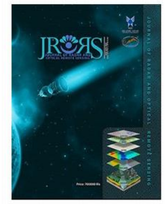
Available online at https://sanad.iau.ir/journal/jrors

Publisher: Ya.C., Islamic Azad University

Journal of Radar and Optical Remote Sensing and GIS

Print ISSN:2645-484X Online ISSN:2645-5161



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

Seyed Aghil Ebrahimi[1], Seyed Ali Almodaresi [2✉], Farhad Hamzeh [3]

1. Department of Geography, CT.C., Islamic Azad University, Tehran, Iran Email: seyedaghil.ebrahimi@iau.ac.ir

2. Department of Remote sensing and Geography Information System, Y.C, Islamic Azad University, Yazd, Iran Email: almodaresi@iau.ac.ir

3. Department of Geography, CT.C., Islamic Azad University, Tehran, Iran Email: fa.hamzeh@iau.ac.irAssistant Professor,

Article Info

Article type:

(Research Article, Review, Short Communication, etc.)

Article history:

Received 17 Jan 2025

Revised form 19 April 2025

Accepted 17 July 2025

Published online Sept 18, 2025

Keywords:

West Tehran region,
land use changes,
LCM,
NDVI,
Landsat

ABSTRACT

Objective: This research evaluated the western region of Tehran regarding changes in vegetation cover as well as land use.

Methods: 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.

Results: Results show that urban areas expanded from 2013 to 2020 and will continue to grow by 2027. Agricultural and vegetation lands declined during this period and are expected to decrease further. Barren land increased between 2013 and 2020 but will likely decline by 2027. Water bodies also decreased and are projected to continue shrinking by 2027.

Conclusion: From 2013 to 2020, urban areas nearly doubled from 14.18 to 26.74 million m² and are projected to reach 29.70 million m² by 2027. Agricultural land sharply declined from 28.04 to 15.35 million m², expected to drop further to 11.91 million m². Vegetation cover decreased from 3.20 to 1.06 million m² but may recover to 5.95 million m². Barren land rose from 11.00 to 14.01 million m², then likely falling to 9.68 million m², while water bodies dropped from 8.05 to 1.23 million m², projected at 1.15 million m² by 2027.

Cite this article: Author name, Initial., Author name, Initial., & Author name, Initial. (2025). Title of paper. ***Journal of Radar and Optical Remote Sensing and GIS***, *8*(3), pages.7-26

Introduction

Land use and land cover changes are driven by natural events, human activities, and socio-economic factors, leading to transformations such as urban expansion, infrastructure development, and the abandonment of certain areas (Hu et al., 2023). 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 important necessity of the present research refers to the fact that changes in land use and land cover can be considered the beginning of human dynamic exploitation of natural resources to meet their needs. Land use is an example of human impact on the environment. In order to reduce the harmful effects of urban growth on the environment and maintain optimal ecosystem function, temporal and spatial patterns of land cover and land use changes and the factors affecting these changes are significantly important in the development of economic, social and environmental policies. In this research, this necessity was addressed in the studied area and at the end, the main problem, which is to identify the extent of land use changes and the factors affecting the process of urban land use change with an environmental approach in order to create an optimal pattern, discover and identify land use changes with an environmental sustainability approach in the southern regions of Tehran, was investigated, analyzed and answered.

- **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.

Arokhi (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.

Ashouri 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.

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.

Kaviyan (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 (2021) 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.

Bakhshi et.al (2022) 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.

Materials and Methods

- **Study Area**

Tehran, the capital city of Iran, is located in the north-central part of the country, between 35° 34′ to 35° 45′ north latitude and 51° 20′ to 51° 40′ east longitude. It covers an area of approximately 730 km² within the Tehran metropolitan region and serves as the political, economic, and cultural center of Iran. The city is surrounded by the Alborz Mountains to the north and the central desert plains to the south, which have a significant influence on its climate and urban development patterns. The study area, as shown in Figure 1, highlights the urban and peri-urban extents of Tehran.As of 2019, the population of Tehran was estimated at over 8.7 million inhabitants, making it one of the most densely populated urban areas in the Middle East (Pak-Khesal et al., 2021). Over the past decades, Tehran has experienced rapid urban expansion, leading to significant changes in land use and land cover, including the conversion of agricultural and barren lands into residential, commercial, and industrial areas.

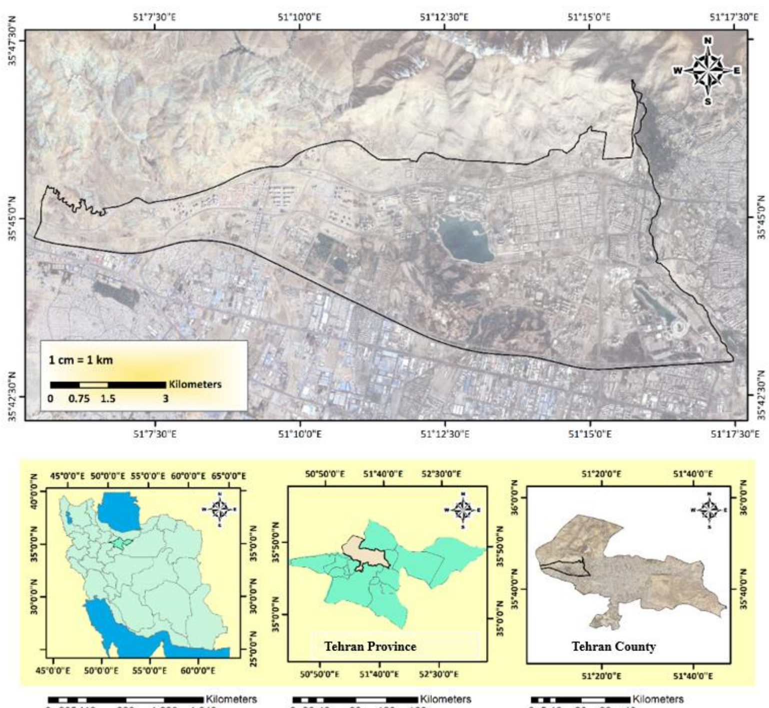


Figure 1: Geographic location of the study area

- **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 1: 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.

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. 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)).

