liu et al., 2012).

To study the relevant studies in the implementation of green city concept using aforementioned metrics, one of the earliest studies is Rafiee et al., (2009) who investigated the green space changes and patterns of Mashhad city in Iran from 1987 to 2006. Most notably, they used the satellite imagery. Next year in another study, Richardson and Mitchell (2010) evaluated the relationship between green lands and the people's health via considering their gender in the United Kingdom using an ecological approach. Following, the implementation of green city in Toronto, Ontario in Canada was studied by Villeneuve et al., (2012). They calculated the mortality rate and the green space relationship using satellite imagery and NDVI metric.

Selmi et al., (2016) estimated the air removal role of trees in Strasbourg city in France. They used the i-Tree Eco model in this regard. Xing and Brimblecombe (2019) analyzed the role of green spaces on the air pollution distribution along parks using computational fluid dynamics. De Carvalho and Szlafsztein (2019) evaluated the vegetation loss and its impact on the air quality and air pollution using NDVI. At last but not least, Jaafari et al., (2020) evaluated the green lands effect on the air pollution diminishment and mortality rate of respiratory diseases in Tehran, Iran. They applied the structural equation modeling and the partial least squares method to the green city concept.

With regards to aforementioned literature and to the best of our knowledge, although the role of urban vegetation on air quality and pollution was repeatedly studied, no study contributed the concept of green city correlation to the clean, healthy and unhealthy days. This study aims to fill this research gap. All in all, the main contributions are summarized as below:

- This study aims to investigate the green space area and its changes in Mashahd, Iran during 2013 to 2019.
- The clean, healthy and unhealthy days are contributed and studied for the first time.
- This paper studies the relationship between clean, healthy and unhealthy days with green space area.

The rest of this paper is organized as follows: Sect. 2 provides the materials and methods for this research including the case study, the research methodology, the logic of metrics and statistical calculations. Section 3 does the computations and discussed the results. Finally, Sect. 4 is the summary of this study with findings and recommendations.

2. Materials And Methods

2.1. Case study

Mashhad is the second largest city in Iran, located in the center of Khorasan Razavi province in south of Toos plain. The geographical map of this city is given in Fig. 1. The Mashahd city has around 3 million population. It should be noted that this city has more than 20 to 30 million visitors each year. This city is historical and cultural for many people in the middle east due to holy shrine of 8th imam of Shias located in Mashhad, Iran (Esmaili, 2018). This city is not modern in the transportation, logistics and factories. That is why the air pollution becomes a major concern for the governors of Mashahd, Iran (Gheibi et al., 2018). The city is suffering from high air pollution rates. In a number of days, this city is the most polluted city in the area of middle east. For example, as reported in 2013, this city was unhealthy for all group ages for 131 days (EPMC, 2013; Mousivand et al., 2017)

2.2. Proposed methodology

To assess the urban green land spaces and their correlation to air quality of the city, the satellite images of Mashhad from 2013 to 2019 were collected and calibrated. Three vegetation indices including NDVI, EVI and OSAVI were calculated to show the green land share of the city. The air quality data of Mashhad has been extracted from Environmental Pollutants Monitoring Center of Mashhad city in Iran based on the annual reports and their correlation to vegetation area of each year has been investigated (Zhang et al., 2020). These methods define the proposed methodology and the research steps are organized in Fig. 2.

2.3. Computation logics

Landsat 8 satellite images of Mashhad were gathered and used for analysis. The Blue (B), Red (R) and Near Infrared (NIR) bands with wavelength of 0.45–0.51 μm, 0.64–0.67 μm and 0.85 – 0.8 μm, respectively, were used for calculating vegetation indices. For each year, an image has been selected in the summer between 27 June to 27 July, when most of trees grew enough and leafed to be detected by spectral imagery. NDVI, EVI and OSAVI were calculated by Eqs. (1), (2) and (3):

$$NDVI = \frac{NIR-R}{NIR+R} \quad (1)$$

$$EVI = \frac{2.5*(NIR-R)}{NIR+6*R-7.5+B+1} \quad (2)$$

$$OSAVI = \frac{(1+0.5)*(NIR-R)}{NIR+R+0.16} \quad (3)$$

2.4. Statistical scrutinizing

For evaluation of clean, healthy and unhealthy days and their relations with green land indices, regression computational efforts are done. Likewise, the mentioned computational practices are calculated regarding the following formula:

$$r^2 = \left\{ \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \right\}^2 \quad (4)$$

where x_i and y_i are the values in the first and second dataset, respectively; moreover $\bar{x}$ and $\bar{y}$ are each datasets mean.

