Modeling the discovery of changes and prediction of land use using optical sensors with Land Change modeler method (Study area: west of Tehran)

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Abstract

In recent decades, due to rapid urbanization, there has been special attention to land use changes, as urban areas are influenced by human activities, and the lives of the world's population are closely linked to human activities at the urban level. This has led to an emphasis on how land use affects social, environmental, and economic aspects. In this context, large cities in Iran, like Tehran, are not an exception. This research evaluated the western region of Tehran regarding changes in vegetation cover as well as land use. The changes, or transformations, in land use classes or urban, agricultural, water, barren lands, and vegetation cover, such as gardens, were examined. The most significant changes among these have been the transformation of green spaces and agricultural areas into barren lands and subsequently into urban areas. However, in places like the Chitgar Forest Park and the National Botanical Garden, we have observed an increase in vegetation cover density. In this research, Landsat satellite images from 2013 and 2020 were used. We employed the method of maximum likelihood to classify land use into five categories: water, barren land, agriculture, vegetation, and urban areas. In the end, a map of changes for the year 2027 was prepared, and the conversion rates of different land uses were presented in a table. The results indicated that the use of urban areas in 2020 has increased compared to 2013, and it's forecasted that this trend will continue to rise in 2027. Agricultural land use decreased in 2020 compared to 2013, and it's expected to decline further in 2027. The use of vegetation cover also saw a reduction in 2020 relative to 2013, and this decrease is projected to carry on into 2027. Barren lands increased in 2020 compared to 2013, covering an area of 11,002,500 square meters, and it's anticipated that this will decrease by 2027. Lastly, the use of water bodies in 2020 decreased compared to 2013, and a further decline is expected by 2027.

Key word: West Tehran region, land use changes, LCM, NDVI

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Introduction

Land is a non-renewable resource that is directly affected by factors like population growth, both now and in the future. To use land properly, it's essential to understand land use changes and how humans utilize land, which can be achieved by making these changes visible (Farsi, Yousefi, 2013). Therefore, one of the environmental hazards and ecological crises the world faces today is the phenomenon of land use change (Mousavi et al., 2016). With the increasing human population and the industrialization of societies, significant changes in land use have occurred (Saadi and Avatefi Akmal, 2018). Land use units are constantly changing under the influence of natural events, human activities, and social and economic issues, especially around major cities. In these changes, various lands are transformed into developed areas, including residential, commercial, industrial, or transportation networks, and in some cases, are left as barren lands (Mohammad-Ismail, 2010). Detecting changes is a process that allows for the observation and identification of differences and temporal discrepancies in phenomena, landforms, and surface patterns (Luo et al., 2004). The pattern of land use is constantly changing due to increased human activities and manipulation of land to meet diverse needs. Urbanization, with the most extensive human alterations to the natural landscape, has put the living conditions of urban residents at risk of threat and destruction. In any case, urban development and changes in land use patterns lead to extensive social and environmental impacts. These impacts include the reduction of natural spaces, an increase in vehicle congestion, a decrease in high-yield agricultural land, effects on natural drainage systems, and a decline in water quality (Kamiyab et al., 2011). Assessing land use change trends and calculating the negative and positive impacts of these transformations using the LCM method and remote sensing data allows for the computation and preparation of practical maps and necessary information. Nowadays, land use change (LUC) is one of the most significant challenges in the management of natural and human resources within urban and rural areas; therefore, the key priority for urban planners and regional authorities is to be aware of these changes. The LCM program is essentially a tool for land management and planning, as well as a decision-support tool. This model is widely used to prioritize planning challenges and environmental protection. The land change model allows users to quickly analyze land use changes and predict future land use scenarios under various conditions while modeling the impacts on species and biodiversity. With its automated and user-friendly execution, the land change model has simplified complex analyses related to land use changes, resource management, and habitat assessment. This model, which is fully integrated with the GIS software, provides multiple facilities for comprehensive and consolidated analyses of land use changes.

The land use change modeling provides a complete analysis of land changes by creating maps of land use changes, charts, land use class transitions, and their trends. Additionally, it is capable of generating land change scenarios by integrating biological, physical, social, and economic factors that influence land use changes. Land Change Modeling (LCM) is one of the modern and widely used models for analyzing land and forecasting future land use changes. Moreover, this model equips researchers to analyze and measure the impacts of projects on habitats and biodiversity. It includes a set of smart tools that deal with the complexity of land use change analysis, resource management, and habitat assessment. This model can create land use change scenarios by integrating biological, physical, and socio-economic factors that affect land use change and is embedded as a vertical program in IDRISI and TerrSet software systems. TerrSet is the latest version of IDRISI software, released in 2015 by Clark University, Worcester, MA, United States (Hatami, 2021).

Research Background

Hosseini et.al (2013) studied the prediction of land use changes using the LCM model, analyzing land use changes based on three scenarios: agricultural, conservation, and a scenario of limited changes in the Deylaman region of Gilan province. The results indicated that management based on the limited changes scenario could lead to better conservation of natural ecosystems and prevent their conversion into agricultural land.

Arkh (2013) utilized Landsat 4 TM images from 1988, Landsat 7 ETM^+ images from 2001, and Landsat 7 TM images from 2011 to analyze five land cover classes: forest, pasture, barren land, agricultural land, and residential areas at three time intervals using the LCM model, based on artificial neural networks and the Markov chain in the Sarabaleh region of Ilam. During the period from 1988 to 2011, 14,691 hectares of forest were destroyed, and barren land expanded by 9,874 hectares compared to its initial area. The forested areas in 2021 are expected to decrease compared to 2011, while barren lands will increase.

Ashoori and (2014) used MSS satellite images from 1984 and TM from 2003 to determine vegetation cover changes in the rangelands of the Seydan watershed. In this study, the LCM change modeling approach was used for monitoring changes. To classify land use for the years 1984 and 2003, the maximum likelihood algorithm was employed. Comparing and monitoring land use changes indicated that between 1984 and 2003, forest and rangeland areas experienced the most negative changes, while barren lands saw the most positive changes. This trend can be attributed to the shift of these land uses towards the development of drylands and gradually moving towards the abandonment of these dry farming areas.

Naranghi et.al (2014) conducted a study aimed at assessing land use changes and vegetation cover percentages in the city and surrounding areas of Yasuj. In this research, land use maps and NDVI index were created using Landsat TM satellite images from December 21 and 22 of 1998 and 2010, as well as June 13 and 14 of 1987 and 2010. The results showed that the largest area in cell 1986 was attributed to barren land use, with 14.2 square kilometers, followed by residential use with 3.26 and green space with 2.15 square kilometers, which had the least area. In 2010, the most significant land use was residential with an area of 10.27 square kilometers, followed by barren land at **8.68** square kilometers, and the least amount was attributed to vegetation cover with 0.66 square kilometers. The greatest changes were in residential land use with a 7 square kilometer increase.

Mirzapor (2016) examined the performance comparison of CA-Markov, Geomod, and LCM models in predicting land use changes in the watershed of Badaavar, Noorabad, Lorestan. After executing the models, the simulation results were compared and aligned with ground reality maps. The results showed that the CA-Markov, LCM, and Geomod models had Kappa coefficients of 0.97, 0.99, and 0.84, respectively, indicating a very high accuracy of the LCM model in the studied region.

Kavian (2017) conducted a study aimed at predicting land use changes in the Haraz watershed using logistic regression and Markov chain. To create the land use map for the study area, the maximum likelihood algorithm and images from Landsat TM L5, ETM^{+} L7, and L8 OLI for the years 1988, 2000, and 2013 were used. The potential transfer modeling was done using the land change modeler and logistic regression method. To forecast land use for the year 2025, calibration periods of 2000-1988, 2000-2013, and 2013-1988 were utilized with the Markov chain and hard prediction model. The results from the land use model for the year 2025 indicated that the areas of forest and pasture land would decrease by 2,978.18 and 6,367.41 hectares, respectively, compared to 2013, while irrigated agriculture, residential land, gardens, and areas without vegetation would increase by 391.86, 29.38, 1,453.42, and 7,214.94 hectares, respectively.