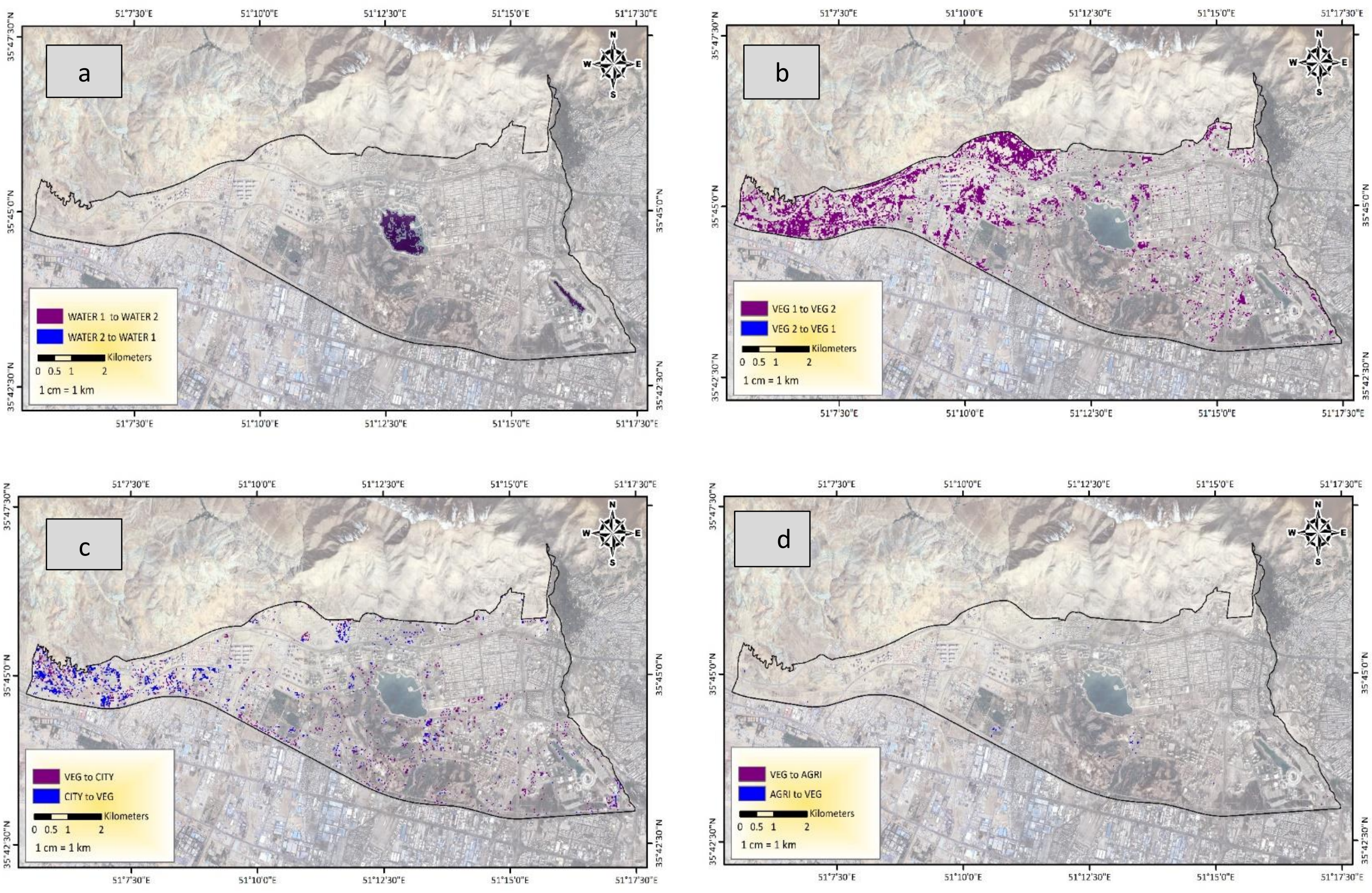


Figure 2: a) Changes in water body area b) Changes in vegetation cover c) Changes between vegetation cover and urban areas d) Changes between vegetation cover and agricultural land

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.

