Chapter 09

Rethinking homo economicus
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Monitoring Land Use and Land Cover Changes in Najaf Using MODIS MCD12Q1 Data (2001-2023)

Monitoreo de los cambios en el uso y la cobertura del suelo en Najaf mediante datos MODIS MCD12Q1 (2001-2023)

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ABSTRACT

This paper considers the temporal dynamics of LULC in Najaf province from 2001 to 2023 using MODIS MCD12Q1 data. The analysis reveals large changes for many classes of land use and land cover, underlining the anthropogenic and environmental drivers of this process. In 2023, barren lands dominated 96,94 % of the entire area, followed by grasslands (1,08 %), cereal croplands (1,25 %), and urban areas (0,39 %). Additionally, water bodies took 0,15 % and trees accounted for a very small percentage of 0,02 %. These results obviously represent the urgent need to adopt sustainable land management practices to balance urban development with agricultural uses and environmental protection in the area. This study provides valuable input to decision-makers and other researchers who need to address the challenges of land degradation and resource allocation in arid and semi-arid regions.

Keywords: LULC; MODIS MCD12Q1; Najaf; Land Cover Change; Sustainable Land Management, Remote Sensing.

RESUMEN

Este artículo analiza la dinámica temporal del uso y cobertura del suelo (UTSC) en la provincia de Nayaf entre 2001 y 2023 utilizando datos MODIS MCD12Q1. El análisis revela importantes cambios en diversos tipos de uso y cobertura del suelo, lo que pone de relieve los factores antropogénicos y ambientales que impulsan este proceso. En 2023, las tierras áridas dominaban el 96,94 % de la superficie total, seguidas de los pastizales (1,08 %), los cultivos de cereales (1,25 %) y las zonas urbanas (0,39 %). Además, los cuerpos de agua representaban el 0,15 % y los árboles un porcentaje muy reducido, el 0,02 %. Estos resultados reflejan claramente la urgente necesidad de adoptar prácticas sostenibles de gestión del suelo para equilibrar el desarrollo urbano con los usos agrícolas y la protección del medio ambiente en la zona. Este estudio proporciona información valiosa a los responsables de la toma de decisiones y a otros investigadores que necesitan abordar los desafíos de la degradación del suelo y la asignación de recursos en regiones áridas y semiáridas.

Palabras clave: ULC; MODIS MCD12Q1; Nayaf; Cambio de la Cobertura del Suelo; Gestión Sostenible de la Tierra, Teledetección.

INTRODUCTION

The dynamics of LULC form an important component of understanding the interlinks between human activities and natural ecosystems. Rapid urbanization, agricultural development, and climate change have become the most prominent drivers of land use and land cover change, particularly in vulnerable regions such as dryland and semi-arid areas.[1] Accurate monitoring of the changes is indispensable for both sustainable land management and ecological conservation. Land use and land cover are changing with time and place, which can be observed over time with the use of remote sensing technologies, particularly MODIS, as an essential tool for observing such variability, supplying consistent and reliable data.[2,3]

The MCD12Q1 MODIS product has been widely used for land cover classification on a global scale, enabling researchers to analyze changes in land use and cover over time and space with reasonable precision. Indeed, this product integrates several data sources to classify land cover into classes that include forests, grasslands, croplands, barren areas, and built-up places, which makes it one of the critical apparatuses in environmental and planning studies.[4] Besides, remote sensing has developed in ways that have improved the study of land degradation, deforestation, and desertification-all issues now relevant in countries with arid environments, of which Najaf, Iraq, is no exception.[5,6]

Najaf represents a district in which land use/cover has been affected by urban growth, population increase, and the intensification of agriculture. Land cover type changes that characterised this area symbolize overarching environmental issues such as water shortage, soil degradation, and habitat loss.[7] Such changes need broad monitoring so as to inform decision-making and therefore plan for the sustainable use of the lands concerned.[8]

The integration of RS and GIS provides a multi-disciplinary platform for analyzing LULC dynamics. Studies have demonstrated the capability of remote sensing data, such as from MODIS, to map land use and land cover changes over different geographical and temporal scales.[9] For example, Karnieli et al.[6] used satellite images to investigate changes in land cover in the deserts of Central Asia, emphasizing the strength of RS in monitoring changes in the environment.