Mohammadiyari et.al (2019) conducted a study evaluating the changes in urban expansion of the metropolitan city of Karaj using Landsat satellite images over the period from 2006 to 2017. To create maps of land use for the years 2006, 2011, and 2017, they utilized Landsat satellite images. They then examined and analyzed the changes in the trend of urban expansion using the LCM model in the Terraset software during two time periods (2006-2011) and (2017-2011). According to the results, in both studied periods, the area of developed land increased. Additionally, in both periods, agricultural lands experienced the greatest degradation among land uses to be converted into developed areas.

Zabardast and DarsKhan (1400) conducted a study to explain the factors contributing to achieving environmental sustainability in the urban management structure of the metropolis of Tabriz. After analyzing the data, they developed 4 categories, 20 subcategories, and 99 sub-subcategories. Economic, cultural-social, institutional, and environmental-spatial capacities were defined as the components necessary for achieving sustainable development for the first time within the urban management framework of Iran's metropolises. As a result, to reach sustainable development, significant attention must be given to the urban management structure.

Bakshi et.al (1401) examined the role of urban growth patterns in creating heat islands in urban areas of the city of Sari. The results of their research indicated that the formation of heat islands in Sari depends on both types of urban growth, and the establishment of heat zones is significantly related to land cover, population density, and building density. Additionally, most of the current heat zones in Sari comprise areas that were added to the city in past decades.

Marwasta (2019) examined the spatial trends of physical growth in cities in Java, Indonesia, from 1995 to 2015. Based on the results of the analysis, it was found that the physical growth of cities in Java underwent relatively diverse changes in the dimensions of urban settlements, infrastructure, and urban functions (Marwasta, 2019).

Hasyim et.al (2019) studied the spatial patterns of land cover change in the coastal area of the Gresik Regency, Indonesia, using land change modeling. They utilized LCM to observe land cover change patterns before and after the implementation of regional spatial plans (RTRW) from 2002 to 2012. The results showed that from 2002 to 2007, there was an increase in built-up areas, while green open spaces and vacant land had decreased.

Surya et.al (2021) investigated land use changes, urban density, and urban expansion, focusing on the sustainable development landscape of Makassar city in Indonesia. The results indicated that the expansion of the Makassar city boundary into the suburbs had an impact on spatial dynamics, spatial segregation, and environmental degradation. Additionally, urban sprawl, land use change, urban density, activity systems, and transportation systems showed a strong positive correlation of 85.9 percent with the degradation of environmental quality.

Research Methodology

Study Area

Tehran province, with Tehran city as its capital, covers an area of 13,841 square kilometers and is situated between 34 to 36.5 degrees north latitude and 50 to 53 degrees east longitude. This province borders Mazandaran province to the north, Qom province to the south, Markazi province to the southwest, Alborz province to the west, and Semnan province to the east. The population of this province in 2019 was over 13 million, which accounts for 17.5% of the total population of the country (Timouri et al., 1402). The area under study in this research is West Tehran. This area is bounded to the north by the Alborz mountains, to the east by Municipal District 5 of Tehran, to the west by the Varamin northern limits, and to the south by the Tehran-Karaj highway. The area is approximately 6,200 hectares, of which about 1,300 hectares are designated as green spaces. Figure 1 shows the location of the study area.

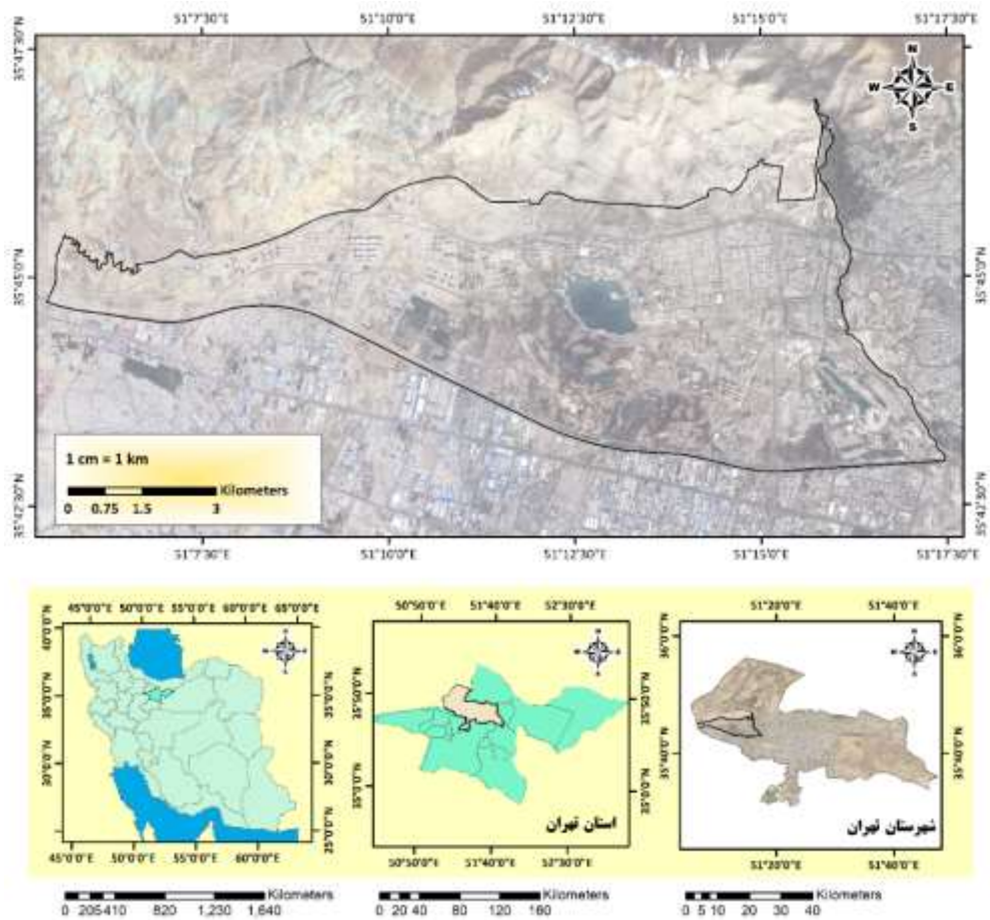


Figure 1: Geographic location of the study area

Research Methodology

The methodological dimensions are one of the crucial components in any research topic. The credibility of the research depends on how the research methods and techniques are utilized. A method refers to the ways and strategies employed for understanding the research and avoiding pitfalls. The current research method is analytical-descriptive.

Data Used

In this research, satellite images from Landsat 8 were used to examine land use changes in the study area. These important data sources were obtained from the internet site gov.usgs.glovis for various time series for the years 2013 and 2020, covering the area under investigation in the specified years. They were processed and analyzed at different stages using the capabilities of the Envi software. Table 1 shows the specifications of the images used.