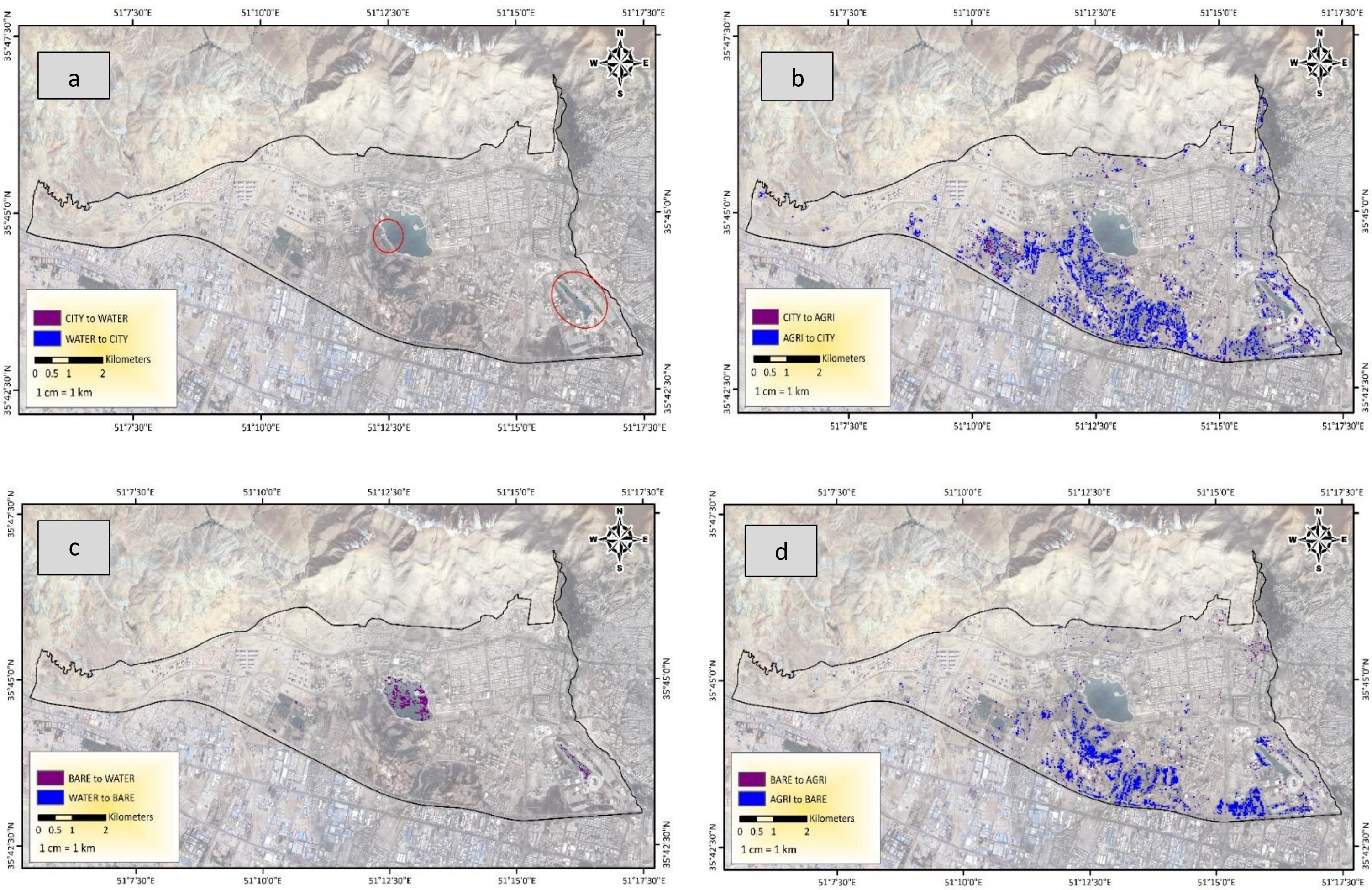


Figure 3: a) Changes from water bodies to urban areas b) Changes from urban areas to agricultural land c) Changes from barren land to water bodies d) Changes from barren land to agricultural land

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.

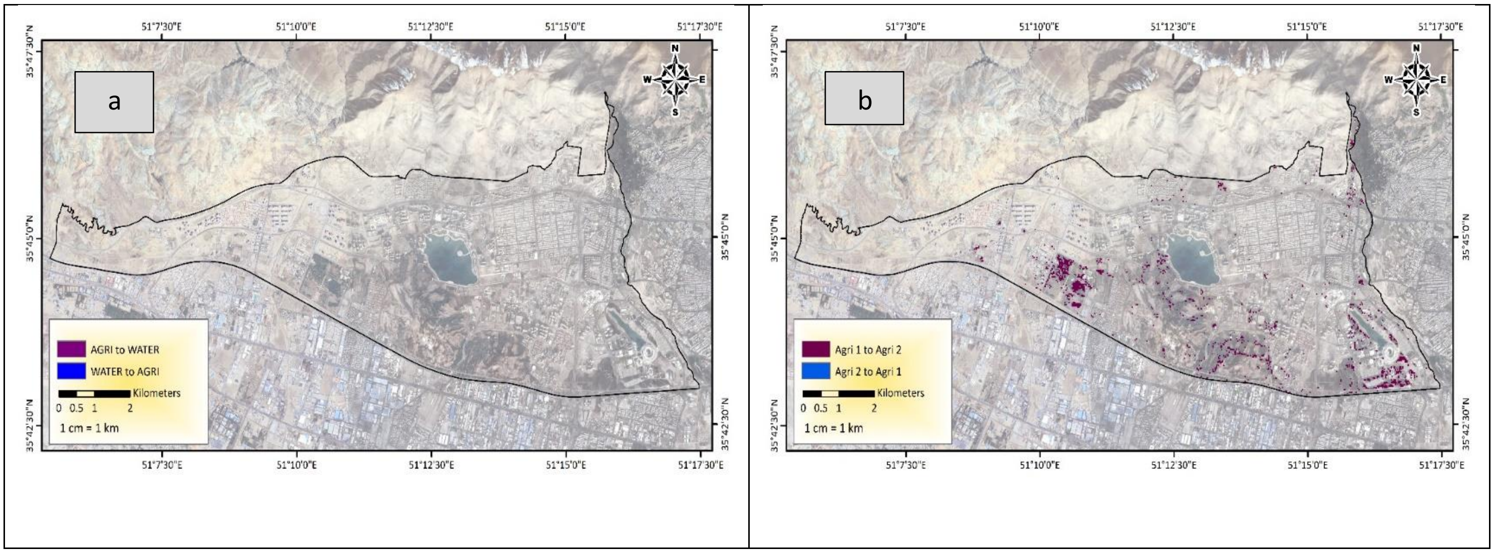
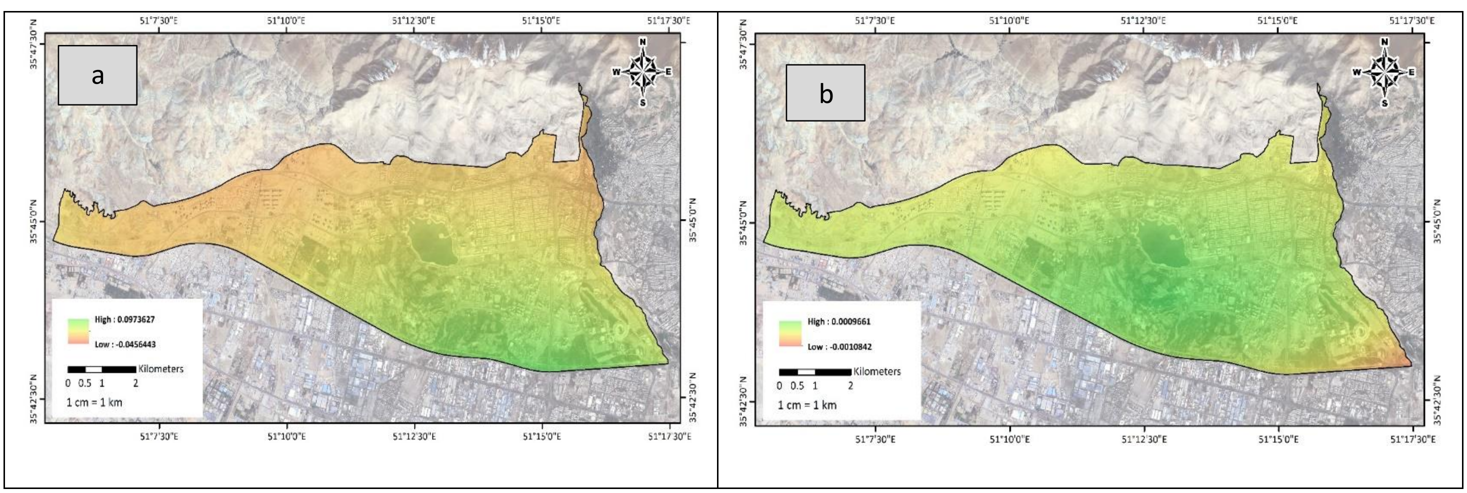


Figure 4: a: Transitions from agricultural land to water area b: Transitions from agricultural land to agricultural land

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.