3. Results And Discussion

The vegetation cover in Mashhad has been increased during 2013 to 2019 by all indices as shown in Fig. 3. Total vegetation by NDVI, EVI and OSAVI has indicated an increase about 64%, 81% and 53% from 2013 to 2019, respectively. It was 1076 ha, 539 ha and 2523 ha in 2013 by NDVI, EVI and OSAVI and become 1752 ha, 980 ha and 3871 ha, respectively. The vegetation detected by OSAVI index in each year is about four times of EVI and two times of NDVI. This agrees with Manna et al., (2013) that detected more vegetation by using OSAVI in comparison to the NDVI and Fern et al., (2018) also detected more cover change by OSAVI than NDVI.

As shown in Fig. 4 total vegetation cover has been increased year to year according to NDVI, EVI and OSAVI except 2016 to 2017. All indices shown a decrease in vegetation from 2016 to 2017 and line chart becomes smooth and almost horizontal or negative but general trend line is slowly upward and show that total vegetation has increased during 7-year period. The vegetation area in 2013 to 2015 has slowly upward trend and the rainfall in each year is almost equal to the other but the rainfall in 2016 becomes 238 mm and caused great increase in vegetation area. The rainfall has decreased to 178 mm in 2017 and caused vegetation diminishment, but it slowly turns back to the growth by rainfall of 238 mm and 255 mm in 2018 and 2019 which caused most vegetation area happens in 2019. The vegetation area has strongly correlated to annual rainfall during the study period which r^2 is 0.75, 0.73 and 0.71 for NDVI, EVI and OSAVI, respectively. Omuto et al., (2010) also found good correlation between NDVI and rainfall in Somalia. It should be noted that the rainfall has been known as key factor for vegetation growth (Blok et al., 2011; Gessner et al., 2013).

Mashhad has experienced clean and healthy days most of the times but 20% of the days was unhealthy during 2013 to 2019 as shown in Fig. 5. The most polluted and healthiest year were 2013 and 2018 with about 35% and 12% unhealthy days, respectively. Comparing the Clean, healthy and unhealthy days of Mashhad during 2013 to 2019 with vegetation area in the city that obtained from NDVI, EVI and OSAVI indices, show that clean and healthy days have positively correlated with vegetation area by all indices, while unhealthy days has negative correlation to vegetation area which values are reported in Table 1.

Table 1
NDVI, EVI and OSAVI correlation (r^2) to clean, healthy and unhealthy days

	NDVI	EVI	OSAVI
Clean days	0.22	0.33	0.08
Healthy days	0.39	0.52	0.46
Unhealthy days	-0.39	-0.53	-0.40

It can be concluded that increasing vegetation area in the city can directly enhance air quality and contribute to air pollution reduction and healthier days. The results are in agreements with previous research which indicate that urban green space reduce air pollution and influence public health (Jennings et al., 2012; Zhou and Parves Rana, 2012). Vegetation mostly impact air quality by dispersion and deposition i.e. they reduce source pollutant concentration by dispersion and act as a barrier between pollution source and receptor (Abhijith and Kumar, 2019), moreover they play as a deposition place in which pollutants deposit on their surface area created by leaves (Barwise and Kumar, 2020; Janhäll, 2015). From the results obtained by this study it can be implied that planting more trees, developing green land and parks which contribute to vegetation and more canopy cover will enhance air quality in mega city of Mashhad.

4. Conclusion

The vegetation area of Mashhad city relationship to have a clean, healthy and unhealthy days has been investigated. The Landsat 8 images has been used to calculate NDVI, EVI and OSAVI indices. All indices have approved that the total city vegetation has been increased from 2013 to 2019 by the average of all about 66%. The research showed that clean and healthy days are positively correlated to vegetation area and unhealthy days have negative correlation to vegetation area. With regards to the findings of this paper, it is suggested that increasing vegetation area and green space of the city directly affected the air quality and can increase the clean and healthy days.