This study relies on the MODIS MCD12Q1 dataset to investigate the land use and land cover changes of Najaf between 2001 and 2023, with a focus on establishing the percentage distribution of different land cover categories. The study aims at equipping policymakers and environmental planners with the necessary practical insights on land use and land cover dynamics within the region, with an emphasis on the need for sustainable resource management and land conservation strategies. El-Baz et al.[5], temporal patterns in land use and land cover are analyzed in this work, therefore enhancing our understanding of land degradation processes, and also informing the formulation of adaptive solutions needed to ameliorate their impacts.

Related Work

The study of Land Use and Land Cover changes has been one of the main focuses of environmental studies over the past years, with various research employing remote sensing technology to monitor and evaluate these changes. Remote sensing data, particularly from the

MODIS, has become an essential tool in understanding recent land use and land cover changes across the world.[2] The annual global land cover classifications found within the MODIS MCD12Q1 dataset have seen significant applications in land cover mapping and in analyzing temporal patterns across diverse landscapes.[3]

Many research works have been carried out on the application of MODIS data in land use and land cover studies over arid and semi-arid regions, indicating its effectiveness in detecting land degradation and desertification processes. Some examples include Karnieli et al.[6], who investigated land cover changes in Central Asia, where large areas of degradation were detected due to climate and human factors. Tucker et al.[7] applied a remote-sensed approach to examine drought characteristics and their impacts on vegetation, showing the value of satellite imagery when other resources are scarce.

The integration of MODIS data with GIS has enhanced the accuracy and extent of LULC studies. Giri[4] discussed the basics and applications of remote sensing in land use studies and emphasized the importance of integrating MODIS data with other spatial data. Zhu et al.[10] further developed the methodology by developing continuous change detection techniques for land cover classification, which allowed the detection of subtle land use and land cover changes.

Land use and land cover change studies in the Middle East have focused on the impacts of urbanization, agricultural expansion, and environmental drivers. In Iraq, studies have emphasized land degradation, water scarcity, and habitat destruction, particularly in arid areas like Najaf.[5] Verburg et al.[8] considered human drivers of change in land systems and the urgent need for sustainable management practices that would help mitigate such problems.[11]

In additional of MODIS, other remote sensing data such as Landsat and Sentinel have been used for land use and land cover studies.[12] These data provide the added benefit of higher spatial resolution to complement the temporal resolution of MODIS. Turner et al.[9] discuss the emergence of land change science, which integrates a large number of data sets in order to address the complexity of global environmental change.

METHOD

Data

This study utilizes the MODIS MCD12Q1 dataset, one of the most established remote-sensing land cover classification products on a global scale. MCD12Q1 provides yearly land cover class data at a 500-meter spatial resolution from 2001 to 2023. It incorporates a number of classification approaches and several input data sources, including spectral, temporal, and auxiliary data, within a unique framework to produce consistent and accurate land cover maps.

Data for this research were acquired from the Najaf governorate, Iraq, an area lying in an arid to semi-arid region characterized by high heterogeneity in land cover. Land cover classes in the dataset used include 17 classes based on the IGBP classification scheme. This research focuses on specific categories relevant to the region, including barren terrain, croplands, grasslands, urban areas, water bodies, and tree cover.

To study the trend in LULC, the percentage of area occupied by each category in land cover was computed on a yearly basis. The dataset pre-processing included delineating the study area and converting raw categorization data into percentages. This transformed data enabled chronological representation and analysis of changes in land use and land cover to capture the trend of important categories such as barren land, agricultural land, and expansion of urban areas.

Other datasets complement the MCD12Q1 dataset to ensure that the analysis is sound, including historical research. These ancillary data sources provide context for interpreting the observed trends and implications for land use planning and environmental conservation in Najaf.