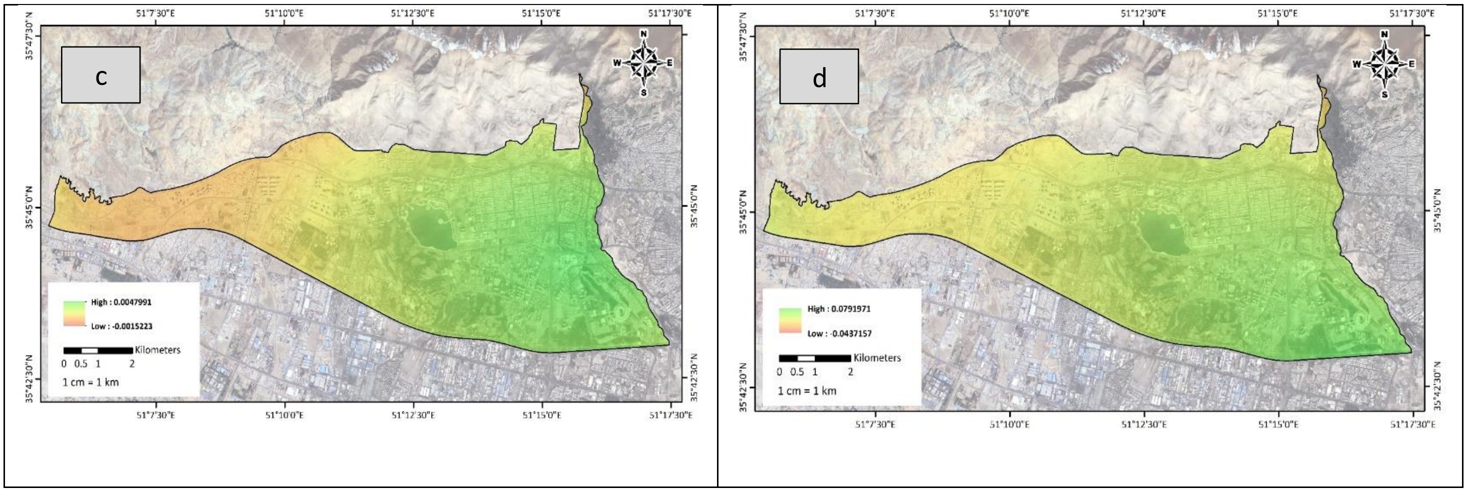
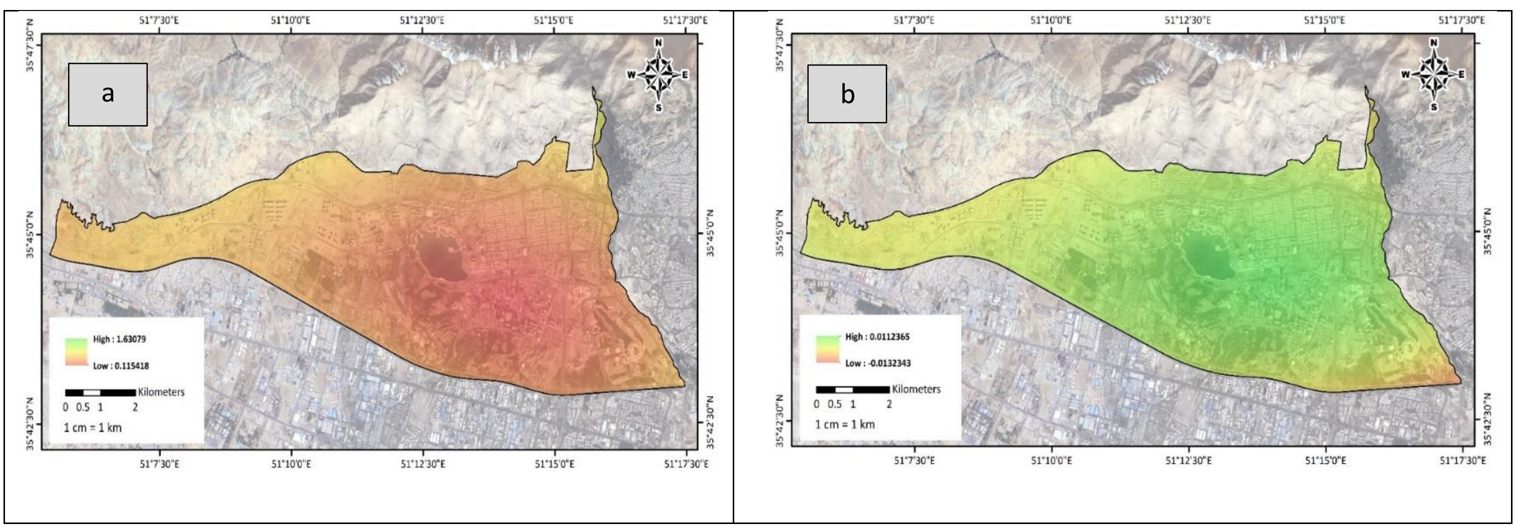


Figure 5: a: trend of agricultural area changes to barren land b: trend of agricultural area changes to vegetation cover c: trend of barren land changes to agriculture d: trend of barren land changes to urban

In Figure 6, the trends of land use conversions are illustrated. The transformation of barren land to vegetation is shown in part A, highlighting areas where restoration or natural regeneration may have occurred. Part B depicts the conversion of barren land to water bodies, which is mostly limited to specific localized areas. The changes from vegetation to agricultural land are presented in part C, primarily occurring in zones suitable for cultivation. Finally, part D shows the conversion of vegetation to barren land, indicating areas experiencing degradation or loss of green cover.