For future researches, there are some recommendations. First, applying the proposed model in a very large-scale region like the all of Khorasan Razavi province is very difficult to calculate the indices. It is suggested to use recent advances in soft computing techniques like social engineering optimizer (Fathollahi-Fard et al., 2018) and red deer algorithm (Fathollahi-Fard et al., 2020c) etc. It goes without saying that merging the concept of blockchain and internet of things (Moosavi et al., 2021) in large cities with the green city concept can introduce the smart and green degrees for the cities.

Declarations

Conflict of interest statement

Not applicable.

Ethical Approval:

The authors declare that there is no conflict of interest.

Consent to Participate:

The authors declare that they agree with the participate of the journal.

Consent to Publish:

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Figures

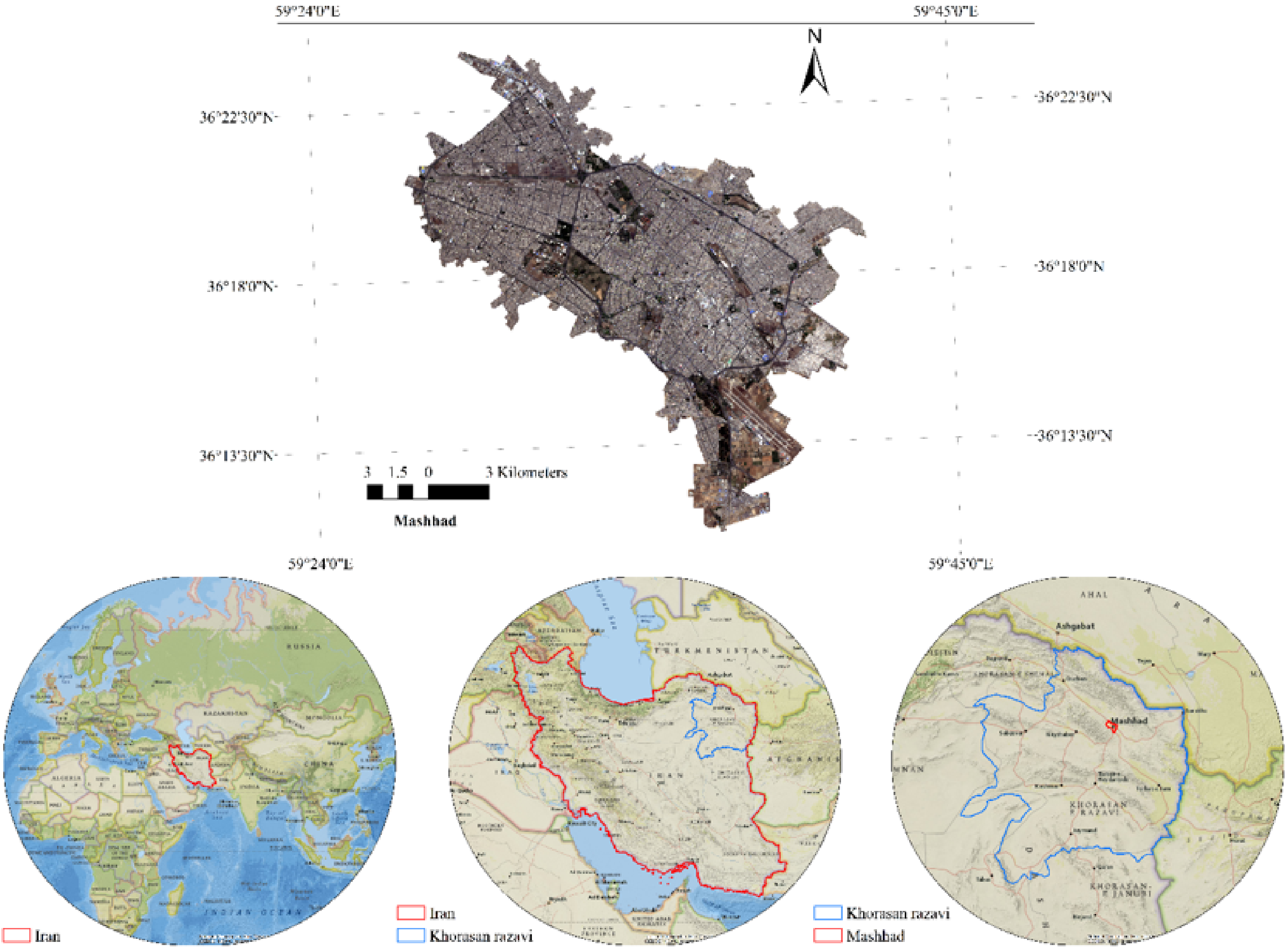

Figure 1

The geographical map of Mashahd city in Iran. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