Study Area

Najaf Province, located in central-southern Iraq, Najaf Province holds great historical, cultural, and economic importance in the country. It measures an area of about 28 824 square kilometers and is bound by Al-Qadisiyyah to the north, Muthanna to the south, and Karbala to the west. Najaf, the provincial capital, is considered a holy city and one of the prominent religious and educational centers, since it houses the Imam Ali Shrine-one of the most important pilgrimage sites visited annually by millions of Muslims. The desert climate of Najaf is marked by a very high temperature during summer, which can reach over 50°C, while winters are mild and with infrequent precipitation. The annual precipitation is low in this area and averages around 100–150 mm; this results in heavy reliance on the Euphrates River and its groundwater resources for agriculture and other local needs. Most of its lands are arid plains where agriculture is possible only along the river and its irrigated areas. Its main crops are wheat, barley, and dates. Agriculture and religious tourism play an important role in the economy of this province. In spite of this economic potential, Najaf faces various serious environmental challenges that include desertification, water scarcity, and soil degradation caused by inappropriate agricultural practices and climate change impacts. Previous studies have emphasized the increasing vulnerability of ecosystems in the province to climatic variability and anthropogenic pressure. Addressing these very challenges calls for adequate land and water management strategies that will ensure long-term ecological and economic sustainability.

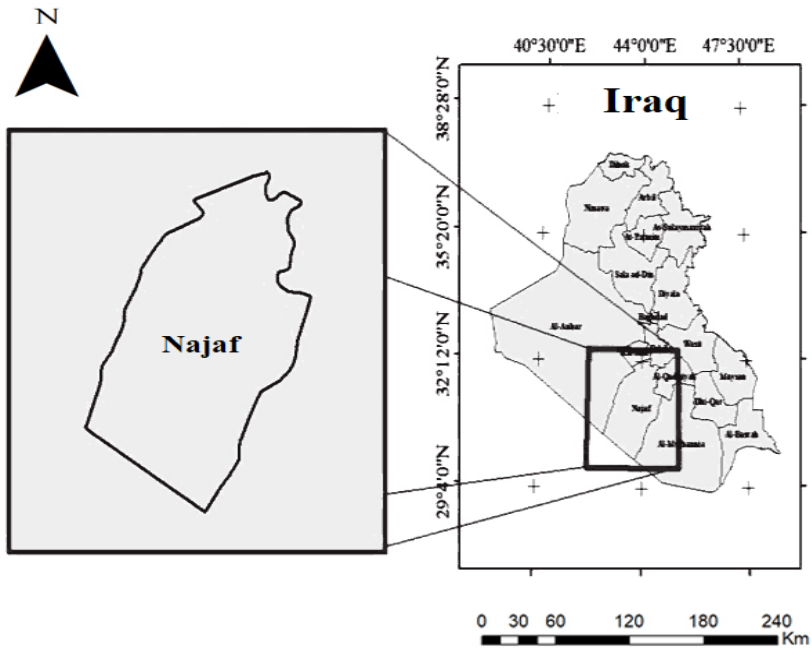


Figure 1. Show locution map of study area

Preprocessing in MATLAB for LULC Analysis

Preprocessing the MODIS MCD12Q1 dataset in MATLAB involves multiple steps, including data loading, extraction of the study area, and aggregation of land cover classes. The key steps and

mathematical operations are outlined below:

Data Loading

The MODIS MCD12Q1 data is often provided in NetCDF format. The dataset is loaded using MATLAB's ncread function:

$$D_{\text{land}} = \text{ncread}(F, V) \quad (1)$$

Where:

- Dland is the land cover dataset,
- F is the file name (e.g. "MCD12Q1_2001_2023.nc").
- V is the variable name (e.g., "Land_Cover_Type_IGBP").

Extraction of Study Area

To extract data for the Najaf province, a bounding box defined by latitude and longitude is used:

$$\mathbf{Id}\text{x}_{\text{lat}} = \{i \mid \text{lat}_{\min} \leq \text{lat}\,[i] \leq \text{lat}_{\max}\} \quad (2)$$
$$\text{Idx}_{\text{lon}} = \{j \mid \text{lon}_{\min} \leq \text{lon}\,[j] \leq \text{lon}_{\max}\} \quad (3)$$

The subset for Najaf is then extracted as:

$$D_{\text{naj)}} = D_{\text{land}}\,[\mathbf{I}\text{dx}_{\text{lon}}, \mathbf{I}\text{Id}_{\text{lat}}, :] \quad (4)$$

Where Dnajaf contains the spatial and temporal land cover data for Najaf.

