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Nexus of Land for Food and Urbanisation: Application of DPSIR Model and Remote Sensing Data in a Developing Economy

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ABSTRACT

Changes in land use and land cover (LULC) are regarded as serious environmental problems globally. LULC assessment is a process that leads to a beneficial understanding of how people and the environment interact. The objective of the current study was to quantify LULC change and to determine its primary causes in the metropolis of Tehran in Iran over a 30-year period (1990–2020) using the DPSIR framework, which includes drivers, pressures, state, impact, and responses. In this study, Landsat 5, Landsat 7, and Landsat 8 OLI/TIRS satellite images were employed for LULC change detection analysis in 1990, 2000, 2010, and 2020. The DPSIR framework was used to identify the main reasons for the LULC changes. The LULC maps were created based on focus group discussions (FGDs) and a survey of farmers for the three dates. The findings indicated that this study region has experienced considerable changes in LULC over the last four decades, largely due to a transition from agricultural and forest land into built-up residential areas. The urban and built-up area expanded by 384.94 km^2 (47.15% of study area), forest land was depleted by 43.06 km^2 (5.9% of study area), and farmland declined by 61.05 km^2 (8.02%) during the study period (1990–2020). Surveys from participants and FGDs recognized population growth, urbanization, degraded lands, urban and rural land tenure systems, and climate change as main driver factors for LULC changes. In addition, the significant increase in migration from the rural to the urban areas caused an increase in population and land scarcity and a decline in land productivity. These findings could be practical for policymakers and decision makers to improve resource sustainability, effective land use planning, and appropriate decision-making.

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1 | Introduction

1.1 | Background on Land Use and Land Cover Change

Land use and land cover change (LULC) processes in developing countries are strongly affected by rapid urbanization with profound socio-economic and environmental effects (Kamali Maskooni et al. 2021; Wang et al. 2018). Urbanization destroys green areas, increases pollution, and fragments habitats, damaging urban ecosystems and reducing biodiversity (Bozkurt and Basaraner 2024). This urban sprawl not only increases climate risks but also generates a significant amount of greenhouse gas emissions, with buildings and construction activities accounted for as much as 40% of greenhouse gas emissions (Zhong et al. 2021). Human-induced land transformation in interaction with environmental changes reshapes landscapes, with implications for resource availability and ecological stability (Belete et al. 2020). Insights into these dynamics are fundamental for better management of the land, as LULC changes significantly affect ecosystem services, carbon storage, and food security (Khan et al. 2024; He et al. 2025). The development of geospatial technology allows researchers to more efficiently assess LULC trends, informing decision-making about urban development, ecological preservation, and climate adaptation (Zhang et al. 2023; Grabowska et al. 2024).

The current pace and intensity of LULC changes are significantly faster than at any other time in history, and they are a primary driver of global environmental change overall (Momin et al. 2022; Zeng et al. 2022). Many reasons, such as ongoing population increase, industrial development, urban expansion, and policy issues, have been among the main drivers of LULC-based human activities over time (Dadi et al. 2016; Peng et al. 2017). The consequences of climatic variability cannot be overlooked. Climate variability leads to changes in temperature and precipitation, and it affects plant growth and water efficiency. Hence, climate variability may change LU and LC. In recent years, the effects of climate change on LULC have received a lot of attention, particularly the spatiotemporal evolutionary features of LULC against the background of future climate change (Dou and Chen 2017). According to Talukdar et al. (2020) LU LC changes have taken place due to natural and anthropogenic reasons, which significantly influence ecosystem services. The transformation is the result of complex interrelationships among biophysical, social, and economic elements that can occur at various temporal and geographical dimensions and are typically caused by agricultural diversification, technological advances, and population pressure. For the development of land use planning and policy, land cover data is required (Mustaphi et al. 2019). Numerous researchers (e.g., Caballero et al. (2022); Yang and Jiang (2021); Wang et al. (2021)) have recently been interested in identifying changes in land cover. Moreover, it is an issue that necessitates research for long-term land management. In other words, it has an impact on biodiversity, the hydrological cycle, the productivity of land, and the long-term sustainability of the natural environment (Meshesha et al. 2016).

Because of rising population and housing demand, urban and rural areas are always competing. Due to this pressure and the accelerated change rate that results in fragmentation in land use patterns, the maintenance of soils, food security, and biodiversity all face extra challenges (Gomes et al. 2019). Landowners have an important role in LULC change caused by various drivers (Paudel et al. 2019; Huang et al. 2020). The three major actors in peri-urban contexts are dominant in a complex process. First, there are developers who want to capitalize on urban expansion in order to maximize profitability. They concentrate on strategies for spatial planning, rising population, and housing demand (Jarah et al. 2019). Second, there are farmers who have their land for lifestyle and amenities benefits or who are impacted by metropolitan area development and intend to make a profit (Van Vliet et al. 2015). Third, land use planners are engaged on a larger scale, and farmers are the main individuals responsible for making land use decisions. Since they have the resources to invest and have a substantial impact on future land use, they participate in the property market as developers, buyers or sellers as well as the market for renting out land (Holman et al. 2017).

Farmers play a significant role in community decision-making regarding production techniques and land use patterns. Their crop selection, farming practices, and land management decisions all have a direct impact on the composition of the landscape. These decisions have far-reaching consequences for local economies and ecosystems, significantly affecting the pattern of development and the sustainability of land use practices. Some studies have examined farmers' perceptions of LULC change. In Austria, Pröbstl-Haider et al. (2016) investigated the influence of climatic changes on LULC change and the preferences of farmers for agricultural land use in future. To minimize the effects of climate change, farmers promoted forestation in the area, which resulted in LULC changes. Kuntz et al. (2018) evaluated the perceptions of farmers about LULC change in rural areas of New York and found that abandonment of land impacted the rural residents' livelihoods. van der Zanden et al. (2018) utilized a combination of statements, photograph rating activities, and open-ended questions in a case study in northern Portugal to establish local people's, visitors', and experts' opinions of LULC change and their preferences for various alternatives after LULC change. Qasim et al. (2016), for example, investigated farmers' perspectives on the drivers, indicators, and local strategies for mitigating desertification in Pakistan's Pishin basin. Understanding the factors associated with land conversion is particularly significant since these factors determine the degree of LULC change, conservation strategies, and agricultural policies. Therefore, although the causes of agricultural LULC change are well understood, actual land use conversion may differ from expectations.

1.2 | Theoretical Context and Methodological Approach

Combining conceptual frameworks and geospatial technology is crucial for analyzing LULC processes and their socio-environmental implications (Dingamo et al. 2023). The DPSIR (drivers, pressures, state, impact, and response) framework offers an organized approach to analyzing the causal links between human activities and environmental changes, making it an important tool for land use planning and policy formation (Yousafzai et al. 2022). Remote sensing (RS) and geographic

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information systems (GIS) play critical roles in assessing geographical and temporal changes in land cover, allowing researchers to identify trends, forecast future scenarios, and assess environmental implications (Foroozesh et al. 2022; MohanRajan et al. 2020; Yousefi et al. 2022). This study improves the precision of LULC evaluations by combining RS data with socioeconomic surveys and participative methods, guaranteeing a more thorough comprehension of land system changes in quickly changing urban environments.

Data from RS provides cost-effective, fast, credible, and accurate information on degraded land during specific time periods. With the help of GIS technology, one can organize and analyze geographical data according to the case study's requirements (Alshari and Gawali 2021). Change detection includes using RS data to quantitatively examine the past consequences of an occurrence, thus assisting in the identification of changes connected to LULC attributes using multiple satellite datasets (Hussain, Mubeen, Akram et al. 2020). Supervised classifications need previous knowledge about the scene area as well as training samples, which must be kept and defined for use in the supervised classification algorithm (Yousefi et al. 2019). In Lucas do Rio Verde, Brazil, Lu et al. (2010) used quick bird (high-spatial resolution) images to evaluate LULC in a complicated urban area. Usman et al. (2015) classified and detected LULC change in Pakistan using multi-temporal MODIS (low-spatial resolution) normalized difference vegetation index (NDVI) data from 2005 to 2012. Hussain, Mubeen, Ahmad et al. (2020) utilized Landsat data over 30 years to reveal a pattern of LULC, normalized difference built-up index (NDBI), and NDVI change in Lodhran district, Pakistan, accounting for four different LULC types: water bodies, built-up regions, bare soil, and vegetation. Supervised classification was utilized to discover LULC fluctuations observed over the Lodhran area since it specifies the maximum likelihood approach in software ERDAS envision 15. Many researchers (e.g., Karimi et al. 2018; Mishra and Singh 2019; Liaqat et al. 2021) in the domains of geospatial science and RS employ medium-resolution photos since they are low-cost and have a good resolution for most purposes (Some satellite owners make images available to the public for free).