Table ١: Specifications of the images used in the research

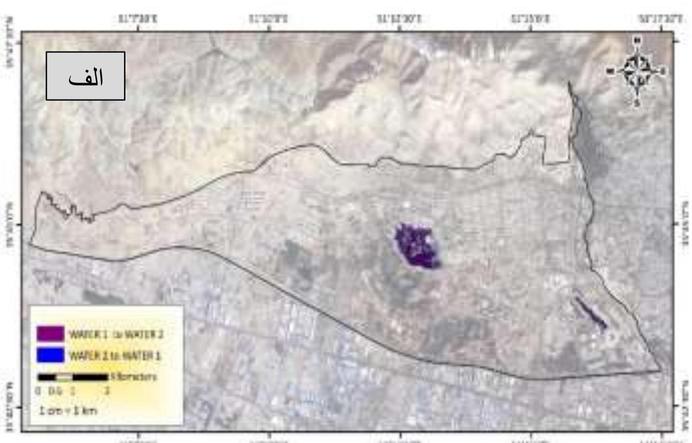
Date	Sensor
2013	**Landsat 8**
2020	**Landsat 8**

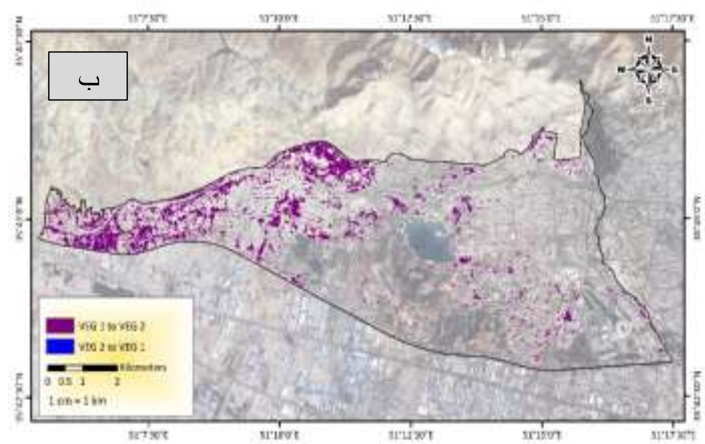
Data preprocessing, which is one of the most important factors influencing the use of satellite images, is utilized to prepare images for the main processing stages (Fatemi and Rezaei, 2017). Landsat satellite images generally have geometric corrections, good quality, recorded in accordance with orbital parameters, and have geographic coordinates. Initially, the necessary processing on Landsat 8 data was conducted in ENVI software, including all preprocessing and corrections such as radiometric and atmospheric adjustments. Following that, the area of interest was clipped, and the types of land cover, agriculture, barren land, water, and urban and residential areas were identified from the region. Classification was carried out using the maximum likelihood method. The normalized vegetation index was also calculated. After this stage, change modeling was explored using the TRIS software, and the LCM model was applied to the classified data. Predictions for changes in 2027 were made using the CA-Markov model.

Research and Results

Modeling Land Use Changes with LCM

We used land use maps created through a maximum likelihood classification method, followed by classifying the changes in the five land use types: water, barren land, agriculture, vegetation cover, and urban areas, using the TERRSET software. Two large water bodies can be seen in the study area: on the right side is the lake near the Azadi Sports Complex, and in the center of the map is the large Chitgar Lake.





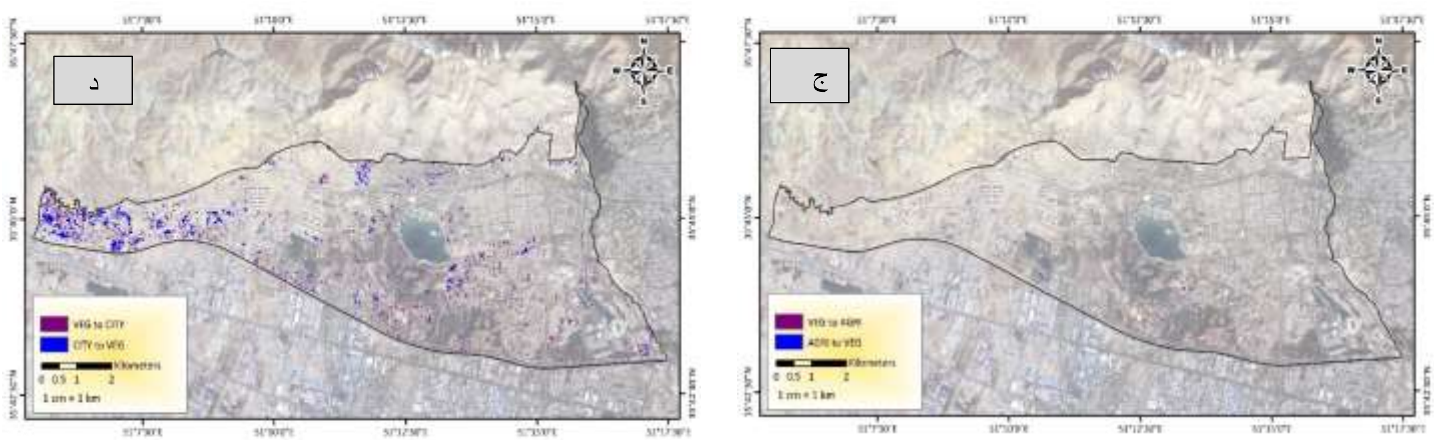


Figure 2: a) Changes in water body area b) Changes in vegetation cover c) Changes between vegetation cover and urban areas d) Changes between vegetation cover and agricultural land

In figure 2 (b), broader changes in vegetation cover are visible in the western parts of the region. Very few pixels show changes from vegetation cover to agriculture and vice versa (figure 2, (d)).