Aggregation of Land Cover Classes

For each year, the percentage of each land cover type is calculated. If Ck represents the count of pixels for class k and N is the total number of pixels in the study area:

$$P_k = \frac{C_k}{N} \times 100 \quad (5)$$

Where:

- Pk is the percentage of class k.
- Ck=∑(Dnajaf ==k), counting pixels classified as k.

For temporal analysis, this is repeated for each year t:

$$P_{k,t} = \frac{C_{k,t}}{N_t} \times 100 \quad (6)$$

Visualization

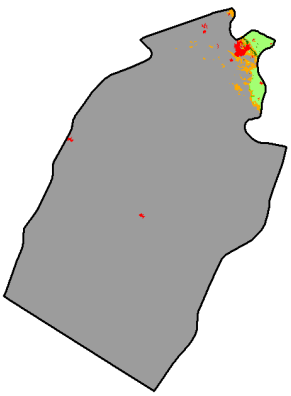
Finally, the data can be visualized using MATLAB plotting functions to illustrate the temporal trends of each LULC class. The percentages Pk,t can be plotted for all k classes over the years.

RESULTS

The analysis of Land Use and Land Cover (LULC) changes in Najaf province over the 22-year period from 2001 to 2023 reveals notable trends in the distribution of various land cover types. The results indicate that barren land consistently dominates the landscape, accounting for over 96 % of the total area throughout the study period. This reflects the arid and semi-arid nature of Najaf's environment, where limited precipitation and high evapotranspiration rates constrain vegetation growth. Urban areas, while representing a small percentage of the total land, show a steady increase over the years, rising from 0,07 % in 2001 to 0,39 % in 2023. This trend is indicative of population growth and urban expansion, driven by economic development and infrastructure improvements.

Cereal croplands, the main agricultural category, have remained relatively stable, covering approximately 1,2 %–1,3 % of the total area across the study period. This stability underscores the reliance on irrigated farming in the province, where water resources are essential for agricultural productivity. Broadleaf croplands, a minor component, exhibit slight variations but remain a minimal part of the overall land cover. Grasslands show modest increases over the years, growing from 0,80 % in 2001 to 1,08 % in 2023, which may reflect localized efforts to maintain natural vegetation. However, tree cover shows a declining trend, reducing from 0,068 % in 2001 to 0,024 % in 2023, indicating the challenges of sustaining forested areas in the region's harsh climatic conditions. Water bodies remain extremely limited, accounting for less than 0,20 % of the total area in any year, with the highest recorded value of 0,188 % observed in 2020.

These results highlight the predominance of barren land in Najaf, driven by its natural environmental constraints. Urbanization, while limited in extent, reflects increasing developmental pressures, which could lead to competition for resources such as water and arable land. The stability of agricultural land suggests that farming practices remain constrained by resource availability, particularly water, while the minimal presence of vegetation and water bodies emphasizes the ecological challenges of the region. The findings underscore the urgent need for sustainable resource management and land planning in Najaf to address issues related to aridity, urban growth, and ecological conservation. This analysis provides a comprehensive understanding of LULC dynamics in the province, offering valuable insights for policymakers and planners aiming to balance development and environmental sustainability. Figure 2 show the Mcd12Q1 Modis LULC from 2001-2023 in Najaf.