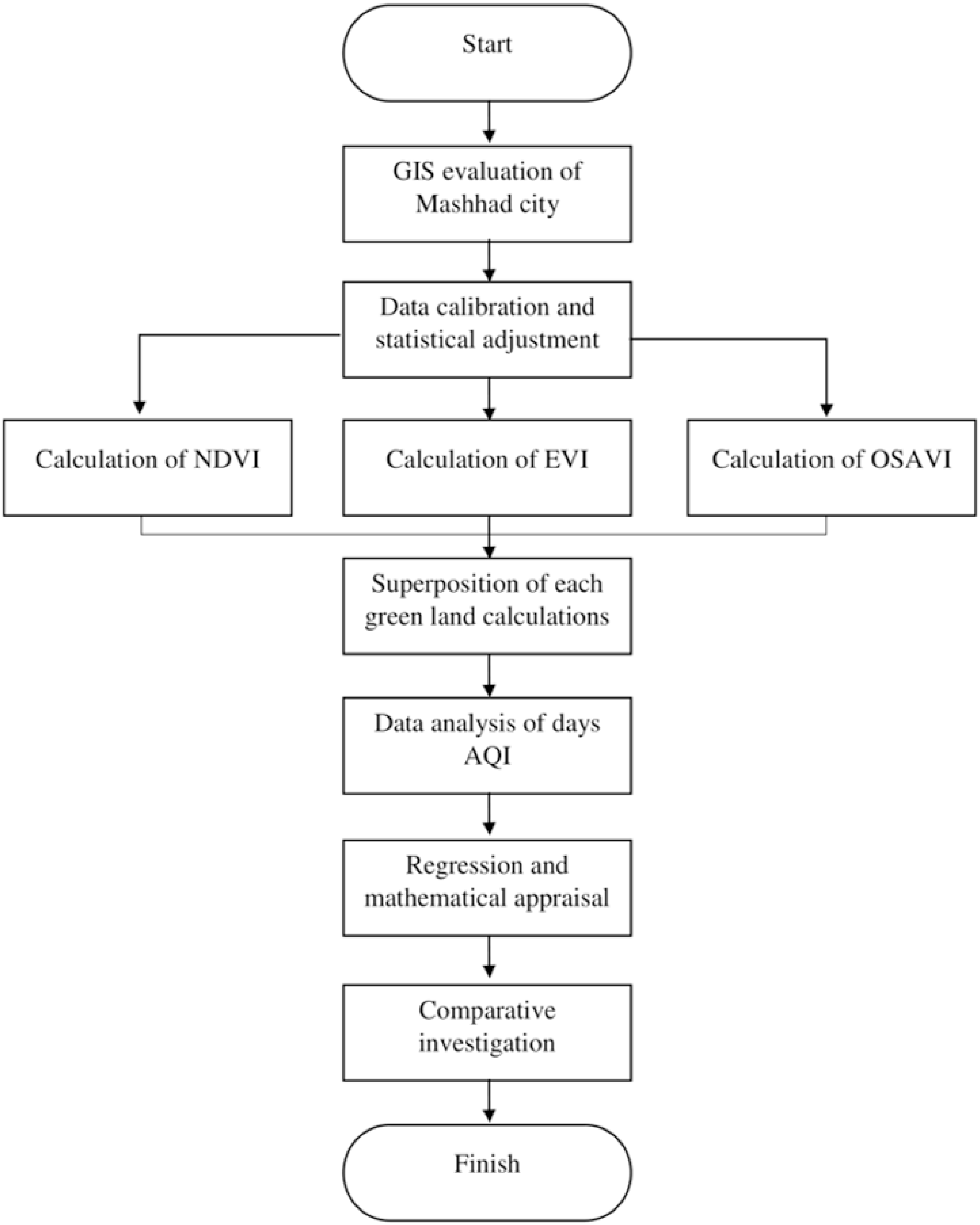

Figure 2

Research road map of present investigation

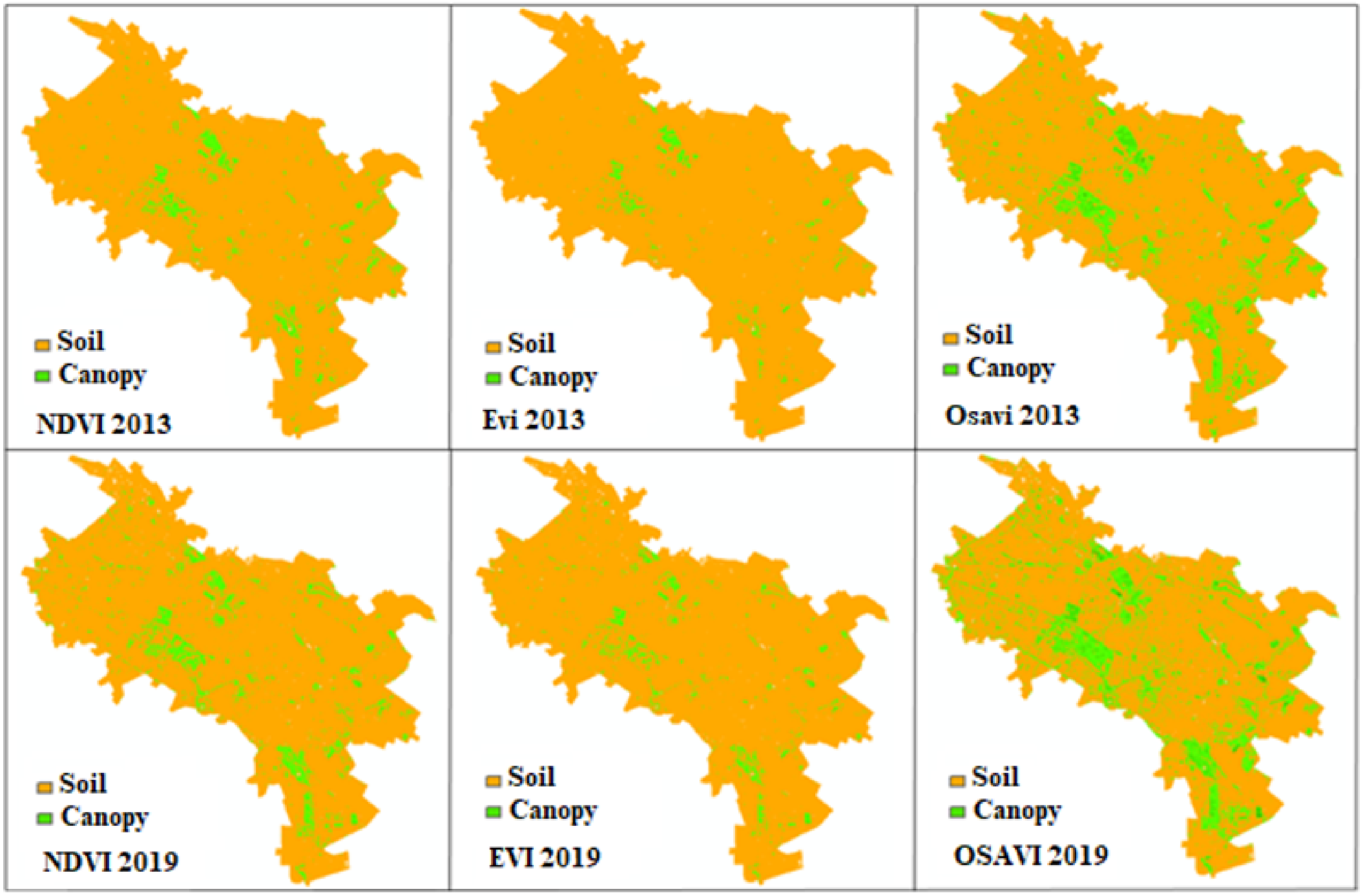

Figure 3

Mashhad vegetation cover during 2013 to 2019 by NDVI, EVI and OSAVI indices Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