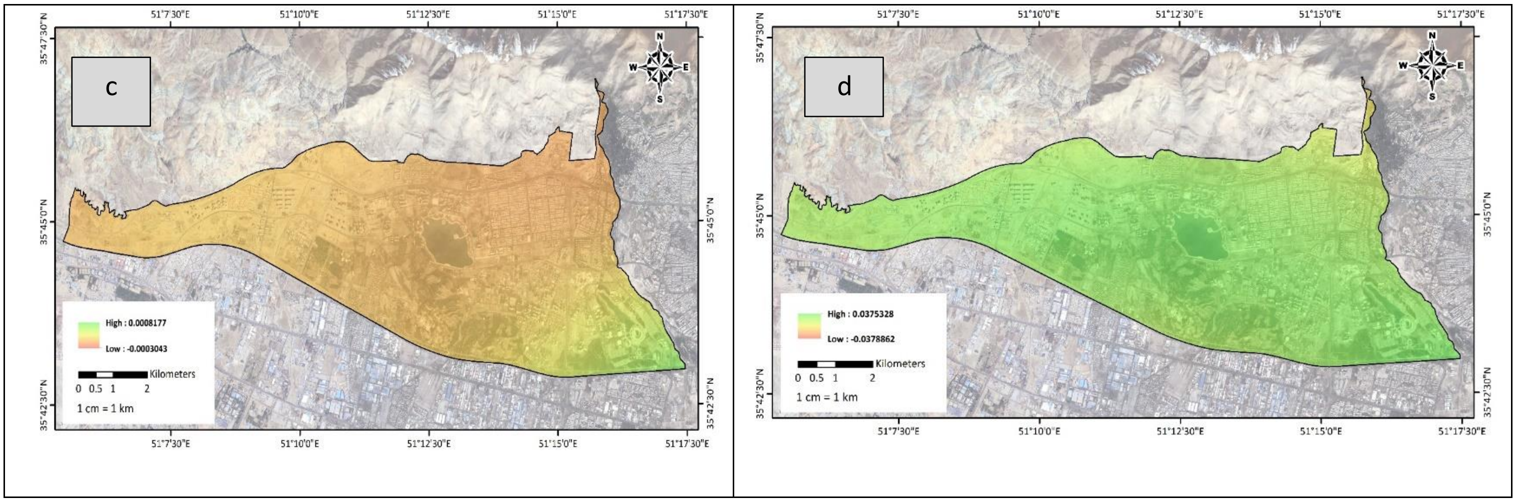


Figure 6: A: Trends in the conversion of barren land to vegetation B: Trends in the conversion of barren land to water bodies C: Trends in the conversion of vegetation to agriculture D: Trends in the conversion of vegetation to barren land

In Figure 7, the overall changes in the studied land uses are presented. The figure provides a comprehensive view of how different land categories, including urban areas, agricultural lands, vegetation, barren lands, and water bodies, have transformed over the study period. This visualization helps to identify the spatial patterns and intensity of land use changes across the region.

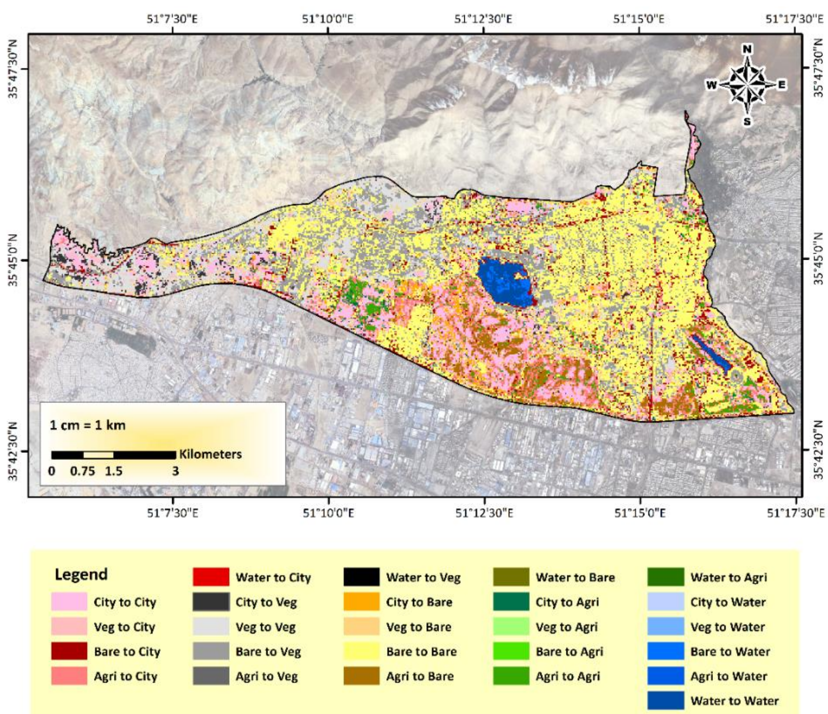


Figure 7: Changes in the land uses under study

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:

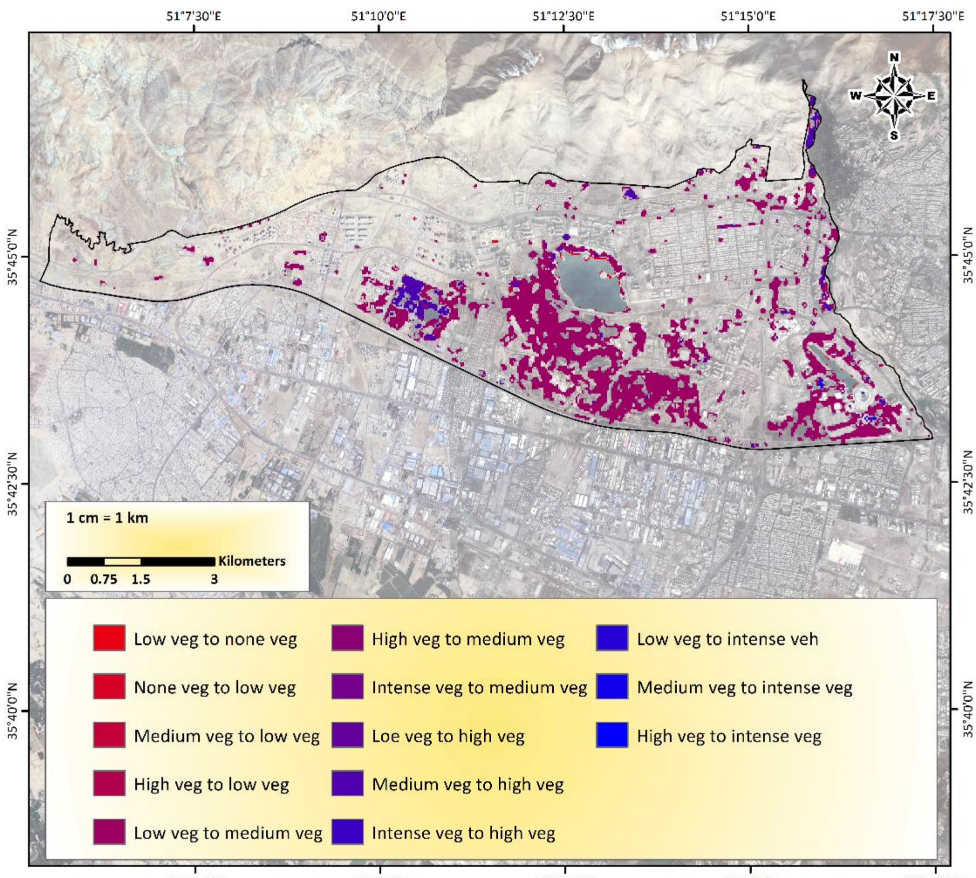


Figure 8: Changes in NDVI Index Classes

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.