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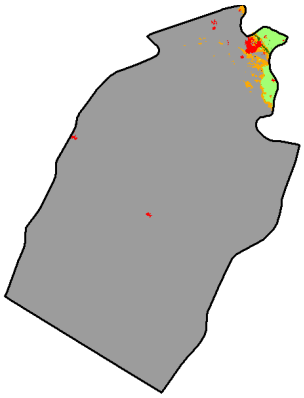

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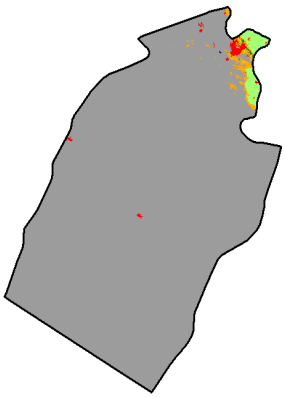

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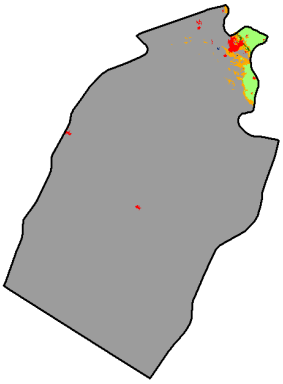

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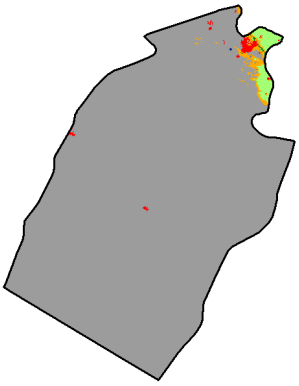

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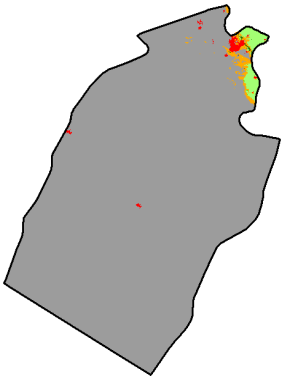

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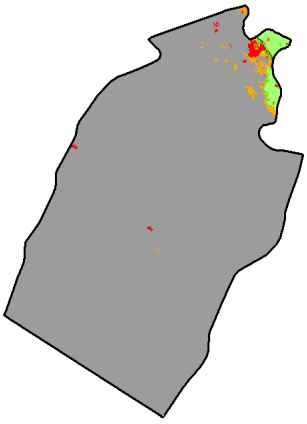

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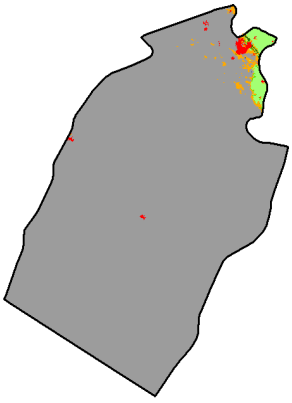

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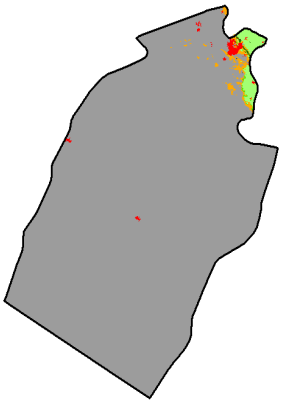

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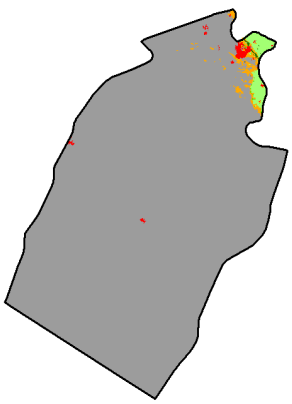

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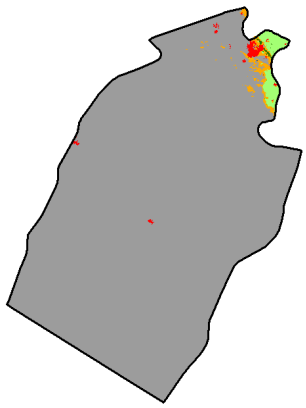

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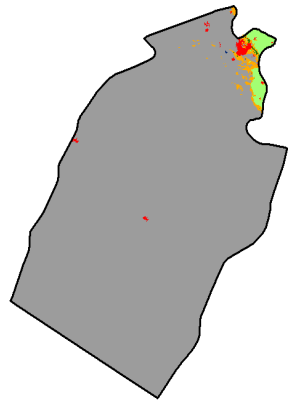