Rapid LULC change may be seen all around the world. As a result, identifying and assessing LULC change is crucial for properly understanding the dynamics of landscapes through time. Land cover can rapidly change as a result of population growth, climate change, and economic activities. Other research has found that anthropogenic activities (e.g., fragmentation of land) are altering LULC on both a spatial and temporal scale, with implications for the entire ecosystem (Shang and Wu 2022). Previous research discussed various perspectives on the primary causes of LULC change. According to Mather and Needle (2000), population expansion is the primary cause of LULC change and the resultant degradation of land. According to Wang et al. (2008), the fundamental driving forces of LULC change on the Tibetan plateau are socioeconomic growth (China). They have demonstrated via their research that LULC change is a result of a combination of human actions, such as farmland development, and basic social processes, such as population increase, as well as policy, institutional settings, and cultural variables. Hailu et al. (2020) argued that population and poverty alone are key drivers of global LULC change. They found that the primary drivers of LULC change are responses of people to economic benefits aided by institutional considerations.

Tehran, the capital of Iran, is the country's largest and most densely populated metropolis, which has undergone major urban expansion and population increase in recent decades (Rahnama and Rajabpour 2017). Tehran is one of Iran's most polluted cities due to its large population, land use change, traffic congestion, and concentration of industry around the city (Nasehi and Salehi 2019). In recent decades, the city of Tehran has witnessed changes in LULC that have made the land less productive or unproductive and have caused chief concern for the sustainable development of the region. Population growth, agricultural intensification, infrastructure accessibility, climate, and invasive alien plant species have all been connected to a significant portion of the observed LULC in Tehran province in recent years (Sobhani, Esmaeilzadeh, and Mostafavi 2021; Yousefi et al. 2022).

Linking various socio-economic factors such as socio-economic development, population pressure, technological progress, and land biophysical characteristics is an essential aspect of LULC change research since these factors impact the changes that occur on the earth's surface (Baulies and Szejwach 1998; Yousefi et al. 2019). The DPSIR framework (drivers, pressures, states, impacts, and responses) is an indicator-based method that implies a cause-and-effect relationship among the components of interconnected environmental, economic, and social systems (EEA 1999). The DPSIR framework has been widely employed for complicated environmental challenges, such as soil and land resources, by connecting ecological and socioeconomic aspects, biodiversity, water resources, marine resources, and agricultural systems (Birhane et al. 2019; Shiferaw and Singh 2011). Driver (D) refers to the social and economic developments that influence the human activities that have a direct impact on the environment (e.g., population growth, urban and rural land tenure system, and urbanization) (Obubu et al. 2022). Pressure (P) represents the consequence of the driving force, which in turn affects the state of the environment. Pressures represent any change in the environment caused by destructive human activities (e.g., deforestation and change in land cover) (Quevedo et al. 2023). State (S) describes the physical, chemical, and biological condition of the environment or observable temporal changes in the system. It may refer to natural systems (e.g., variability of rainfall and temperature and soil erosion), socio-economic systems (e.g., living conditions of humans, economic situations of an industry), or a combination of both (Kim et al. 2021). Impact (I) refers to how changes in the state of the system affect human well-being. It is often measured in terms of damage to the environment or human health (e.g., migration, land scarcity, and decline in the quality of soil) (Obubu et al. 2022). Response (R) refers to actions taken to correct the problems of the previous stages by adjusting the drivers, reducing the pressure on the system, bringing the system back to its initial state, and mitigating the impacts (Quevedo et al. 2023). Therefore, the DPSIR framework seeks to analyze and assess environmental problems by bringing together various scientific disciplines, environmental managers, and stakeholders, and then solving these problems by incorporating sustainable development (Kim et al. 2021). The DPSIR framework has advantages

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over other theoretical and socioeconomic models, especially in data-limited places such as Tehran, because it is simple and adaptable while allowing for a large range of relevant indicators to run the model.

1.3 | Research Objectives

Previous studies (e.g., Kumar et al. 2017; Wang et al. 2018; Kumar and Dhorde 2021; Enoh et al. 2023; Chisanga et al. 2024) put more focus on LULC dynamics in order to gather quantified data on LULC for the purpose of sustainable development. Moreover, some studies (e.g., Meshesha et al. 2016; Madhu et al. 2017; Guha and Govil 2022; Hussain et al. 2024) investigated LULC changes over different intervals to find the major changes in the region. However, the reason behind the change is, in most cases, not taken into account. Therefore, to fill this gap, the primary goal of this study is to propose a novel framework for analyzing the drivers of LULC change and their effects on society and land use properties. This study tries to identify these factors and link them to land use statistics derived from geospatial data. The DPSIR technique has been adopted to examine the cause-and-effect links between the different drivers of LULC change. This approach has been combined with satellite data from Tehran during the previous 30 years (1990–2020) in order to determine the primary drivers of LULC changes in the research area and to compare farmers' views of LULC changes. The research area has been chosen with regard to the fact that Teheran is one of the Middle East's fastest-growing cities. Consequently, LULC dynamics in the city center and its suburbs are significantly affected, resulting in direct and indirect impacts on land resource dynamics. Hence, this study investigates LULC change in Tehran over a 30-year time span both to supply the information needed for prompt action towards sustainable development in the Tehran area and to provide insights into possible future development and challenges connected to LULC in the Middle East.

2 | Methodology

2.1 | Study Area

Tehran, Iran's capital city, is situated in northern Iran on the southern hillside of the Alborz mountain range, and it lies between the latitudes of 35°30′ to 35°51′ and longitudes of 51°00′ to 51°40′ (Figure 1). In 1921, the population of Tehran was 0.21 million, in 2016 it was 8.52 million (T.W.C 2018), and in 2020, it was the city in Iran with the largest number of inhabitants (9.14 million) (SCI 2020). There are two landscape types in Tehran, the plains in the southern part and the mountainous area in the northern part, with altitudes of 900–1800 m, respectively. Altitude change in Tehran leads to the occurrence of distinct climatic conditions. Mostly, the northern areas of Tehran have a cold and dry climate and the southern part has a dry and warm climate. In Tehran, the average long-term annual rainfall is 422 mm with 89 rainy days in the northern part and 145 mm with 33 rainy days of in the southern part (Mostofi and Hasanlou 2017). Tehran's average yearly temperature has ranged from 15°C–18°C with fluctuations of 3°C due to altitude change (Bokaie et al. 2016). Tehran includes vegetation of natural forests, with plant species such as Persian almond (*Prunus scoparia*), pistachio (*Pistacia* spp.), fig (*Ficus* spp.), and barberry (*Berberis* spp.), as well as planted forests (Chitgar Forest Park, Lavizan Forest Park, and Sorkh Hesar Forest Park) that include pine (*Pinus* spp.), acacia (*Acacia* spp.), and European ash (*Fraxinus excelsior*). The study area covered 730 km^2 containing 22 municipality districts (Mostofi and Hasanlou 2017).