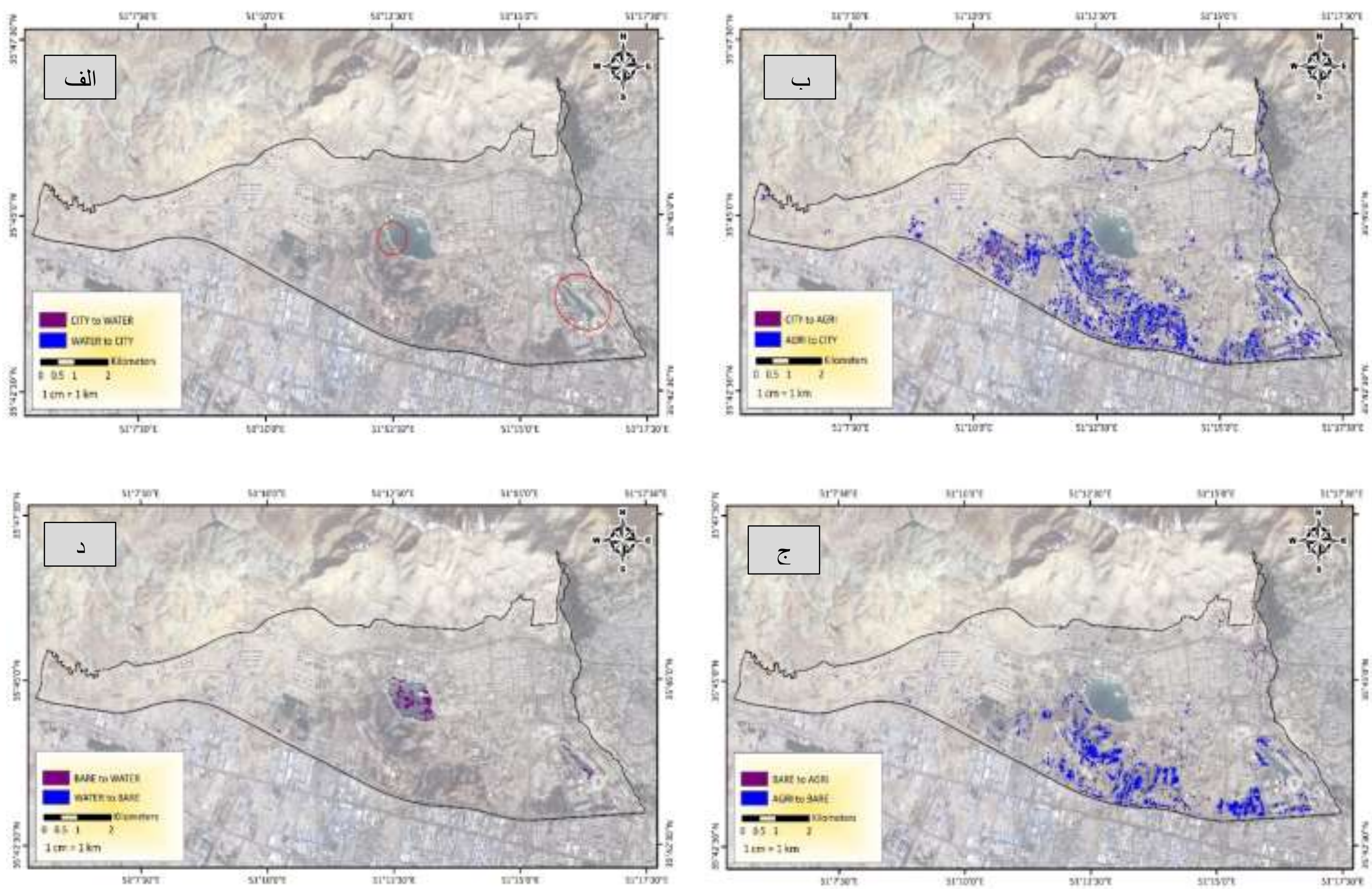


Figure 3: a) Changes from water bodies to urban areas b) Changes from urban areas to agricultural land c) Changes from barren land to water bodies d) Changes from barren land to agricultural land

As shown in Figure 3 (a), during this period, we haven't seen significant changes in the transformation from urban areas to water bodies. A large part of the land use changes were from agricultural land to urban areas, which can be seen in Figure 3 (b). Most of the changes occurred in the central and southern parts of the region. In Figure 3 (c), you can see a representation of the changes between agricultural land and barren land, and vice versa. The land use changes that took place that year have led to the current outcome. One aspect that needs more attention is that the changes are mostly geared towards converting to an environment that ultimately leads to urban uses (residential, commercial, etc.). In Figure 3 (d), you can also see the transformations from water bodies to barren land.

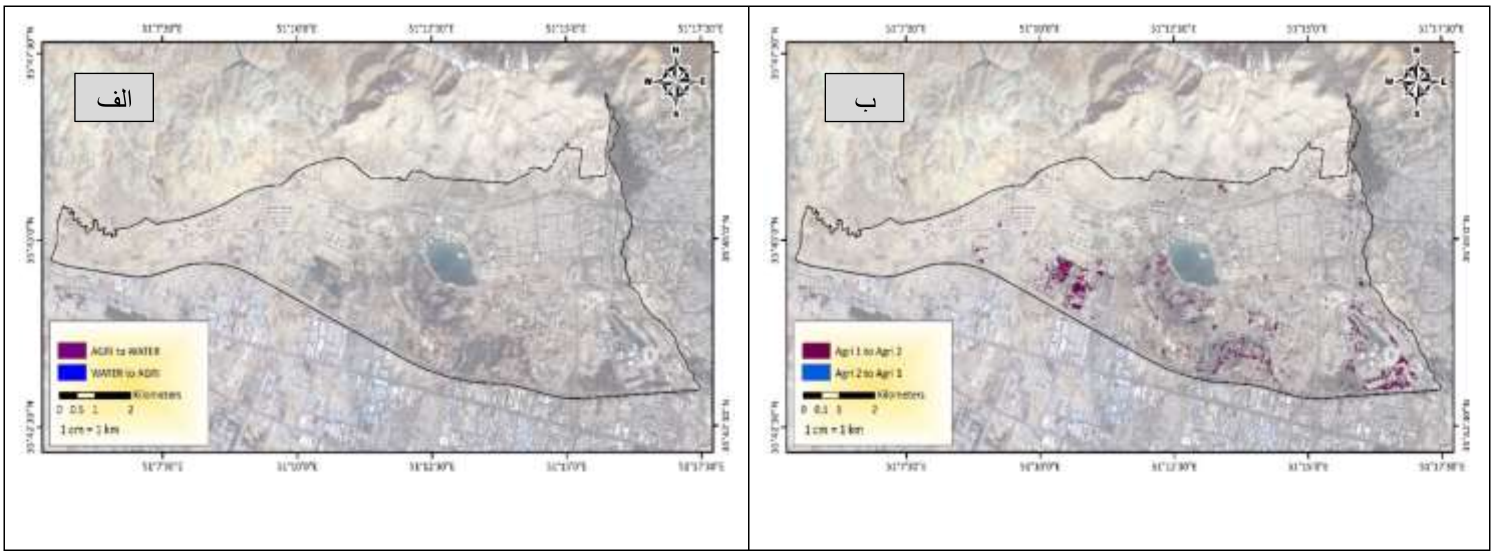


Figure 4: a: Transitions from agricultural land to water area b: Transitions from agricultural land to agricultural land

According to the results shown in Figure 4 (a), there aren't significant changes in the transitions from agricultural land to water area, and the results depicted in Figure 4 (b) indicate that agricultural changes have mostly involved the transformation and alteration of the appearance of agricultural lands. Following this, maps showing the trends in these changes are also provided, illustrating the nature and extent of changes along with the maximum and minimum changes in various sections of the area. We have mostly observed transitions from agricultural land to fallow land (a) particularly in the southern and southeastern parts of the studied area.