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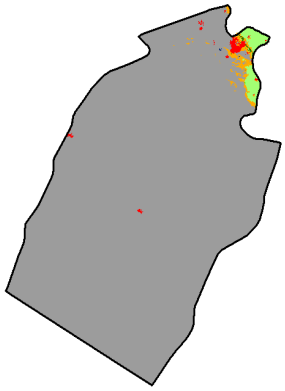

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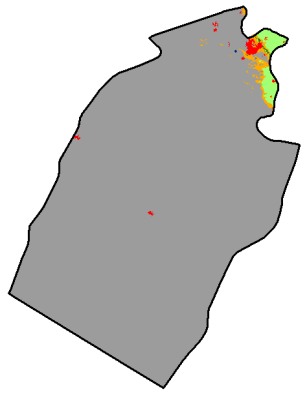

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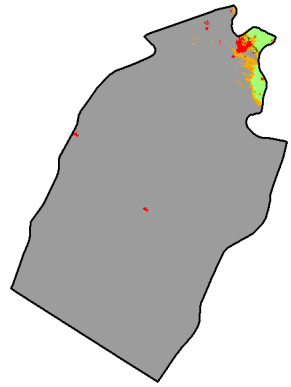

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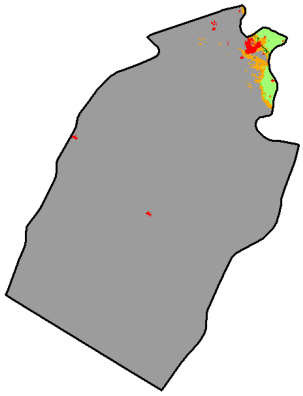

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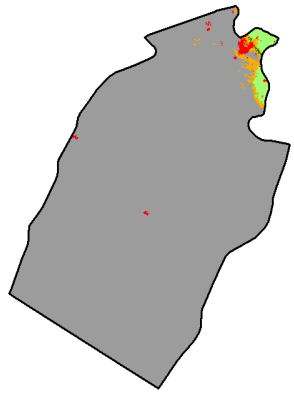

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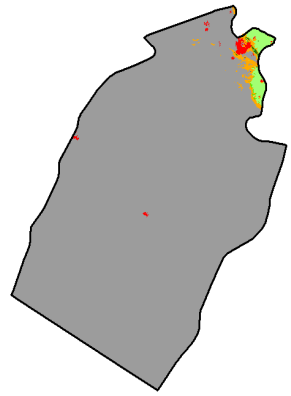

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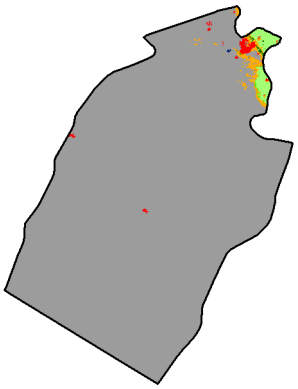

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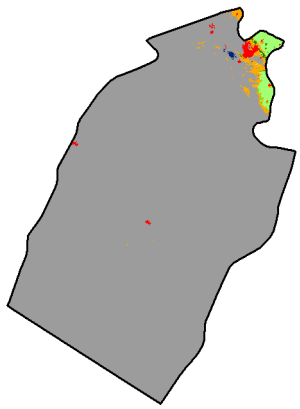

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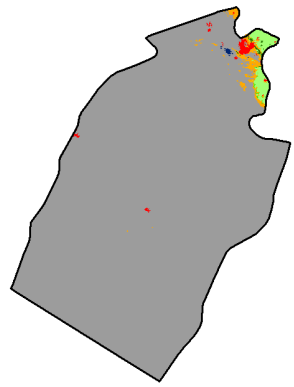

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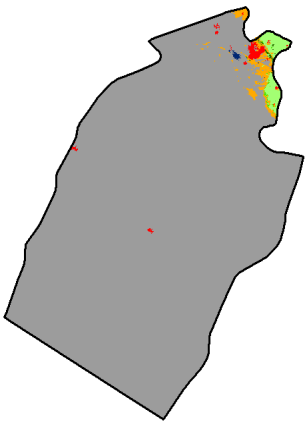