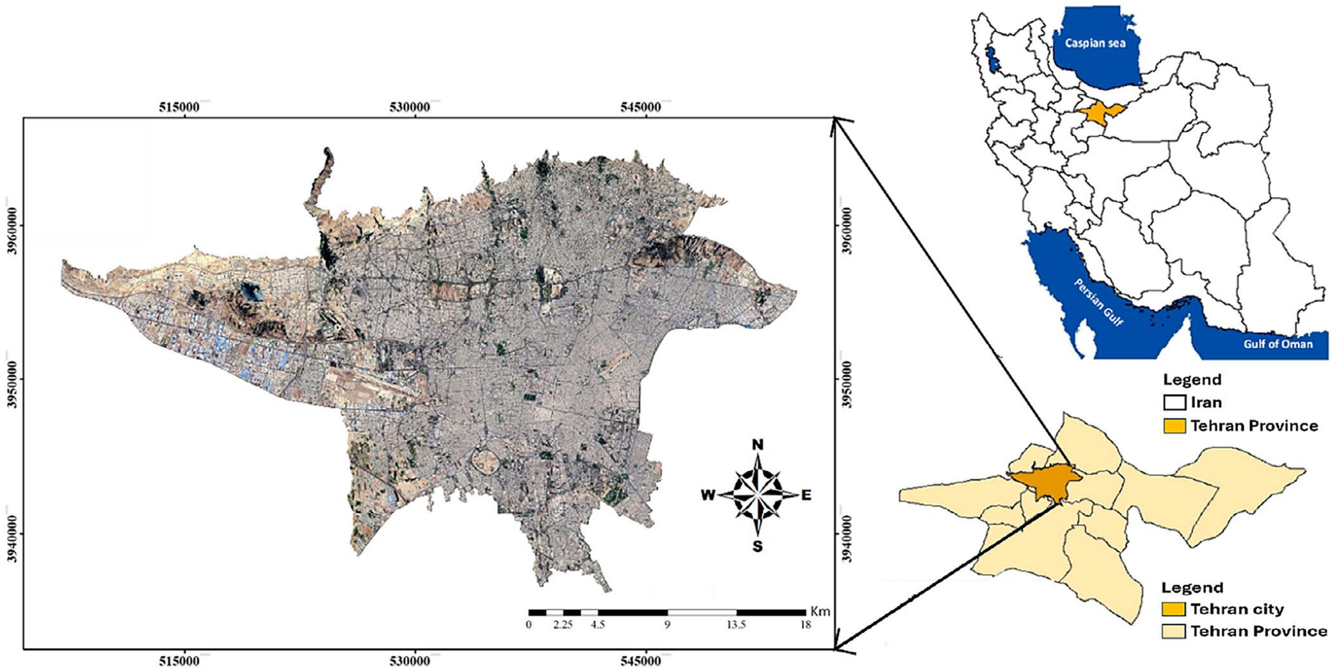

FIGURE 1 | Geographical location of the Study area. *Source:* https://earth.google.com/ (modified). [Colour figure can be viewed at wileyonlinelibrary.com]

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Figure 2 shows the four main stages of the present study. In the first step, satellite images were used for producing land cover maps. Farmers' perspectives on the DPSIR framework and its importance for LULC change were gathered through surveys aimed at determining the present state of LULC. In the context of the DPSIR framework, pressures are environmental stressors caused by external driving forces that in turn affect LULC dynamics. Finally, the DPSIR framework was utilized to analyze the drivers and pressures of change, as well as their relationships, in order to manage LULC in a sustainable manner.

2.2 | Classification of Satellite Images

In this study, Landsat data that were obtained from the United States Geological Survey (USGS) portal was used to extract LULC. Table 1 shows Landsat 5 thematic mapper (TM) datasets used for the years 1990, 2000, and 2010 and Landsat 8 OLI/TRIS datasets of 2020. ENVI 5.3 software was used to preprocess each image, which included atmospheric correction and radiometric calibration. In order to visualize the LULC intensification, 10-year intervals were used to reveal large-scale city

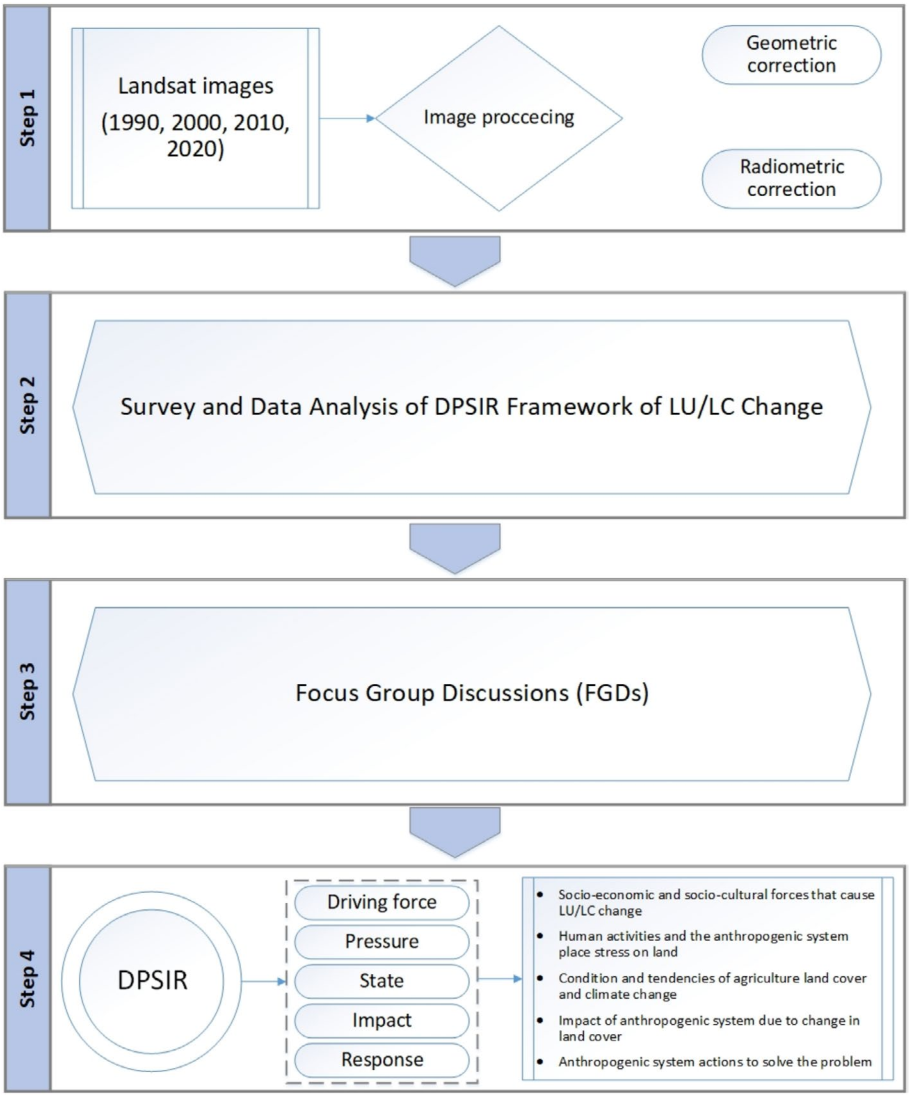

FIGURE 2 | Flowchart of the methods applied in this study. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 | Details of the Landsat imagery (1990 to 2020).

Satellite	Scene ID	Interval	Cell size (m)	Date
Landsat TM	LT05_L1TP_174035_19900717_20190208_01_T1	1990	30×30	15 July 1990
Landsat-7 TM	LT07_L1TP_174035_20000721_20191207_01_T1	2000	30×30	19 July 2000
Landsat-7 TM	LT07_L1TP_174035_20100801_20191030_01_T1	2010	30×30	21 August 2010
Landsat OLI/TIRS	LC08_L1TP_174035_20200712_20200712_01_RT	2020	15×15	12 August 2020

Source: Study findings.

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development. These intervals allowed the best detection of the dynamic variations in LULC.

2.3 | LULC Change Detection

Understanding the link between land use and remote sensing data requires a theoretical framework that explains how different land cover changes appear in remotely sensed imagery. Remote sensing is a useful technique for analyzing land use trends because it captures spectral, thermal, and structural features of the Earth's surface (Li et al. 2023). Land use encompasses the human use of land for a variety of reasons, including agriculture, urbanization, forestry, and conservation. Remote sensing gathers physical and biological characteristics of land cover, which may be utilized for determining land use. The spectral reflectance of different surfaces, thermal emissions, and texture information obtained from satellite imagery provide insights into land use dynamics (Xu et al. 2023).

Theoretically, land use affects remote sensing data via a causal pathway: land use change alters surface materials, which modifies spectral and thermal signatures. For instance, urbanisation raises impervious surfaces, which raises land surface temperatures, whereas deforestation decreases vegetation cover, changing spectral reflectance (Jamal et al. 2023). Because of seasonal growth cycles, agricultural activities can have an impact on vegetation indices. Remote sensing offers a systematic and scalable technique to monitor land use changes, although accuracy is dependent on factors such as temporal variability, spatial resolution, and atmospheric conditions. Integrating these theoretical ideas improves the reliability of land use analysis using remote sensing (Peng et al. 2024).