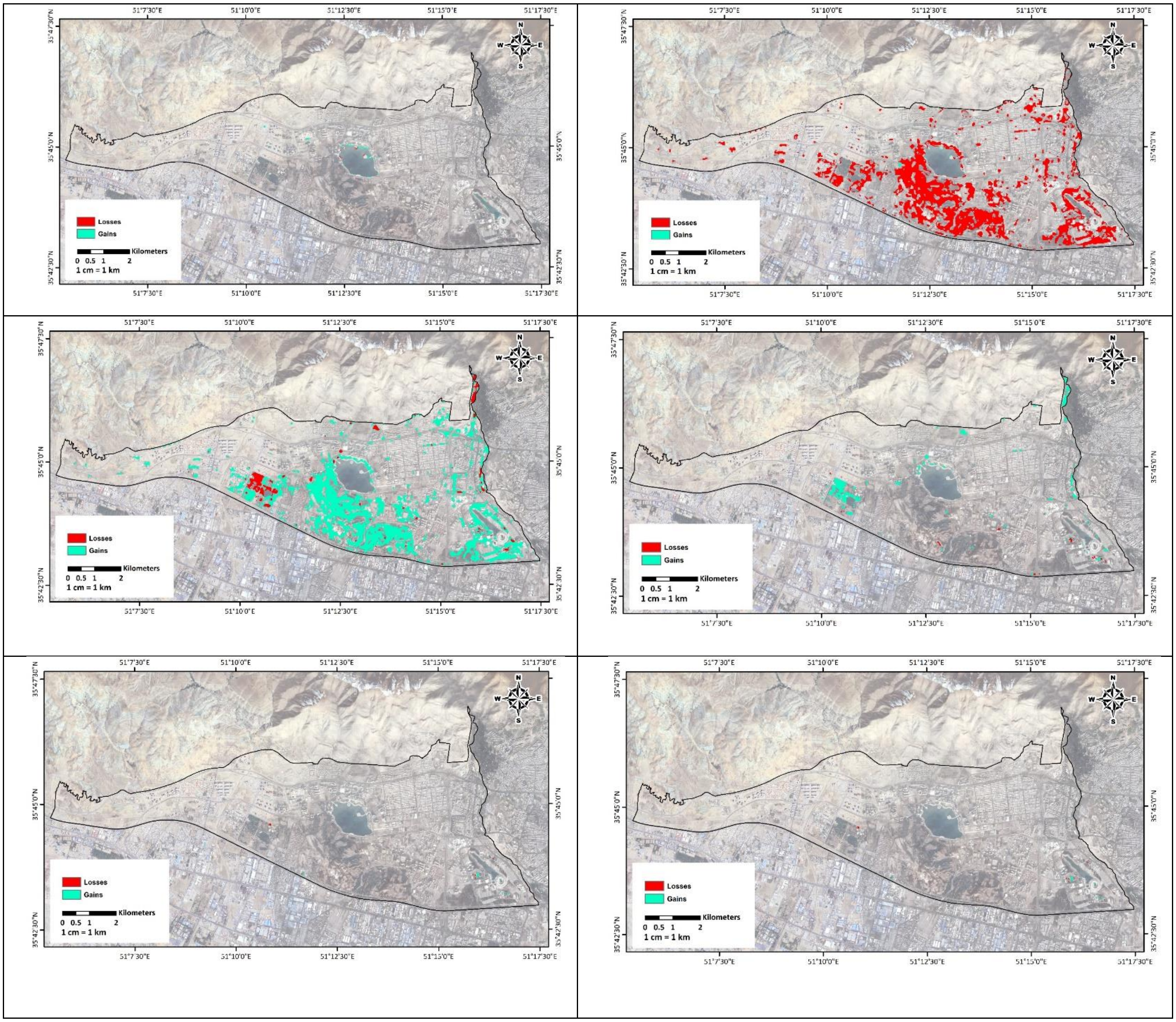


Figure 9: A: Increase and decrease of classes without vegetation B: Increase and decrease of low vegetation coverage class C: Increase and decrease of medium vegetation coverage class D: Increase and decrease of high vegetation coverage class E: Increase and decrease of very high vegetation coverage

In Figure 10, the final classification map of land use changes in 2013 is presented. This figure illustrates the spatial distribution of different land use categories at the beginning of the study period, providing a baseline for understanding subsequent transformations in urban, agricultural, vegetation, barren, and water body areas.

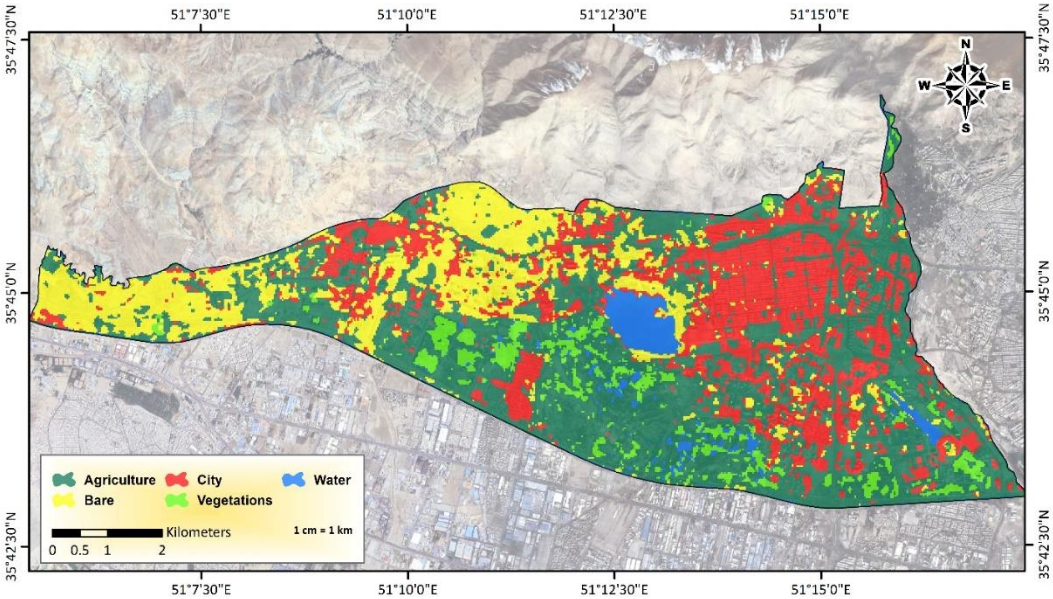


Figure 10: Final classification map of land use changes in 2013

In Figure 11, the final classification map of land use changes in 2020 is shown. This figure highlights the spatial distribution of land use categories during this year, allowing for comparison with the 2013 baseline and helping to identify areas of significant transformation in urban, agricultural, vegetation, barren, and water body lands.