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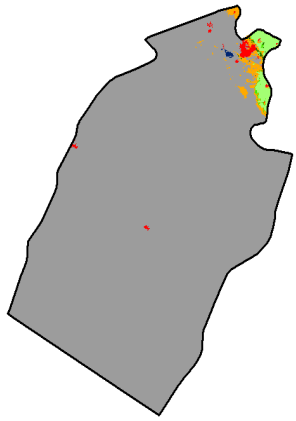

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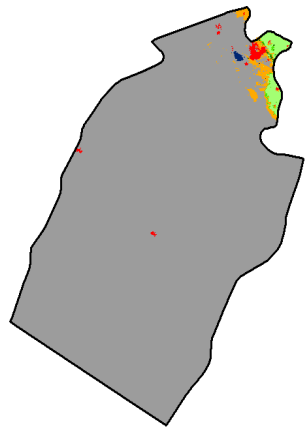

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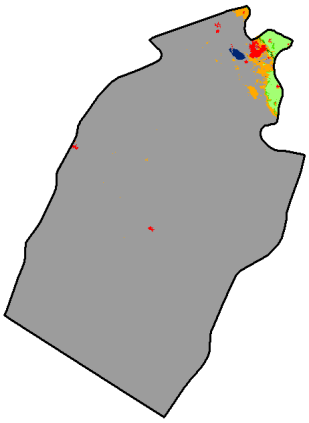

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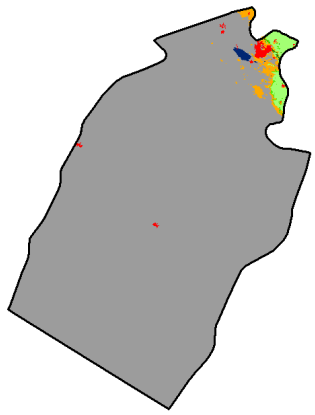

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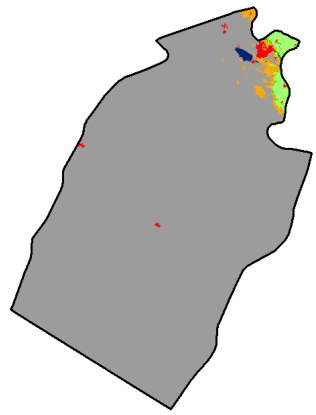

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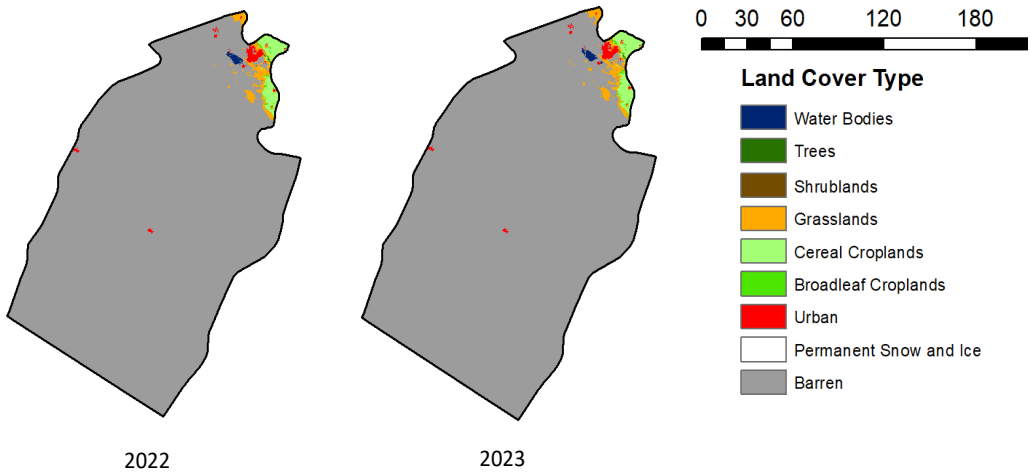