Satellite imagery was used in four time periods including Landsat TM for 1990, 2000, 2010, and Landsat OLI/TIRS for 2020 in Tehran to obtain LULC information. The ENVI 5.3 software was used to obtain LULC maps in five classes including urban and built-up, bare land, forest land, farmland, water bodies, and rural areas through the maximum likelihood technique in supervised classification. A stratified random sample approach was used to determine the class's accuracy and then test the LULC classification accuracy. To evaluate the accuracy of visual interpretation of all classes, 1000 training points were selected in four distinct time periods. Then, the user accuracy (Ziaul and Pal 2016), the producer accuracy (Sexton et al. 2013), and overall accuracy (Sultana and Satyanarayana 2018) were measured based on the confusion matrix (Equations 1–3). In order to determine the accuracy of the classification, the kappa coefficient was also determined. Kappa is regarded as a non-parametric test that was used to determine the degree of agreement between values that the user supplied and values that were pre-set (Equation 4).

$$\text{Overall Accuracy} = \left\{ \frac{\sum \text{CCP(Diagonal)}}{\sum \text{CRP}} \times 100 \right\} \tag{1}$$

where CRP stands for corrected reference pixels and CCP (Diagonal) stands for corrected categorized pixels (diagonals);

$$\text{User Accuracy} = \left\{ \frac{\sum \text{CCP(Category)}}{\sum \text{CPC(Row)}} \times 100 \right\} \tag{2}$$

where CPC (Row) represents the categorized pixels in that class (the complete row), whereas CCP (Category) represents the corrected classified pixels (category);

$$\text{Producer Accuracy} = \left\{ \frac{\sum \text{CCP(Category)}}{\sum \text{CPC(Column)}} \times 100 \right\} \tag{3}$$

where CCP (Category) represents the total number of correctly classified pixels (diagonals) within this category and CPC (Column) represents the total number of classified pixels within this category;

$$\text{Kappa Coefficients} = \frac{N \sum_{i=1}^{r} X_{ii} \sum_{i=1}^{r} \left(X_{i+} \times X_{+i}\right)}{N^2 - \sum_{i=1}^{r} \left(X_{i+} \times X_{+i}\right)} \tag{4}$$

where N represents the maximum number of samples, r represents the number of rows in the matrix error, X_{ii} represents the maximum number of corrected samples in the column and row, N^2 represents the square of the maximum number of samples, X_{i+} is the total of columns, and X_{i+} is the total of rows.

2.4 | Survey and Analysis of DPSIR Framework of LULC

Surveys were conducted to better understand the evolution of the LULC situation and to learn more about the DPSIR of LULC change from farmers. In this study, 382 farmers were randomly selected from the city of Tehran's farmer population. The sample size was specified using Cochran's sample size determination algorithm, and it was representative of the investigation's purpose due to the farmers' relative homogeneity in terms of culture, resources, and environmental characteristics. A semi-structured questionnaire was used to collect farmers' perspectives on the five dimensions of the DPSIR framework. Questions on basic information related to homes, farmers, and LULC history of land parcels were included in the questionnaire. The data was analyzed using descriptive statistics such as frequencies and percentages. In this study, FGD were conducted to obtain deeper understanding about each element of DPSIR framework of LULC change as perceived by members of local communities in Tehran and rural regions. A purposive sample strategy was used to choose participants for the FGD, guaranteeing representation from varied backgrounds and viewpoints relevant to the study's goals. Three FGDs, each of which had 6 to 10 members of the local community and Ministry of Agriculture professionals, were organized. The data obtained from the FGDs was subjected to thematic analysis, narrative analysis, and qualitative description. The participants were balanced in terms of age and gender.

Table 2 indicates the sociodemographic distribution of the respondents. According to the statistics, just 6% of farmers were under the age of 30, 39.1% of them were between 46 and 60 years, and the mean age of respondents was 56.8 years old. Respondents with a secondary education had the highest sample prevalence (53%). Farmers with 40 years of farming experience and more had a frequency of 36%, while farmers with 5–10 years had about a 2% frequency. Farmers had an average of 43.4 years

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TABLE 2 | Sociodemographic characteristics of the participants in the study area ($n = 382$).

Demographic and characteristics	Frequencies	%	Mean	SD
Age (years)			56.8	9.8
< 30	23	6		
31–45	92	24.9		
46–60	150	39.1		
> 60	117	30		
Farmer's experiences of farming (based on years)			43.4	12.7
5–10	5	2		
11–20	45	11		
21–30	58	16		
31–40	131	35		
> 40	143	36		
Educational status				
Illiterate	8	1. 9		
Primary school	133	35		
Secondary school	196	53		
Collegial	45	12		
Land size				
< 1 ha	160	41.1		
> 1 ha	222	58.9		
Ownership of land				
Private ownership	341	90		
Rented land	4	1		
Sharecrop fifty–fifty	9	3		
Private and rented land	28	6		
Household income (annual)				
< \$10,786	125	32.0		
\$10,786–\$15,679	215	57.0		
> \$15,679	42	11.0		

Source: Study findings.

of experience. Only 1% of farmers had leased land, whereas 90% of them had private land. In terms of farm size, 58.9% of farmers had > 1 ha, 41.1% had < 1 ha, and the average farm size was 0.8 ha. In addition, most of the farmers (57%) stated an average income (\$10,786–\$15,679).

2.5 | The DPSIR Model for Identifying LULC Factors

To manage LULC in a sustainable manner, identifying the causes of primary changes and their relationships is critical (drivers and pressures). Hence, the DPSIR framework was applied in this study. In 1994, the organization for economic cooperation and development established the DPSIR framework, which has been extensively used by international organizations (Ramos-Quintana et al. 2018). This framework assists in comprehending the interplay of variables and interactions that alter the environment. The drivers that cause socio-economic and cultural forces to meet fundamental requirements are known as drivers. Such forces can act on the local, regional, or global level. Human activities that threaten the environment can be seen as drivers as well.

Pressures are environmental stresses induced by driving factors such as LULC. The land cover condition is referred to as the state of the LULC. Depending on the stresses applied, the state of the land cover may change. LULC then in turn has an impact on human well-being. Responses may be implemented at various levels, including local policies and practices, for reform. Responses might address the pressures while also attempting to preserve and enhance the land cover state. LULC data from four separate collection dates (1990, 2000, 2010, and 2020) were applied to attain the status of the landscape, LULC change detection, and monitoring responses of potential management. The DPSIR framework is an effective tool for determining cause-and-effect links among interconnected elements of environmental systems and socio-economic factors, such as: (1) Drivers of LULC; (2) Pressures that possess on the LULC; (3) State of LULC due to some changes in conditions; (4) Impacts on population, environmental condition, and economy due to the LULC; (5) Response of the community to the LULC. Figure 3 depicts the way human activities put pressure on resources of land and, as a result, alter the state of the land and environment. People's health, natural resources, and ecosystems may all be influenced by the state of the land and environment. These impacts may lead to responses for the management practices, policies, or activities that change the driving forces, pressures, and finally the environmental state. Over time, impact changes can lead to modifications in the response of individuals to these impacts. Solutions that may be used as a response to ensure sustainability can be found in approaches that respect the planetary boundaries (Rockström et al. 2009), the social foundation (Raworth 2017), and economic sustainability (Kardung et al. 2021) of a chosen solution (Keesstra, Mol, et al. 2018). Solutions based on natural processes can be most suitable for such cases (Keesstra, Nunes, et al. 2018; Keesstra et al. 2021).

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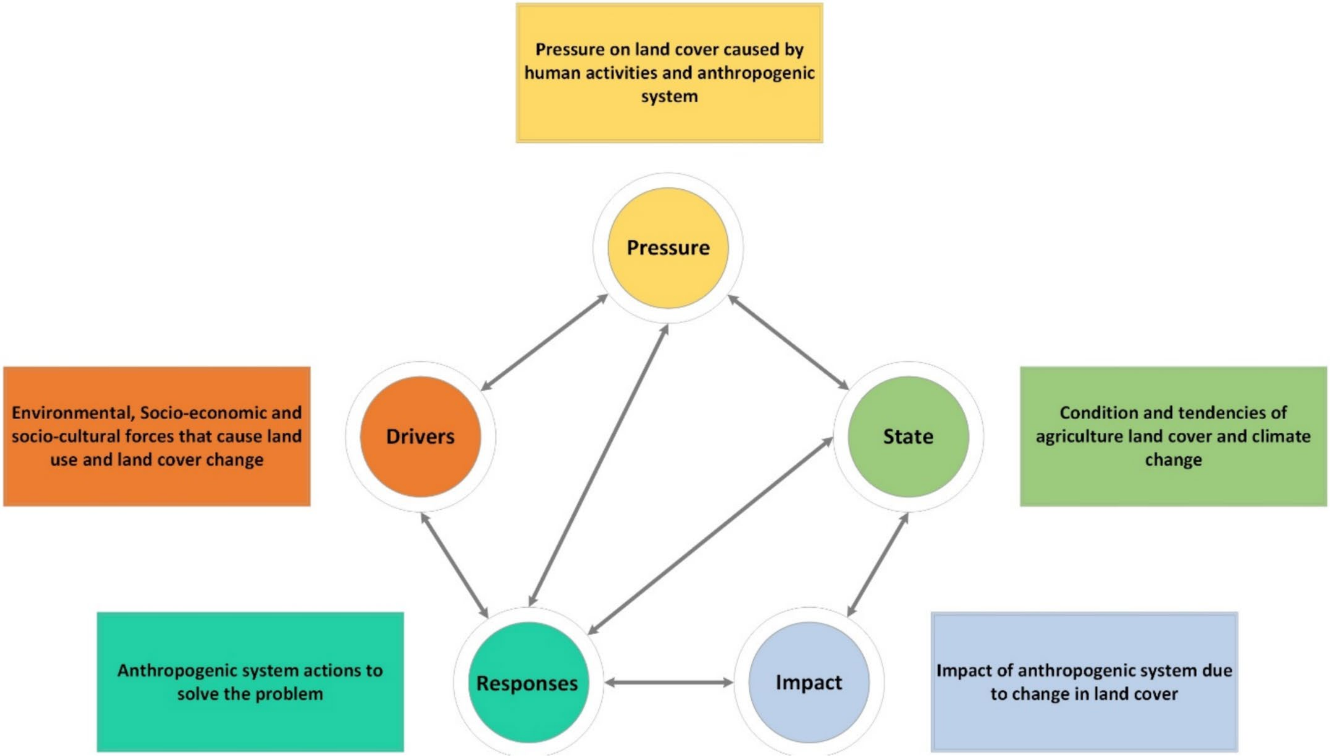