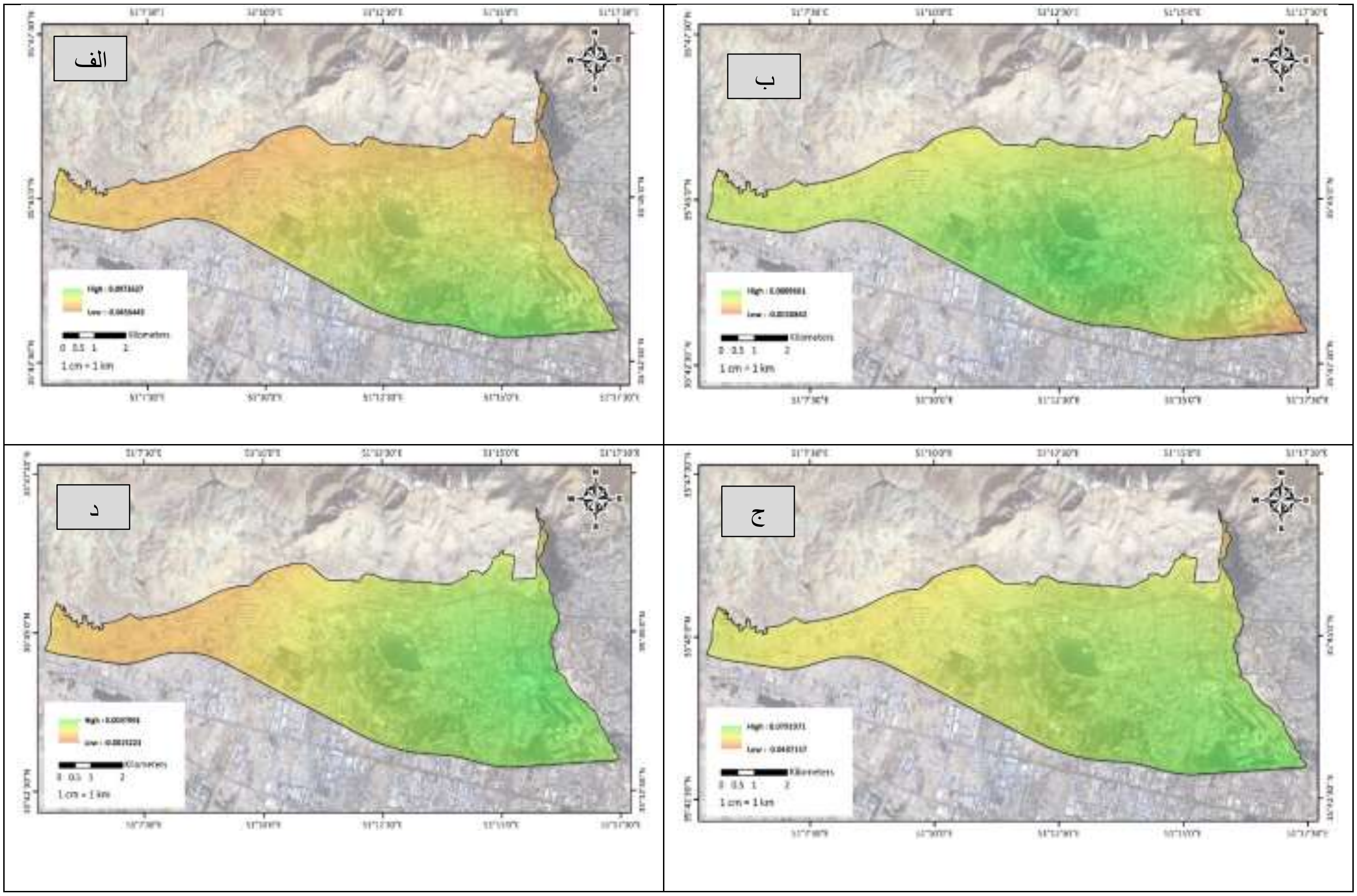


Figure 5: a: trend of agricultural area changes to barren land b: trend of agricultural area changes to vegetation cover c: trend of barren land changes to agriculture d: trend of barren land changes to urban

In Figure 5, the trend of changes in vegetation cover and agricultural area to vegetation cover in the southern and central parts of the studied area is shown. A small portion of barren land has been converted to agriculture (c), which is indicated in the eastern part of the area. The heaviness of the transition from barren land to urban (d) is felt more in the eastern and southeastern regions.

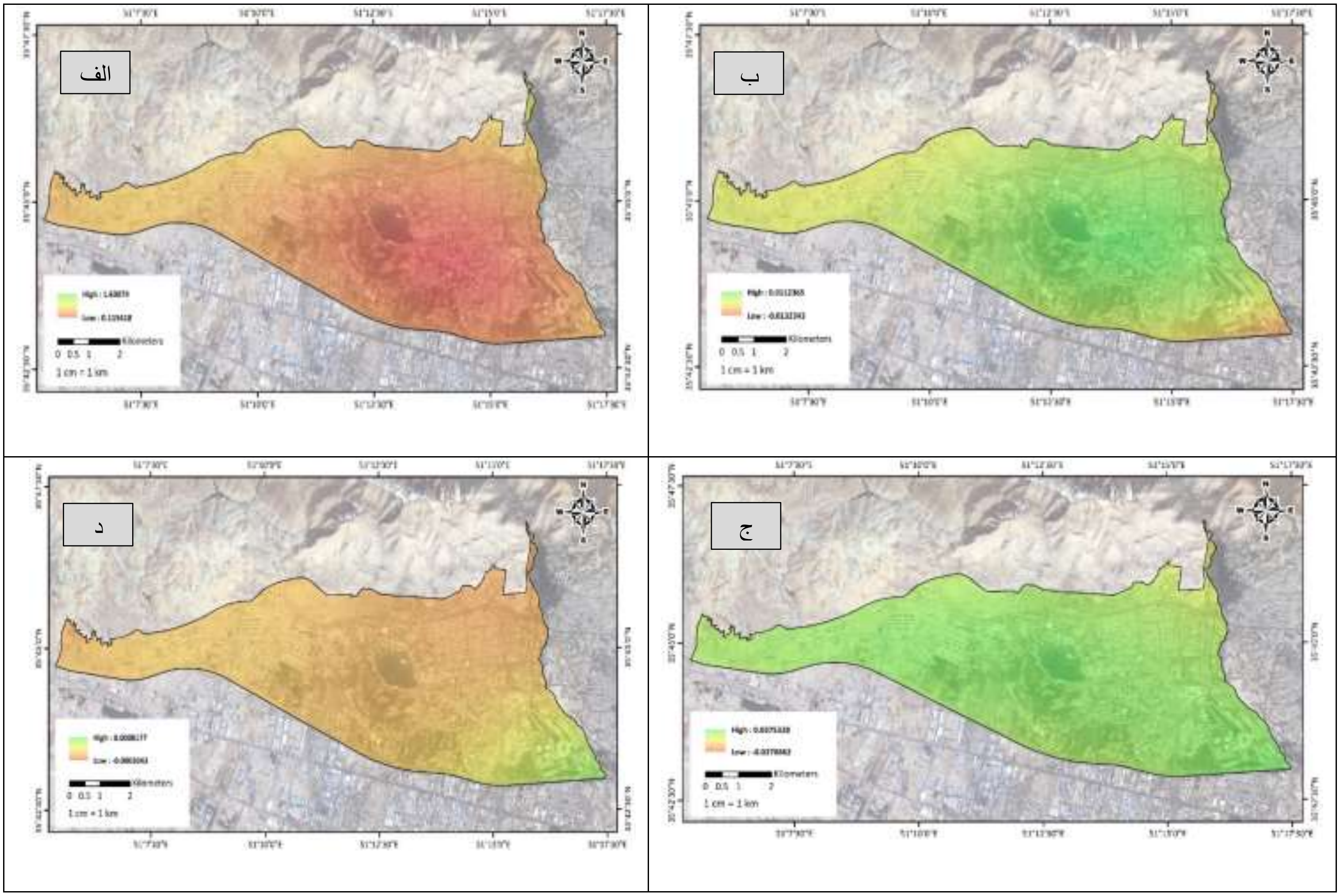


Figure 6: A: Trends in the conversion of barren land to vegetation B: Trends in the conversion of barren land to water bodies C: Trends in the conversion of vegetation to agriculture D: Trends in the conversion of vegetation to barren land

In the conversion of barren land to vegetation (A), no specific trend has been observed, and these changes have been virtually nonexistent. The intensity of changes from barren land to water bodies (B) is noticeable in the center of the area and around Chitgar Lake. Almost throughout the region, the trend of changes from vegetation to barren land (D) is observed uniformly.

The changes and developments are as follows.

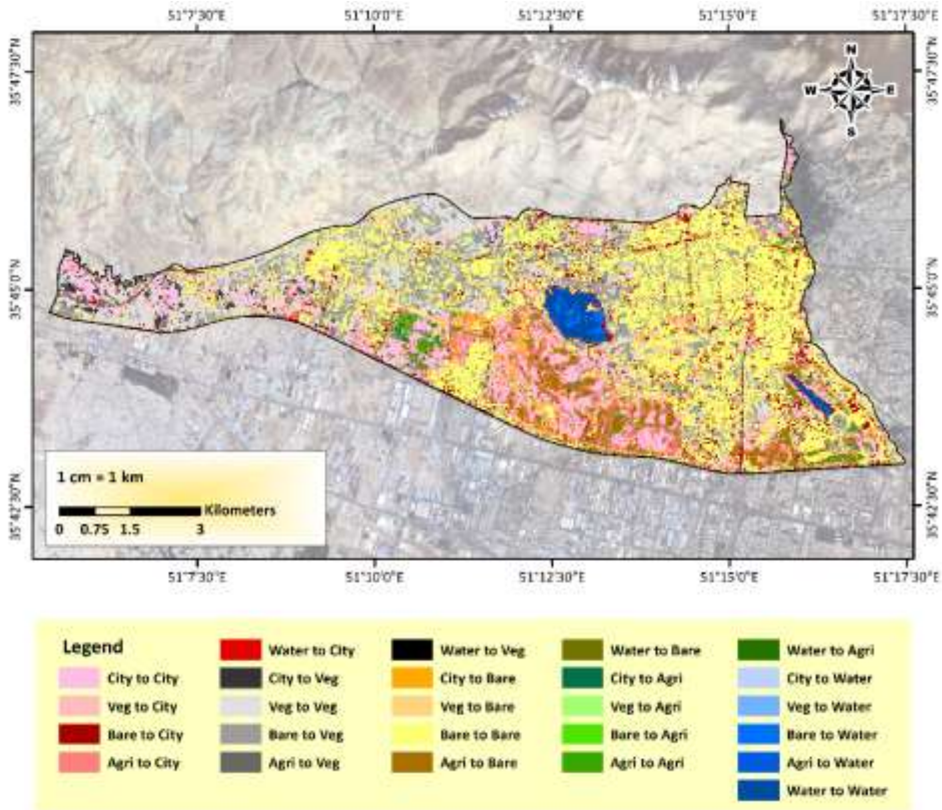


Figure 7: Changes in the land uses under study

Normalized Difference Vegetation Index (NDVI)