Figure 2. Show land cover change in Najaf from 2001- 2023

Table 1. Percentage of land cover change in Najaf

Year	Water Bodies	Trees	Grasslands	Cereal Croplands	Broadleaf Croplands	Urban	Barren
2001	0,002	0,068	0,797	1,315	0,105	0,07	96,693
2002	0,002	0,062	0,768	1,359	0,048	0,065	96,696
2003	0,002	0,055	0,747	1,352	0,06	0,063	96,721
2004	0,002	0,057	0,825	1,316	0,028	0,067	96,705
2005	0,002	0,06	0,833	1,317	0,006	0,072	96,71
2006	0,007	0,048	0,828	1,349	0,004	0,072	96,692
2007	0,007	0,043	0,808	1,342	0,006	0,068	96,726
2008	0,009	0,04	0,773	1,338	0,006	0,07	96,804
2009	0,002	0,04	0,817	1,277	0,011	0,075	96,778
2010	0,002	0,043	0,833	1,245	0,022	0,09	96,707
2011	0,061	0,083	0,966	1,25	0,049	0,25	96,341
2012	0,084	0,079	1,007	1,216	0,05	0,276	96,288
2013	0,068	0,066	1,09	1,205	0,076	0,3	96,195
2014	0,066	0,063	1,035	1,191	0,098	0,315	96,232
2015	0,095	0,054	1,059	1,188	0,104	0,32	96,18
2016	0,201	0,04	1,072	1,248	0,121	0,33	96,008
2017	0,151	0,038	1,06	1,262	0,127	0,35	96,012
2018	0,147	0,034	1,066	1,254	0,133	0,37	96,01
2019	0,155	0,04	1,072	1,248	0,121	0,28	96,7
2020	0,188	0,038	1,06	1,262	0,127	0,35	96,875
2021	0,201	0,034	1,066	1,254	0,133	0,39	96,822
2022	0,151	0,025	1,07	1,228	0,109	0,36	96,957
2023	0,147	0,024	1,078	1,25	0,132	0,39	96,979

Table 1 presents the percentage distribution of different LULC classes for the Najaf province during the period 2001-2023. From the table, it can be observed that the category of barren terrain is consistently the highest in terms of area, justifying the arid nature of the study region. The urban classes, although scant at first, show a gradual increase over the years. This is a good indication of continuous development and population increase. Agricultural land-use classes, which include cereal croplands, remain fairly steady. This maintains the course of farming activities despite the harsh conditions posed by the environment. Grasslands and trees show slight changes; this is because climate variability and land management practices can either promote or hinder their growth. Water bodies form a minimal percentage of the land cover. This is expected since the general nature of this region is semi-arid. The information derived from this table provides essential data for sustainable land management and resource planning in the province. Table 1 show the percentage of land cover change in Najaf.

CONCLUSIONS

This study performed a comprehensive analysis of the changes in LULC in Najaf province from 2001 to 2023 using MODIS MCD12Q1 data. Results highlighted barren land as the most dominant category throughout the study period, representing the arid and semi-arid nature of the region. The urban category increased progressively over the years, reflecting continuous development and expansion. Agricultural categories, mainly cereal croplands, were relatively stable over the period, showing the continuation of agriculture despite unfavorable environmental conditions. The findings revealed that there was limited vegetation cover and water body classes due to water scarcity and harsh climatic conditions. This study emphasizes that sustainable land management solutions are urgently needed to balance urban growth, agricultural development, and conservation of the environment. The trends identified require detailed policy intervention for improving land use, finetuning water resource management, and mitigating the impacts of climate change on the fragile ecosystem of the region. Remote sensing information, such as MODIS, has proven to be useful in monitoring and mapping the changes in land use and land cover over time, providing key information to policy makers, researchers, and other stakeholders. In summary, the study emphasizes the need for continued LULC monitoring to inform strategies for sustainable development and to ensure natural resources are used efficiently in Najaf. Future studies should focus on integrating higher-resolution datasets with terrestrial observations to enhance the accuracy and reliability of land use/land cover assessments, providing better decision-making for regional development.

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