FIGURE 3 | The flowchart of the DPSIR framework for LULC change. *Source:* Study findings. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 | Specified LULC classification of Tehran metropolis.

LULC classification	Description of classes
Urban and built-up	Transportation network, parking, residential areas, industrial estates, and commercial settlements
Forest land	Mixed type of forests, forest-steppe
Waterbody	Open water, ponds, and lakes
Farmland	Crop farms and fallow farms
Bare land	Barren land and abandoned land

Source: Study findings.

3 | Results

3.1 | LULC Classification Accuracy Evaluation

In this study, Tehran city is categorized into different classes of LULC, including urban and built-up areas, forest land, waterbody, farmland, and bare land using maximum likelihood classification (Table 3). In this research, four various time series (1990, 2000, 2010, and 2020) were considered to illustrate the LULC dynamic spatial pattern, showing that the accuracy of all LULC classes is above 80%. The overall accuracy level for this study obtained for all classes was over 86%. Moreover, the results of the kappa coefficient were 0.854, 0.884, 0.897, and 0.907 in 1990, 2000, 2010, and 2020, respectively (Table 4).

3.2 | Spatio-Temporal LULC Classification Patterns

Figure 4 shows the LULC maps. The urban and built-up class was the most widespread of all land uses, as it was 155.83 km^2 in 1990 and rose to 345.65 km^2 in 2000. As shown in Table 4, again in 2010, the urban and built-up class rose to 443.83 km^2, and finally, in 2020, it rose to 540.77 km^2 (Figure 4). This indicates that 384.94 km^2 (47.15%) of other land uses from 1990 to 2020 have been converted to urban and built-up classes. Maintaining the lowest rate of development, in 1990, the class of waterbody was about 0.52 km^2, and in 2000 it rose to 0.71 km^2. Finally, in 2020, the class of waterbodies rose again to about 2.11 km^2 (because an artificial lake was constructed in 2010) (Figure 5). This shows that 0.29% of the other LULC classes from 1990 to 2020 turned into waterbody (Table 5).

The class of bare land experienced the largest decline of all land uses from 417.49 km^2 in 1990 to 266.86 km^2 in 2000. Following this, in 2010, it declined to 183.39 km^2 and in 2020 to 135.07 km^2. So, this totals 282.42 km^2 (33.52%) of bare land from 1990 to 2020, which has been converted to another LULC class (particularly urban and built-up). The second most declined class was Forest land, since it was 83.20 km^2 in 1990, down from 76.76 km^2 in 2000. In 2010, it declined to 69.47 km^2 and in 2020 to 40.14 km^2. This indicates that from 1990 to 2020, 43.06 km^2 (5.9% of the total land) of forest land changed to another LULC class. The farmland class, the smallest of all land uses, was 69.04 km^2 in 1990 and declined to 36.1 km^2 in 2000. In 2010, it declined again to 28.79 km^2 and in 2020 to 7.99 km^2. This shows that from 1990 to 2020, 61.05 km^2 (8.02%) of the farmland changed to another LULC class (Table 6 and Figure 6).

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TABLE 4 | LULC classes accuracy evaluation report (1990–2020) in Tehran metropolis.

LULC classification		1990	2000	2010	2020
Accuracy of user	Urban and built-up	83.0	85.0	88.0	93.0
	Forest land	87.0	83.0	89.0	91.0
	Waterbody	99.0	97.0	98.0	99.0
	Farmland	85.0	87.0	88.0	91.0
	Bare land	84.0	89.0	94.0	94.0
Accuracy of producer	Urban and built-up	85.5	89.4	91.0	92.3
	Forest land	92.3	92.0	88.7	52.1
	Waterbody	97.8	97.1	95.3	97.0
	Farmland	87.0	87.0	88.9	91.0
	Bare land	84.0	88.0	94.0	93.0
Overall accuracy		88.3	89.5	90.5	93.7
Kappa coefficient		0.854	0.884	0.897	0.907

Source: Study findings.

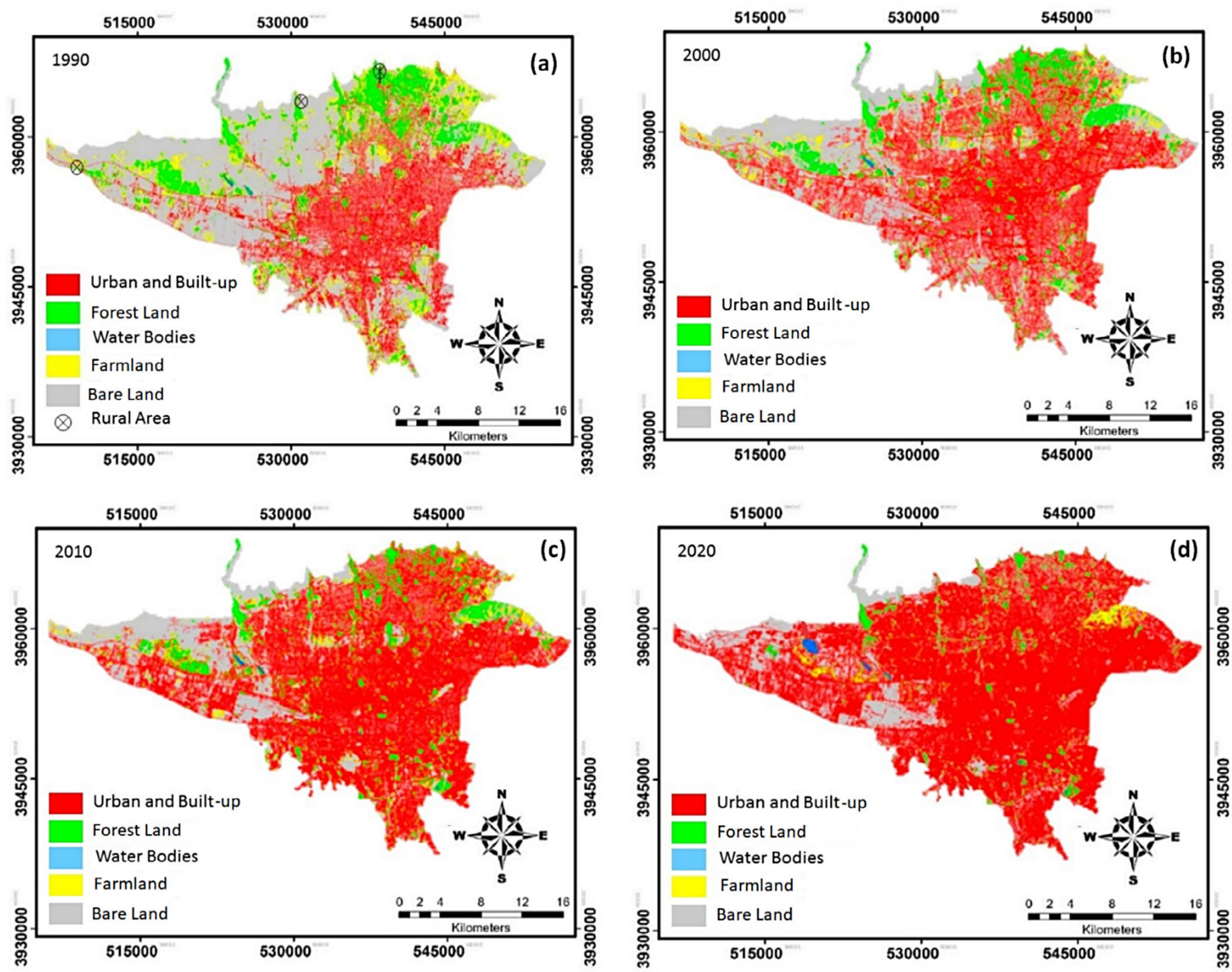

FIGURE 4 | LULC cover in the metropolis of Tehran: (a) LULC Map of 1990, (b) LULC Map of 2000, (c) LULC Map of 2010, and (d) LULC Map of 2020. *Source:* Study findings. [Colour figure can be viewed at wileyonlinelibrary.com]