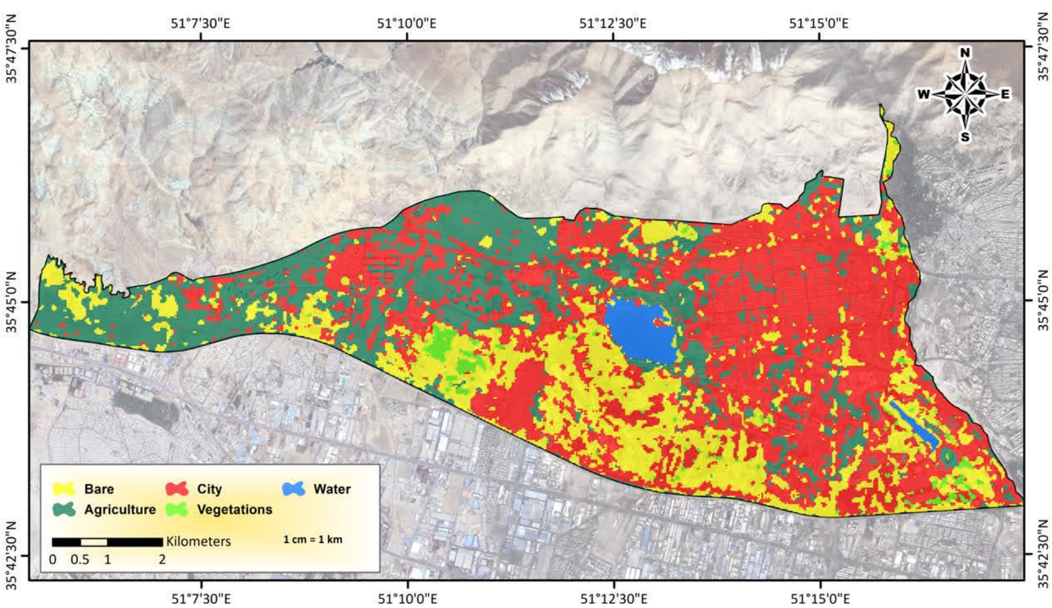


Figure 11: Final classification map of land use changes in 2020

In Figure 12, the predicted final classification map of land use changes for 2027 is presented. This figure illustrates the anticipated spatial distribution of land use categories in the study area, providing insights into potential future transformations in urban, agricultural, vegetation, barren, and water body lands.

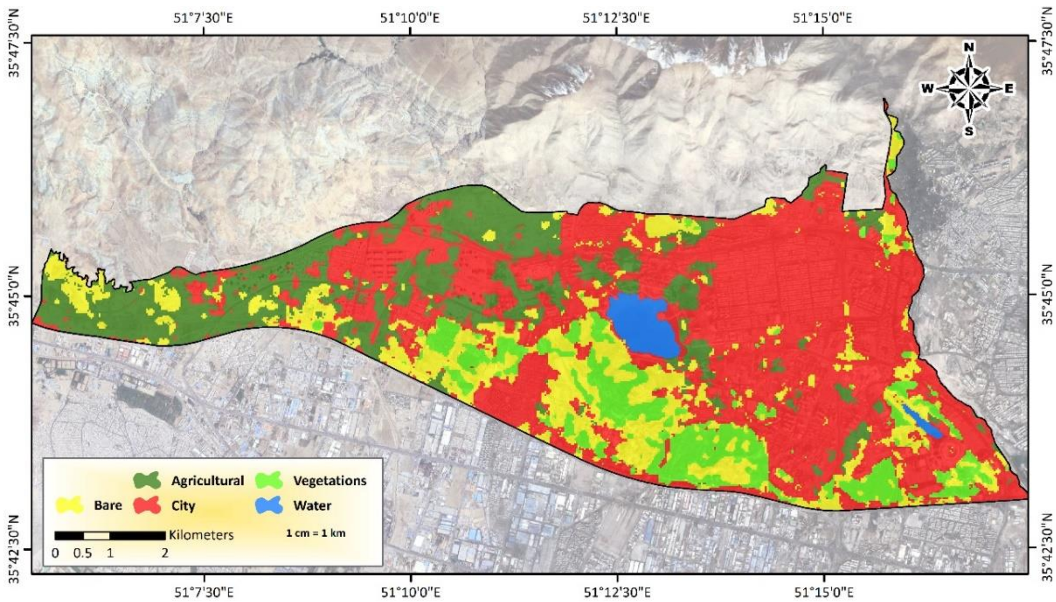


Figure 12: Final classification map predicting land use changes in the area for 2027

Table 2 summarizes the area changes for different land uses in 2013, 2020, and the predicted values for 2027. It provides a clear view of how urban, agricultural, vegetation, barren, and water body areas have changed over time, highlighting key trends in land use transformation.

Table 2: Amount of area changed for land uses in 2020, 2013, and 2027

LandUse Classes in 2013	measured (square meters)
Urban	14178600
Agricultural	28044900
Vegetation	3198600
Barren Land	11002500
Water Bodies	8047080
LandUse Classes in 2020	**measured (square meters)**
Urban	26739900
Agricultural	15354000
Vegetation	1056600
Barren Land	14012100
Water Bodies	1233900

LandUse Classes in 2027	measured(square meters)
Urban	29702700
Agricultural	11908800
Vegetation	5954400
Barren Land	9684900
Water Bodies	1145700

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.

Discussion

The present article, like similar works by other researchers, including Hosseini et al. (2013), Arokhi (2013), Ashouri and (2014), Mohammadiari et al. (2019), Zabardast and Darskhuan (2020), Bakhshi et al. (2022), Surya et al. (2021), examined changes in an urban area and had acceptable results. The distinction of this research from other research was the use of more up-to-date data and accurate methods, and the fact that no research had been conducted on this subject in District 22 of Tehran so far, and this in itself is an innovation and distinction between this work and other similar works.