Each image was classified into five categories as follows:

- No vegetation
- Low vegetation
- Moderate vegetation
- High vegetation
- Very high vegetation

The changes can be seen in Figure 8:

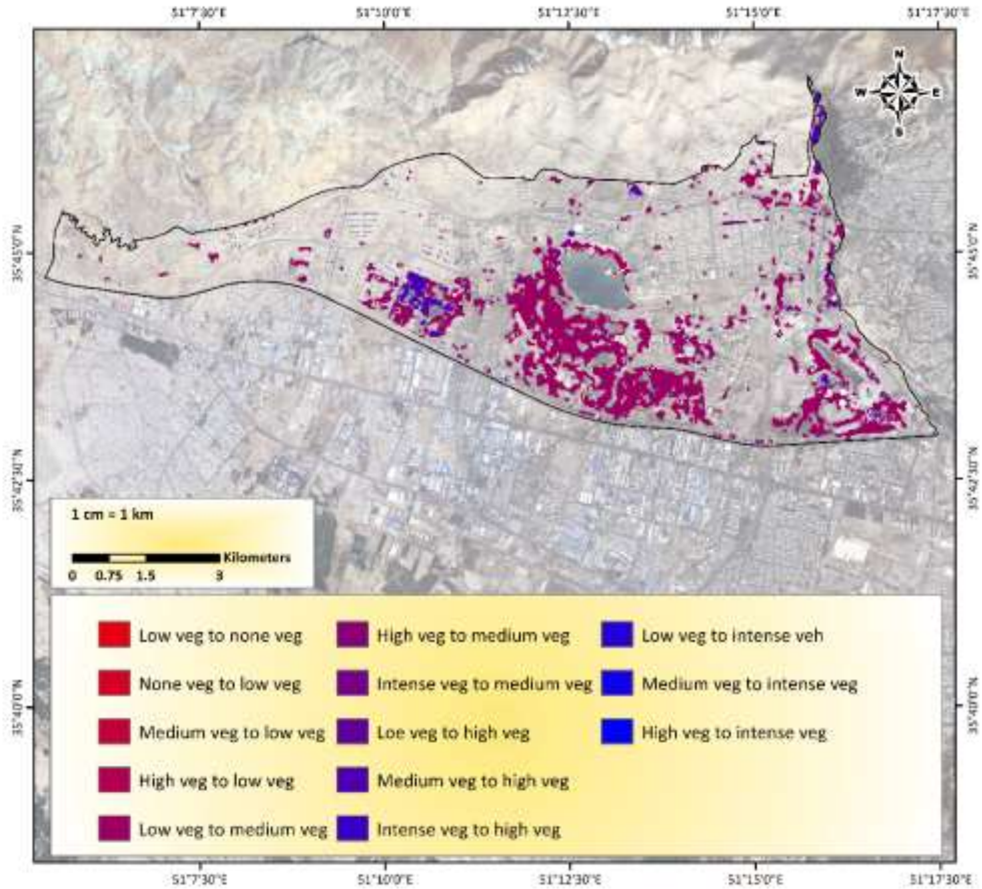


Figure 8: Changes in NDVI Index Classes

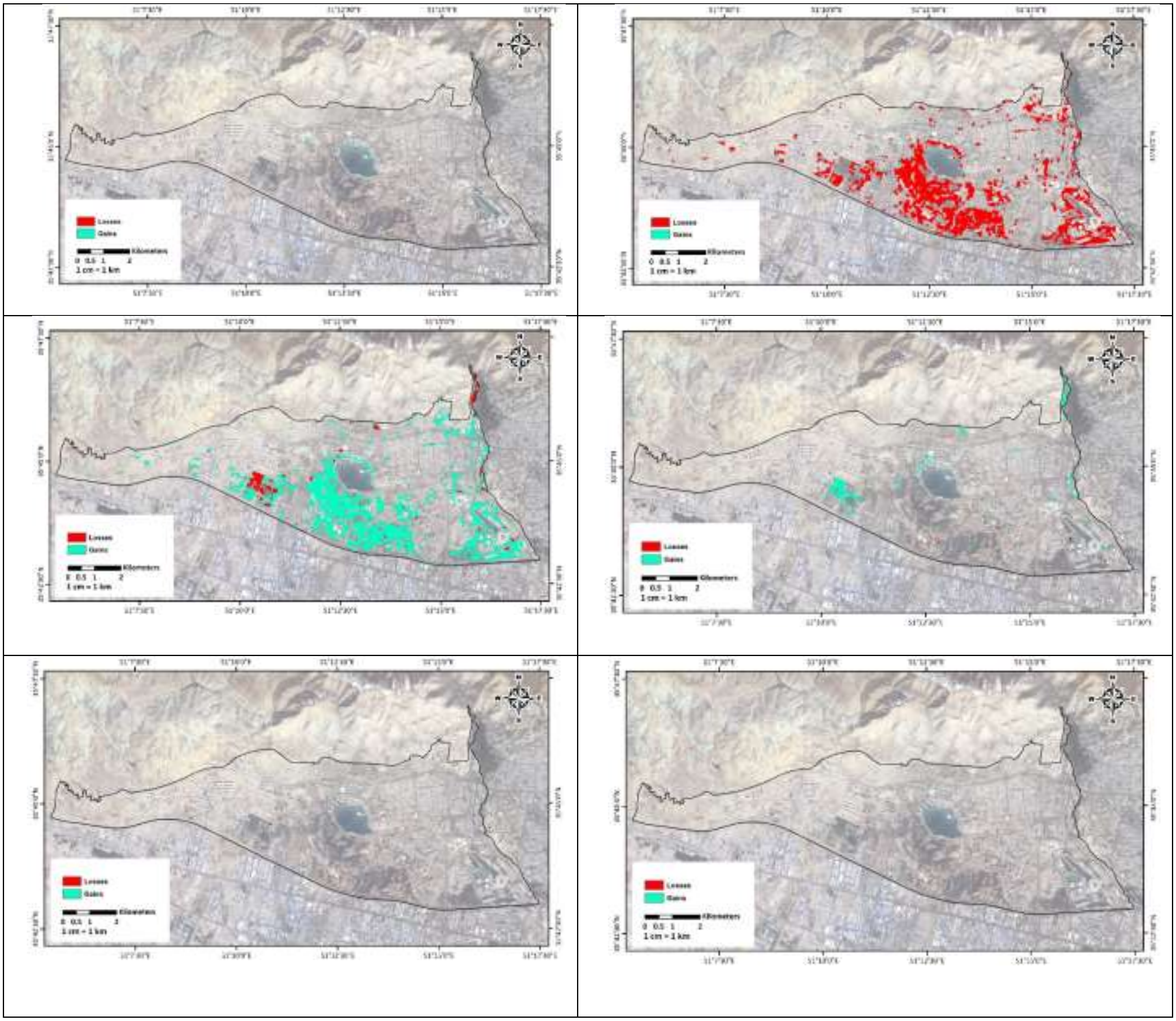


Figure 9: A: Increase and decrease of classes without vegetation B: Increase and decrease of low vegetation coverage class C: Increase and decrease of medium vegetation coverage class D: Increase and decrease of high vegetation coverage class E: Increase and decrease of very high vegetation coverage

The instances of increase and decrease for each class can be seen in Figure 9. The reason for focusing on the trend of changes from low to medium vegetation coverage is due to the significant transformations between these classes.