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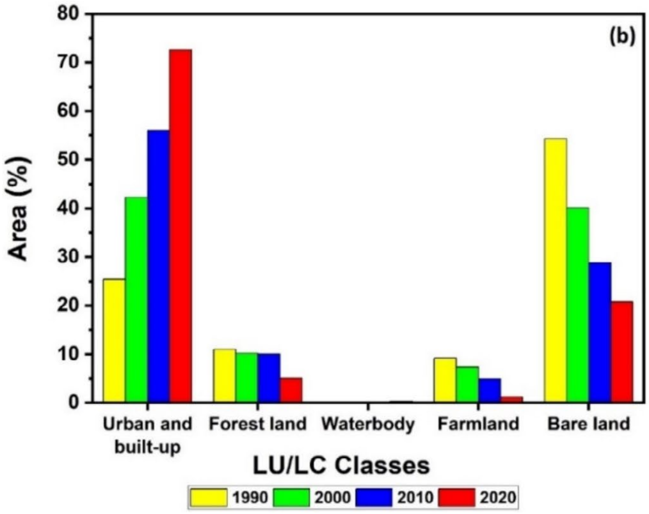

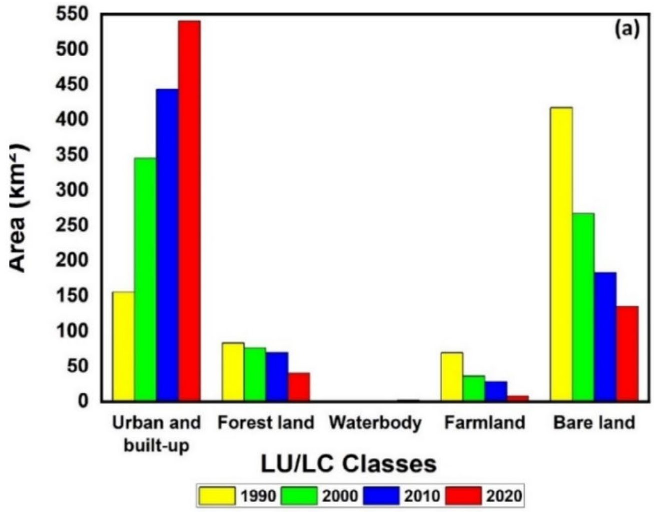

FIGURE 5 | Distribution of area in different LULC classes in km^2 and percentage. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 5 | Statistical summary of LULC from 1990 to 2020.

	1990		2000		2010		2020	
Types of LULC	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**	**km^2**	**%**
Urban and built-up	155.83	25.42	345.65	42.26	443.83	56.01	540.77	72.57
Forest land	83.20	11	76.76	10.18	69.47	10.03	40.14	5.1
Water body	0.52	0.08	0.71	0.08	0.60	0.1	2.11	0.37
Farmland	69.04	9.21	36.1	7.38	28.79	5.01	7.99	1.19
Bare land	417.49	54.29	266.86	40.1	183.39	28.85	135.07	20.77
Total	726.080	100.00	726.080	100.00	726.080	100.00	726.080	100.000

Source: study findings.

3.3 | Results of DPSIR Elements' Analysis in Relation to LULC

According to Table 7, 80% of farmers believed that the urban and constructed areas have risen during the previous 30 years. In total, 86% of farmers also noticed a decrease in forest area, and 77%, 76%, and 62% of them believed that farmland, bare land, and water bodies were decreased, respectively (Figure 7). Farmers' perception of LULC changes was studied through interviews utilizing the quantitative findings of LULC mapping and RS techniques.

3.3.1 | Drivers, Pressure, State, Impact, and Response of LULC Change

LULC changes are the consequence of a number of driving factors. Other research (e.g., Geist et al. (2006); Van Vliet et al. (2015); Piquer-Rodríguez et al. (2018); Betru et al. (2019)) highlighted socio-cultural, technological, demographic, economic, institutional, and political elements as drivers of land cover change. Moreover, the present study included an investigation of drivers for LULC changes. Table 8 shows the perceived and reported driver factors of LULC change by farmers. The primary drivers in Tehran were population growth (84.3%), change in agricultural land use activities (70.5%), urbanization (67.8%), degraded lands (67.2%), decrease in farm size (64.5%), climate change (64.2%), and urban and rural land tenure system (42.2%).

The pressures created due to LULC change and perceived by farmers included agricultural land demand (81.0%), expansion of urban, commercial, and industrial areas (75.8%), increase in temperature (73.5%), overcompetition on land (71.0%), deforestation (67.2%), changes in soil moisture (47.2%), and rising demand for agricultural products (44.1%).

According to the findings presented in the previous sections, the current conditions observed in the study area due to LULC change by farmers were land cover change of forest (83.1%), change in biodiversity (77.7%), rise in the price of land (77.1%), variability of rainfall (72.1%), increase in fragmentation of land (64.3%), and soil erosion (60.4%).

According to Bokaie et al. (2016) and Sobhani et al. (2021), changes in land cover in Tehran are connected to significant environmental and economic impacts. For the city of Tehran, the major impacts reported by farmers, as indicated in Table 8, included a rise in migration from rural to urban areas (82.1%), a change in the size of the population (77.5%), land scarcity

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TABLE 6 | Statistics of LULC changes in 1990, 2000, 2010, and 2020.

Types of LULC	1990–2000		2000–2010		2010–2020		1990–2010		1990–2020		2000–2020	
	km²	percent	km²	percent	km²	percent	km²	percent	km²	percent	km²	percent
Urban and built-up	189.82	16.84	98.18	13.75	96.94	16.56	288	30.59	294.94	47.15	195.12	30.31
Forest land	−6.44	−0.82	−7.29	−0.15	−29.33	−4.93	0.08	0.02	−43.06	−5.9	−36.62	−5.08
Waterbody	0.19	0.0	−0.11	−0.02	1.51	0.27	0.08	0.02	1.59	0.29	1.59	0.29
Farmland	−32.94	−1.83	−7.31	−2.37	−20.8	−3.82	−40.25	−4.2	61.05	8.02	−28.11	−6.19
Bare land	−150.63	−14.19	−83.47	−11.25	−48.32	−8.08	−234.1	−25.44	−282.42	−33.52	−131.79	−19.33

Source: study findings.

(74.2%), a decrease in land productivity (69.7%), an increase in consumption of resources (65.3%), a decline in the quality of soil (62.1%), and loss of biodiversity (52.2%).

Based on the findings (Table 8), responses from farmers' perceptions of the impacts of LULC change were increasing farmers' awareness in the management of land (85.2%), resource conservation and restoration (80.8%), using proper land use planning (66.8%) and investment and proper management of land resource (50.6%).

3.3.2 | Application of the DPSIR Framework to the LULC Change

A DPSIR model was developed based on farmers' responses on their perceptions of several factors related to the LULC change. Figure 8 depicts all of the responses collected from farmers in the questionnaire survey, as well as issues mentioned in the focus group discussions.

4 | Discussion

4.1 | LULC Change

Tehran is Iran's capital and one of the world's oldest cities with a rich civilization history (Bokaie et al. 2016; Roshan et al. 2009). Tehran's landscape is divided into two distinct types: mountainous areas in the north and plains in the south (Falahatkar et al. 2017; Habibi et al. 2017; Hasanlou and Mostofi 2015). The city of Tehran has a long history of drawing people to its region. It has experienced exponential, uncontrollable expansion in the form of dwellings, transit systems, industrial and commercial zones, parking lots, and other facilities. This trend has changed the dynamics of LULCs and their distribution on a large scale (Zhou and Chen 2018). One of the key drivers for all these changes is the explosive population growth over the last decades. The population increased to approximately three million people in 2020, resulting in massive demand for land for residences, healthcare centers, schools, recreation areas, parking spaces, and roads (Sobhani, Esmaeilzadeh, and Mostafavi 2021). The same change has been observed as a result of the rapid expansion of built-up lands in various locations throughout the globe, especially in developing countries (e.g., Dissanayake et al. 2019; Chanu et al. 2021; Topaloğlu et al. 2022).