.

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.

Author Contributions

The first author, Seyed Aghil Ebrahimi, played a greater role in the paper, including collecting data, processing it, and producing maps.

Seyed Ali Al-Modaresi, as the supervisor, provided detailed guidance from beginning to end, resulting in better and acceptable results for the paper. He also wrote the results section.

Farha Hamzeh played the role of consultant and wrote the research background section. Finally, he wrote the final editing.

Data Availability Statement

In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study (see examples). Data available on request from the authors.

If the study did not report any data, you might add “Not applicable” here.

Acknowledgements

He authors sincerely thank all those who supported and contributed to this study. Special appreciation goes to the participants for their generous cooperation, as well as to colleagues and technical staff whose guidance, assistance, and provision of essential resources made the research possible. Their valuable support played a key role in the successful completion of this study.

Ethical considerations

The study was approved by the Ethics Committee of the University of ABCD (Ethical code: FR.AMU.REC.2022.500). The authors avoided data fabrication, falsification, plagiarism, and misconduct.

Funding

The study was funded by the University of ABCD, Country ABCD, and Grant No. 111111. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest

It is hereby confirmed that an article under the title of (Modeling the discovery of changes and prediction of land use using optical sensors with Land Change modeler method (Study area: west of Tehran) is compiled by (corresponding author) syede Ali Almodaresi and Seyed Aghil Ebrahimi and Farhad Hamzeh, and the article is sent for the journal for examination purposes, being notified and accepting of ethical principles on Journal of Article, especially the below stated items: The article is not formerly published in another journal and is not sent to other journals for examination purposes. The article is a result of research conducted by the corresponding author ; thus, I accept its responsibility and undertake that all intellectual rights contributed in the research are observed. No part of the article is copied from other articles and safekeeping principles are fully observed in connection with reference to other’s work.

References

Ansari-fard, Ahmad (2019). Evaluation and Prediction of Land Use Changes Using the LCM Model (Case Study: Bozngan Watershed). *Master's Thesis, Department of Rangeland and Watershed Management, Faculty of Natural Resources and Environment, Ferdowsi University of Mashhad, Iran.*

Arokhi, Saleh (2014). Prediction of Spatial Land Use Change Trends Using the LCM Model in a GIS Environment (Case Study: Sarableh Region). *Iranian Journal of Forest and Rangeland Protection Research*, Vol. 12, No. 1, pp. 1-19.

Ashouri, Hanieh; Jangjoo, Mohammad; Sepehr, Adel; and Nik Iqbal, Mahboobeh (2015). Detection of Rangeland Land Use Changes in the Seydan Watershed Using Satellite Images. *National Conference on New Research in Natural Resource Management.*

Bakhshi, Amir; Rasouli, Seyyed Hassan; and Rahimi, Nima (2022). Examining the Role of Urban Growth Patterns in the Formation of Urban Heat Islands (Case Study: Sari City). *Urban Environment Planning and Development*, 2(6), pp. 77-94.

Farrokh, Mohammad (2020). Urban Growth Prediction Based on Land Use Changes Using Landsat Images and the LCM Model (Case Study: Amol City). *Master's Thesis, Department of Remote Sensing and Geographic Information Systems, Faculty of Sciences, Aban Hezar Higher Education Institute, Iran.*

Hasyim, A. W., Sianturi, R. E. P., & Hidayat, A. R. (2019, October). Spatial Pattern of Land Cover Change in The Coastal Area of Gresik Regency, Indonesia Using Land Change Modeler. In *IOP Conference Series: Earth and Environmental Science* (Vol. 328, No. 1, p. 012059). IOP Publishing.

Hosseini, Seyyed Mohsen; Falahatkar, Samereh; Salman Mahini, Abdolrasoul; and Ayubi, Shamsollah (2013). *Prediction of Land Use Changes Using the LCM Model. Environmental Research*, Vol. 7, No. 13, pp. 163-174.

Hu., Raza, A., Syed, N. R., Acharki, S., Ray, R. L., Hussain, S., Dehghanisanij, H., Zubair, M., & Elbeltagi, A. (2023). Land Use/Land Cover Change Detection and NDVI Estimation in Pakistan's Southern Punjab Province. *Sustainability*, *15*(4), 3572. https://doi.org/10.3390/su15043572

Kamiyab, H., SalmanMahiny, A., Hoseini, S., Mohsen, , & Gholamalifard, M. (2011). *Using Neural Network for Urban Growth Modeling (Case Study: Gorgan City). Human Geography Research Quarterly, 43(76).*

Kaviyan, Ataollah; Zargush, Zarifeh; Jafariyan Jaloodar, Zeinab; and Darabi, Hamid (2017). Modeling Land Use Changes in the Haraz Watershed Using Logistic Regression and Markov Chain. *Natural Environment, Iranian Journal of Natural Resources, Vol. 70, No. 2, pp. 397-411.*

Luo, D., Mausel, P., Brondizio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, *25*(12), 2365–2401. https://doi.org/10.1080/0143116031000139863

Marwasta, D. (2019). Spatial Trends of Urban Physical Growth of Cities in Java, Indonesia, 1975–2015. *ASEAN Journal on Science and Technology for Development, 36(2), 53-56.*

Mirzapur, Hafez (2016). Comparison of the Performance of CA-Markov, Geomod, and LCM Models in Predicting Land Use Changes in the Badavour Watershed, Noorabad, Lorestan. *Published Master's Thesis, University of Lorestan, Lorestan, Iran.*

Mohammadiyari, Fatemeh; MirSanjari, MirMehraad; and ZarehDiyan, Ardavan (2019). Assessment of Urban Expansion Changes in the Metropolis of Karaj Using Landsat Satellite Images from 2006 to 2017. *Fourth International Conference on New Research in Civil Engineering, Architecture, Urban Management, and Environment*, Karaj.

Pak-Khesal, Oladi Qadikelayi, Jalilvand, & Akbari. (2021). Detecting land use changes using remote sensing data (Case study: Tehran city). *Geography Quarterly (Regional Planning)*, 11(44), 287–298.

Surya, B., Salim, A., Hernita, H., Suriani, S., Menne, F., & Rasyidi, E. S. (2021). Land use change, urban agglomeration, and urban sprawl: *A sustainable development perspective of Makassar City, Indonesia. Land, 10(6), 556.*

Zabardast, A., & Darskhan, R. (2021). Explaining the components of achieving sustainable environmental development in the urban management structure of Tabriz metropolis. *Sustainability, Development & Environment*, *2*(3), 21-40.