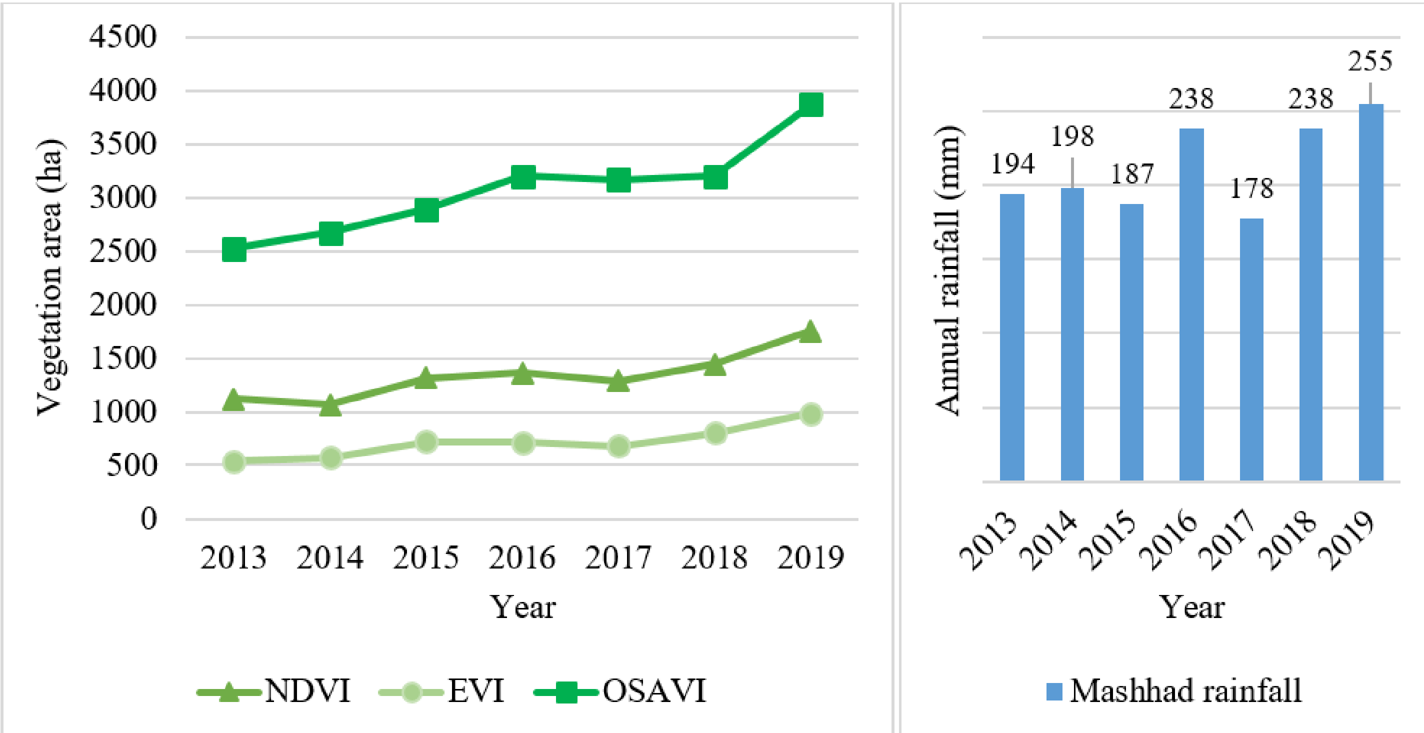

Figure 4

The total vegetation growth by NDVI, EVI and OSAVI index and Mashhad rain fall in each year of 2013 to 2019.