This study discovered a link between the occurrence of the urban and built-up classes and an increased rate of LULC change. The findings showed that 384.94 km² (47.15%) of other LULC classes have been converted to urban and built-up classes between the years 1990 and 2020. The other changes in LULC classes between 1990 and 2020 include 1.59 km² (0.29%) of waterbody, 282.42 km² (33.52%) of bare land, 43.06 km² (5.9%) of forest land, and 61.05 km² (8.02%) of farmland (Table 5 and Figure 5). At each 10-year interval, it was noticed that urban and built-up areas increased quite suddenly on the northern, southern, and western sides of Tehran (Figure 4). This development is due to the considerable population pressure which had already been predicted by the United Nations as it stated that Tehran's population would reach 9.9 million by 2030. As a result, it is

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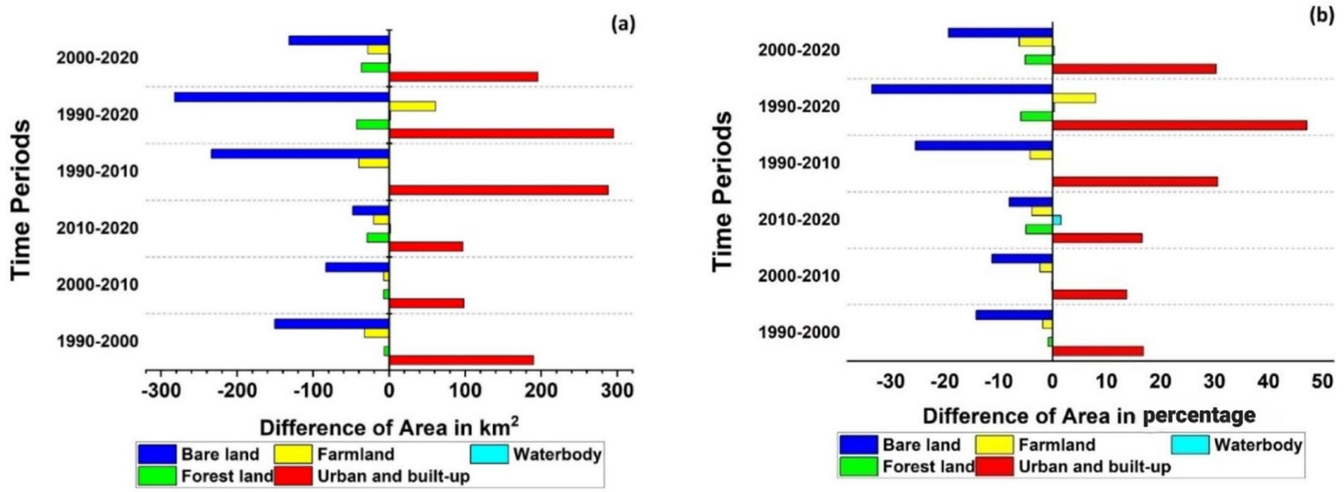

FIGURE 6 | Classification of LULC in various time scales in Tehran metropolis: (a) LULC classes at different time scales in area (km²) and (b) percentage of each LULC class at different time scales. *Source:* Study findings. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 7 | Farmers' perception of LULC change for 1990–2020.

Types of LULC	Increase	Decrease	No change
Urban and built-up	80%	15%	5%
Forest land	10%	86%	4%
Waterbody	20%	62%	18%
Farmland	19%	77%	4%
Bare land	16%	76%	8%

Source: Study findings.

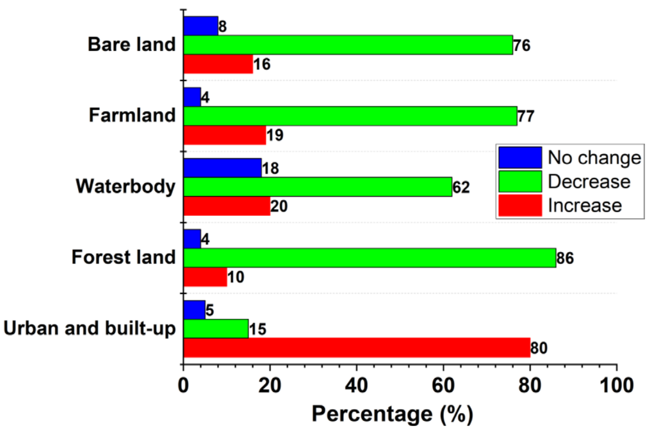

FIGURE 7 | Perceptions of farmers' of LULC changes over the period 1990–2020; figures show the proportion of farmers who noticed the changes for each category of land cover (sample: 382 farmers). [Colour figure can be viewed at wileyonlinelibrary.com]

likely that the city will expand to northern and western areas where bare land is still available (T.W.C 2018).

The results of our study show that, as the built-up area increased, agricultural and forest lands decreased in size. The high rate of land conversion from residential to agricultural is the cause of the growth of urban and rural communities within and around agricultural areas. The findings of FGDs and field observations also showed that the development of built-up areas was highly influenced by the rising need for public facilities including schools, universities, shopping malls, health centers, and residential areas to accommodate a growing population. The results of the present study are in the same direction as the published studies by Jiang et al. (2013), Sewnet (2016), and Ustaoglu and Williams (2017). Jiang et al. (2013) investigated the relationship between changes in urban expansion on agricultural land and agricultural land use intensity in China. Sewnet (2016) assessed LULC changes in the Infraz watershed during 1973–2011. This study found that due to population growth and expanded settlement areas, agricultural lands were diminished. Ustaoglu and Williams (2017) investigated the factors influencing the conversion of agricultural land to urban uses in 25 European Union nations from 2000 to 2006. Differences in urbanization processes across Europe highlighted regional changes in the process of urban conversion of agricultural land use. Movahhed Moghaddam et al. (2025) conducted a meta-analysis of 62 studies on agricultural land conversion to urban use (ALCU), highlighting that land tenure security significantly influences ALCU. They found that land farmed by its owner reduces ALCU by 3.42%, with titled and designated agricultural lands also showing notable decreases. The study emphasizes the importance of securing land tenure to promote sustainable farmland management. Shahab et al. (2024) examined the socioeconomic impacts of agricultural land conversion (ALC) on tenant farmers and sharecroppers in developing countries, finding that ALC significantly reduced agricultural income from 65% to 25% of total income as farmers transitioned to wages and other sources. The study also noted declines in animal rearing and agricultural production, along with reduced consumption of essential commodities.

4.2 | LULC Change in the Context of Developing Economy

The findings of this study indicate major LULC changes in Tehran during the last three decades, with far-reaching consequences for the larger context of developing economies. Rapid urbanization, growth in population, and socioeconomic pressures

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TABLE 8 | DPSIR (drivers, pressure, state, impact, and response) perceived by farmers due to LULC change ($n = 382$).

Drivers	Total ($n = 382$)	%
Population growth	290	84.3
Urbanization	230	67.8
Degraded lands	230	67.2
Decrease in farm size	218	64.5
Change in agricultural land use activities	244	70.5
Urban and rural land tenure system	142	42.2
Climate change	212	64.2
Pressures		
Competition on land	241	71.0%
Expansion of urban, commercial, and industrial areas	260	75.8
Demand in agricultural lands	279	81.0
Rising demand for agricultural products	152	44.1
Deforestation	228	67.2
Changes in soil moisture	159	47.2
Increase in temperature	255	73.5
States		
Variability of rainfall	250	72.1
Land cover change of forest	290	83.1
Soil erosion	210	60.4
Decline in soil fertility	230	66.2
Increase in prices of land	265	77.1
Increase in fragmentation of land	244	64.3
Changes in biodiversity	269	77.7
Impacts		
Increase in migration from rural to urban areas	280	82.1
Land scarcity	259	74.2
Decline in the productivity of land	235	69.7
Change in the size of the population	271	77.5
Decline in the quality of soil	219	62.1
Loss of biodiversity	184	52.2
Increase in consumption of resources	229	65.3
Response		
Resource conservation and restoration	282	80.8
Investment and proper management of land resource	181	50.6
Increasing farmers awareness in management of land	297	85.2
Using proper land use planning	234	66.8

(Continues)

TABLE 8 | (Continued)

Source: Study findings.

have resulted in significant shifts from agricultural and forest lands to urban and built-up areas. This pattern mirrors trends observed in other developing economies, where similar factors drive LULC changes. Population growth emerged as the most influential driver, identified by 84.3% of survey participants, aligning with broader trends in the Global South (Sylvester et al. 2024). Urbanization and changes in agricultural practices were other significant factors driving LULC change. The need to accommodate growing populations has increased demand for land, particularly for both residential and commercial purposes. This urban expansion has led to the conversion of 47.15% of land from other uses to built-up areas in Tehran, illustrating a trajectory common to rapidly growing cities in developing economies. The study also underscores the role of land tenure systems and climate variability as exacerbating factors. These challenges are not limited to Tehran but rather reflect wider structural and environmental vulnerabilities that prevent effective land management in many developing countries.