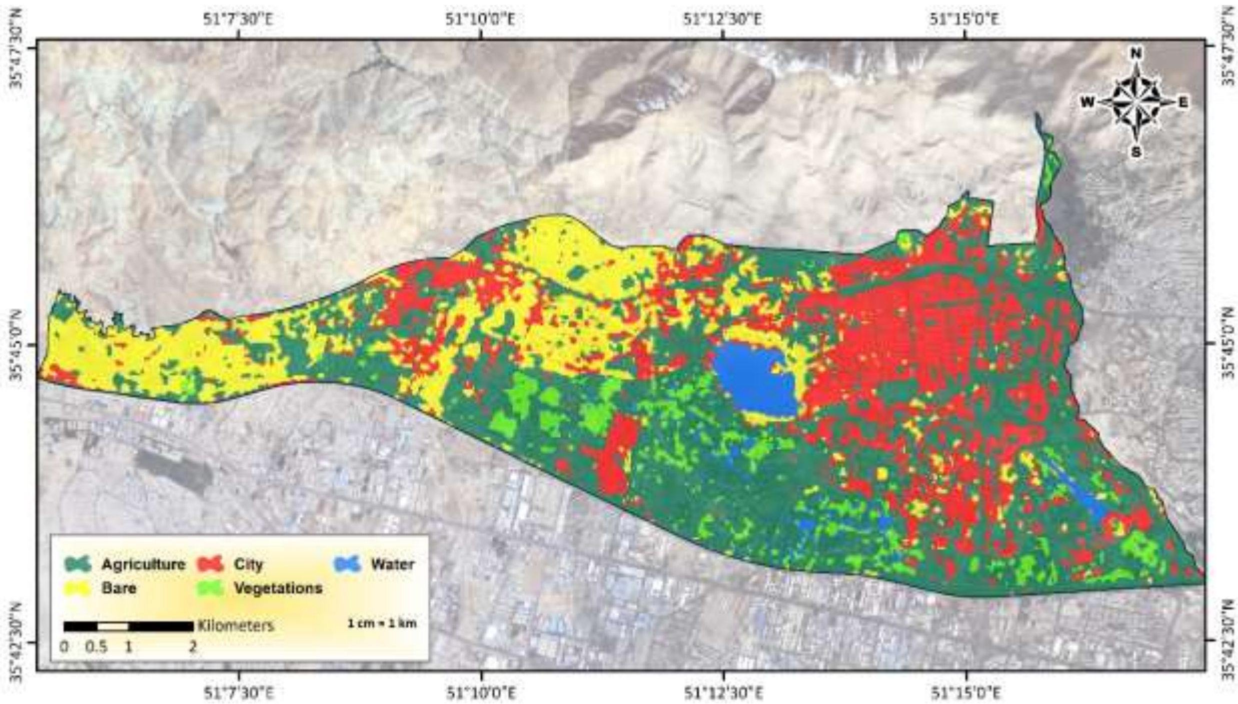


Figure 10: Final classification map of land use changes in 2013

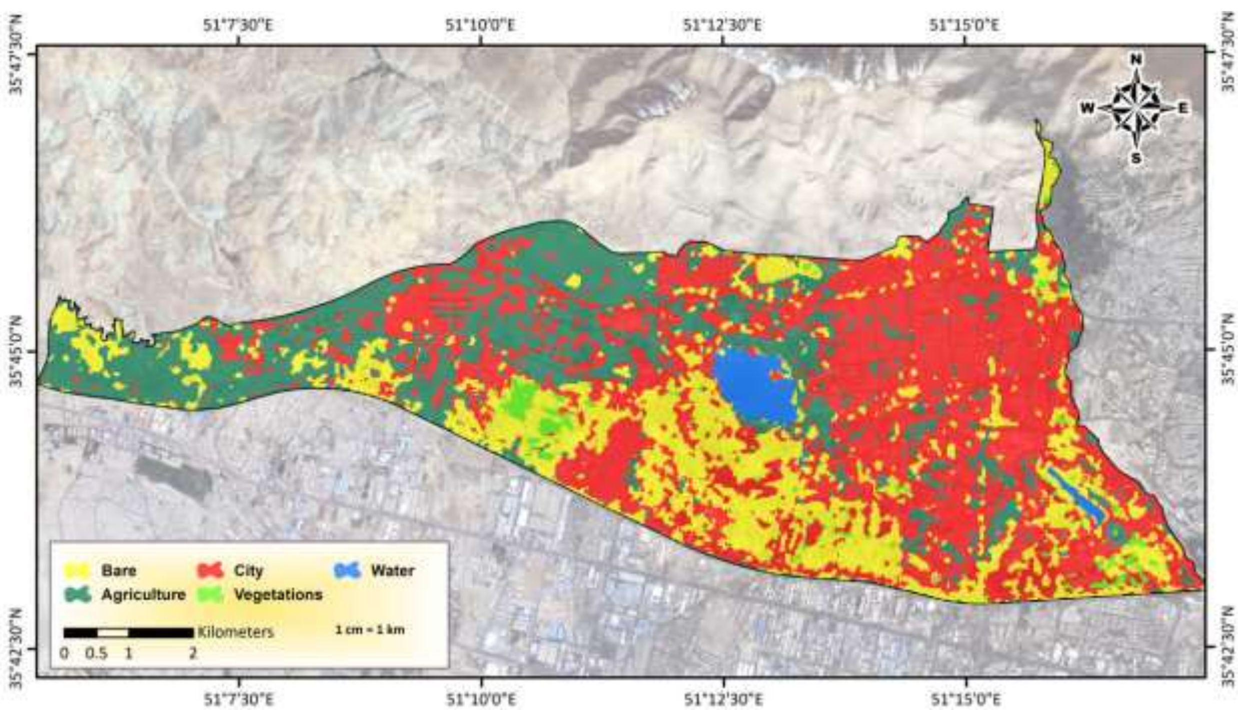


Figure 11: Final classification map of land use changes in 2020

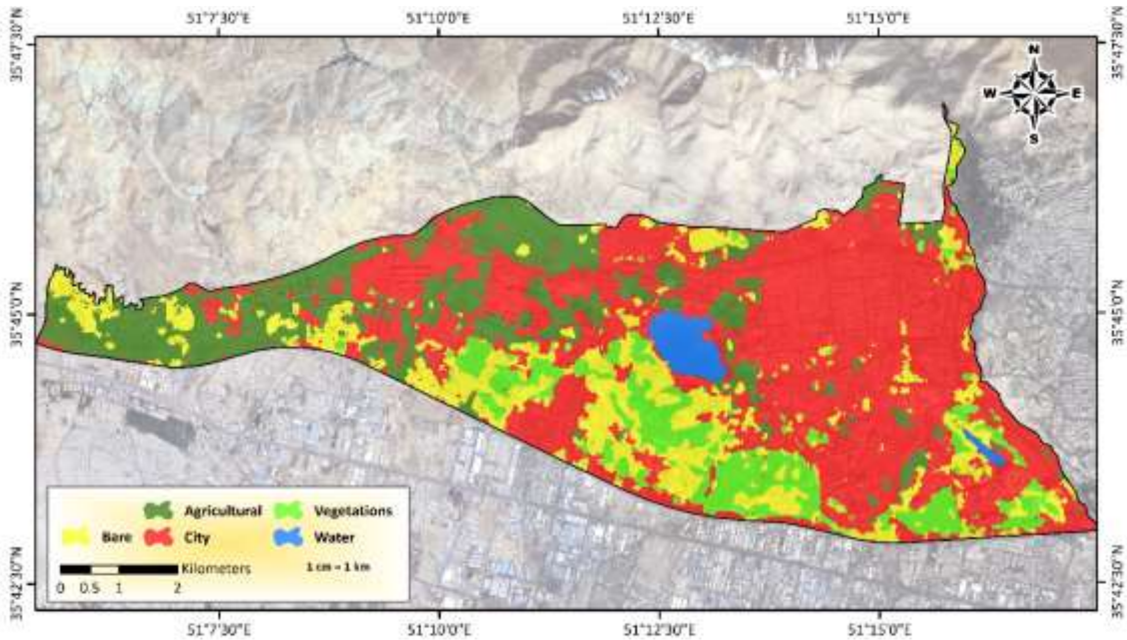


Figure 12: Final classification map predicting land use changes in the area for 2027

Table ۲ shows the amount of changes in the specified land uses.