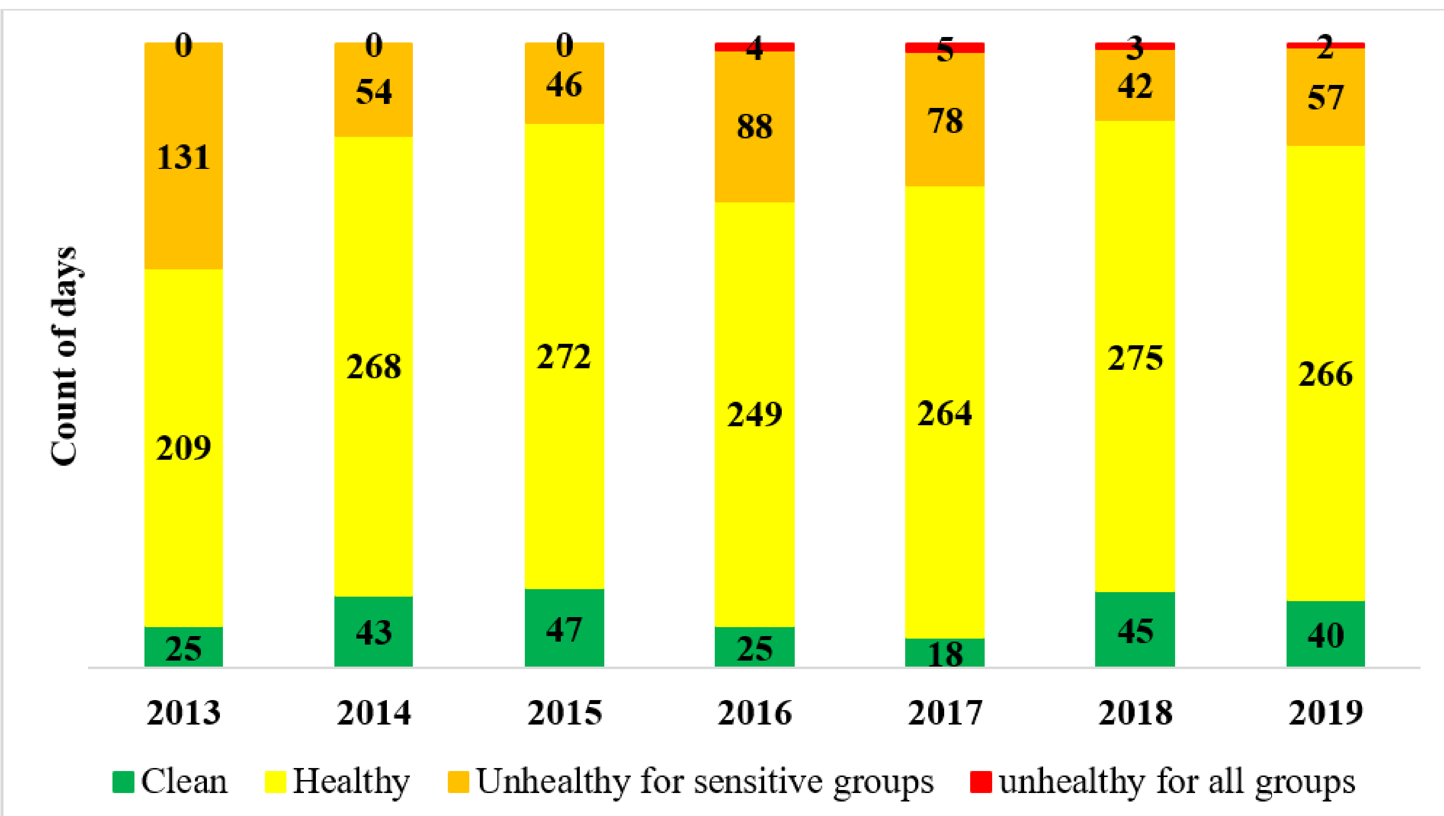

Figure 5

Mashhad clean, healthy and unhealthy days during 2013 to 2019.