Table ۲: Amount of area changed for land uses in 2020, 2013, and 2027

measured (square meters)	**Land Use Classes in 2013**
۱۴۱۷۸۶۰۰	**Urban**
۲۸۰۴۴۹۰۰	**Agricultural**
۳۱۹۸۶۰۰	**Vegetation**
۱۱۰۰۲۵۰۰	**Barren Land**
۸۰۴۷۰۸۰	**Water Bodies**
measured (square meters)	**and Use Classes in 2020**
۲۶۷۳۹۹۰۰	**Urban**
۱۵۳۵۴۰۰۰	**Agricultural**
۱۰۵۶۶۰۰	**Vegetation**
۱۴۰۱۲۱۰۰	**Barren Land**
۱۲۳۳۹۰۰	**Water Bodies**
measured (square meters)	**and Use Classes in 2027**
۲۹۷۰۲۷۰۰	**Urban**
۱۱۹۰۸۸۰۰	**Agricultural**
۵۹۵۴۴۰۰	**Vegetation**
۹۶۸۴۹۰۰	**Barren Land**
۱۱۴۵۷۰۰	**Water Bodies**

In the present study, similar to other research in the field discussed briefly in the literature review section, various land-use classifications were conducted, and the results were presented using maps. Given that this research focused on the western region of Tehran, where no previous studies have been conducted, it stands out compared to other similar works. Furthermore, due to the use of Google Earth Engine systems and the classification points collected through Google Earth, this study offers innovation and advantages over previous research.

Conclusion

Urbanization has been the most significant human activity of the 20th century, with approximately 50% of the world's population now living in cities (Farrokh, 2020). Today, the complexities surrounding our living environments are rapidly increasing. Sustainable management of natural resources requires regular and up-to-date monitoring to plan for their conservation. Examining past changes in a region and predicting future changes helps improve planning toward the region's sustainable development (Ansari-Fard, 2019). Knowledge of the types and percentages of various land uses and coverages is essential for understanding and managing a region. One of the effective, useful, and applicable sources of information for identifying land cover and its changes is remote sensing data. In this study, Landsat 8 images from 2013 and 2020 were used to analyze land use and achieve the required classifications. In the land use classification using Landsat 8, five classes were identified: urban, barren, agricultural, vegetation, and water bodies. As shown in Table 3, the extent and area changes of these land uses were specified. In 2013, the urban area covered 14,178,600 square meters, which increased to 26,739,900 square meters in 2020, and is projected to reach 29,702,700 square meters by 2027. Agricultural land covered 28,044,900 square meters in 2013, decreased to 15,354,000 square meters in 2020, and is expected to reach 11,908,800 square meters by 2027. Vegetation land covered 3,198,600 square meters in 2013, dropped to 1,056,600 square meters in 2020, and is projected to expand to 5,954,400 square meters by 2027. Barren land covered 11,002,500 square meters in 2013, increased to 14,012,100 square meters in 2020, and is expected to decrease to 9,684,900 square meters by 2027. Water bodies covered 8,047,080 square meters in 2013, reduced to 1,233,900 square meters in 2020, and are projected to reach 1,145,700 square meters by 2027.

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مدل‌سازی کشف تغییرات و پیش‌بینی کاربری اراضی با استفاده از حسگرهای نوری با روش Land Change Modeler منطقه مورد مطالعه: غرب تهران

چکیده:

در دهه‌های اخیر، به دلیل شهرنشینی سریع، توجه ویژه‌ای به تغییرات کاربری زمین شده است، زیرا مناطق شهری تحت تأثیر فعالیت‌های انسانی قرار دارند و زندگی جمعیت جهان ارتباط نزدیکی با فعالیت‌های انسانی در سطح شهر دارد .این امر منجر به تأکید بر چگونگی تأثیر کاربری زمین بر جنبه‌های اجتماعی، زیست‌محیطی و اقتصادی شده است .در این زمینه، شهرهای بزرگ ایران، مانند تهران، نیز از این قاعده مستثنی نیستند .این تحقیق منطقه غرب تهران را از نظر تغییرات در پوشش گیاهی و همچنین کاربری زمین ارزیابی کرد .تغییرات یا دگرگونی‌ها در طبقات کاربری زمین یا کاربری شهری، کشاورزی، آب، اراضی بایر و پوشش گیاهی مانند باغ‌ها مورد بررسی قرار گرفت . مهم‌ترین تغییرات در بین این موارد، تبدیل فضاهای سبز و مناطق کشاورزی به اراضی بایر و متعاقباً به مناطق شهری بوده است .با این حال، در مکان‌هایی مانند پارک جنگلی چیتگر و باغ گیاه‌شناسی ملی، افزایش تراکم پوشش گیاهی را مشاهده شده است در این تحقیق، از تصاویر ماهواره‌ای لندست مربوط به سال‌های ۲۰۱۳ و ۲۰۲۰ استفاده شد .ما از روش حداکثر احتمال برای طبقه‌بندی کاربری اراضی به پنج دسته آب، زمین‌های بایر، کشاورزی، پوشش گیاهی و مناطق شهری استفاده کردیم .در نهایت، نقشه تغییرات برای سال ۲۰۲۷ تهیه شد و نرخ تبدیل کاربری‌های مختلف زمین در یک جدول ارائه شد .نتایج نشان داد که استفاده از مناطق شهری در سال ۲۰۲۰ در مقایسه با سال ۲۰۱۳ افزایش یافته است و پیش‌بینی می‌شود که این روند در سال ۲۰۲۷ نیز ادامه یابد. استفاده از زمین‌های کشاورزی در سال ۲۰۲۰ در مقایسه با سال ۲۰۱۳ کاهش یافته است و انتظار می‌رود در سال ۲۰۲۷ بیشتر کاهش یابد. استفاده از پوشش گیاهی نیز در سال ۲۰۲۰ نسبت به سال ۲۰۱۳ کاهش یافته است و پیش‌بینی می‌شود که این کاهش تا سال ۲۰۲۷ ادامه یابد. زمین‌های بایر در سال ۲۰۲۰ در مقایسه با سال ۲۰۱۳ افزایش یافته و مساحتی معادل ۱۱۰۰۲۵۰۰ متر مربع را پوشش می‌دهد و پیش‌بینی می‌شود که این میزان تا سال ۲۰۲۷ کاهش یابد. در نهایت، استفاده از منابع آبی در سال ۲۰۲۰ در مقایسه با سال ۲۰۱۳ کاهش یافته است و انتظار می‌رود تا سال ۲۰۲۷ کاهش بیشتری داشته باشد.

کلمات کلیدی: منطقه غرب تهران، تغییرات کاربری زمین، LCM، NDVI