Similar to those encountered in other developing economies (e.g., Zhang et al. 2016; Dai and Wang 2022; Jayawardena et al. 2023; Waldén et al. 2024), Tehran's declining farmland (8.02%) and forest land (5.9%) have significant consequences for food security, biodiversity, and ecosystem services. As agricultural and natural landscapes decrease, communities become more economically vulnerable and less resilient to environmental changes (Lanlan et al. 2024). In particular, land fragmentation and the loss of fertile soil have been noted as significant consequences of these changes (Borrelli et al. 2017). The study's gathering of farmer perspectives emphasizes the detrimental impact on rural livelihoods, migration patterns, and resource scarcity. These findings align with global research, which shows that LULC changes in developing economies often result in rural–urban migration, heightened land competition, and biodiversity loss (Thekkeyil et al. 2023; Idowu and Ajibade 2024; Sarfo et al. 2024). Policies and practices for sustainable land management that achieve a balance between environmental preservation and development requirements must be given top priority in responses to these challenges. Policy measures such as tree planting initiatives, incentives for forest preservation, and integrated land use planning are critical for addressing these issues. Tehran as

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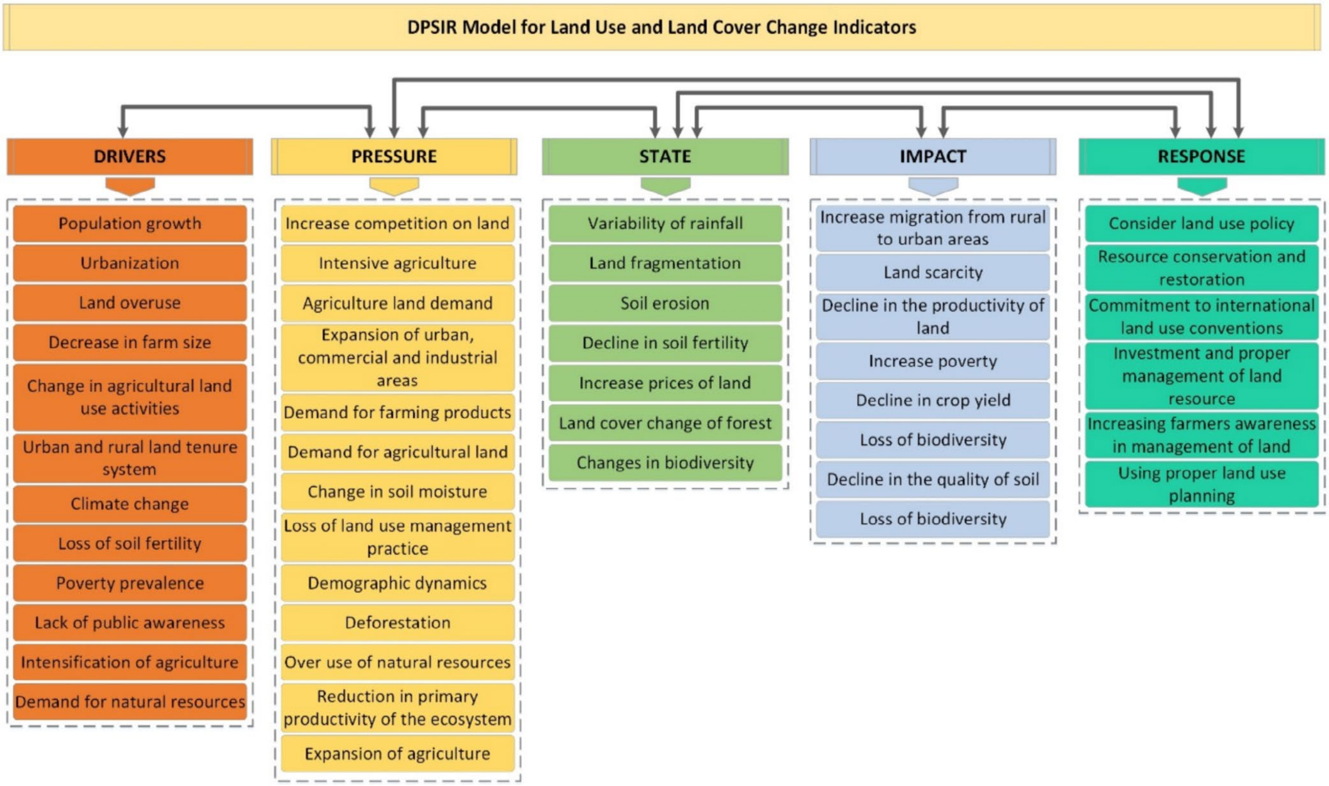

FIGURE 8 | DPSIR of LULC change indices analyzed in the study area. *Source:* Study findings. [Colour figure can be viewed at wileyonlinelibrary.com]

a case study highlights the necessity of proactive urban planning and resource management policies used in the unique socio-economic and environmental contexts of developing economies. These policies should draw on successful case studies from other regions while incorporating local knowledge and stakeholder input, as demonstrated by this study's application of the DPSIR framework.

4.3 | DPSIR Indicators in Respect to LULC Change

4.3.1 | Drivers of LULC Change

The LULC change of an area's surface is the consequence of a complex interaction of socio-economic, biophysical, demographic, and institutional factors (Sobhani, Esmaeilzadeh, and Mostafavi 2021). Farmers identified seven factors as the primary drivers of LULC change in this study. During the whole observation period, 84.3% identified population expansion as a primary driver for the observed LULC change patterns. The rising population growth has resulted in a greater demand for land. LULC changed throughout time as a result of the alarming rate of population growth. According to the present findings, research in the north of Tehran has revealed that rapid population growth is a driving force behind LULC change. Other studies also found population pressure as a main driver of LULC change. Nasehi and Salehi (2019) found that with the growth of the urban population, the built-up areas of Tehran have expanded, resulting in land use changes both inside and outside the city. A study carried out by Sobhani, Esmaeilzadeh, Barghjelveh, et al. (2021) in Tehran province showed that population growth is the primary driver for LULC change, particularly in changes of vegetation lands into built-up areas. LULC change was also influenced by urbanization. Degraded lands, reduced farm size, changes in agricultural land use activities, the urban and rural land tenure system, and climate change were also identified by the FGD participants as important drivers of LULC change.

4.3.2 | Pressures in LULC Change

Pressures are human activities that have a direct impact on the system and are caused by driving forces. LULC change and desertification are caused by unsustainable human activities in already vulnerable regions that are exacerbated by natural disturbances such as drought or flooding. Recurrent droughts and over-exploitation of natural resources have aggravated the situation. Poor land management exacerbated the LULC change. In general, direct pressures leading to LULC change include: land use trend, intensity of land use trend, management of crop lands, deforestation, vegetation over-exploitation, overgrazing, urbanization, industrial activities, natural causes, high per capita resource consumption, trade imbalance, and so on. The demand for agricultural land was identified by 81% taking part in the survey as the main pressure of LULC change over the last few decades. In general, increased population puts forward a greater demand on

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available land resources, particularly agricultural land. Land in the Tehran region is under pressure due to increased demand for land resources. Land is also under pressure due to the type of agriculture practiced. Subsistence agriculture is largely irrigated and rain-fed in the study area, requiring more land to provide more food for the growing population. In line with these findings, Keesstra, Mol, et al. (2018) found that land resources are rapidly degrading as a result of increased pressure on land, and this will put even more pressure on the remaining land. This requires a new and more sustainable strategy for land use planning and land management. Hence, the Land Degradation Neutrality target (2030) is urgent, especially in light of environmental concerns, and there is a sense of urgency. Achieving many of the socioeconomic objectives outlined in the Sustainable Development Goals (SDGs) depends on having healthy soil and land (Molenaar and Cleen 2017). To establish sustainable systems, wide-ranging and integrated approaches from the environmental, economic, and social viewpoints need to encompass the socio-ecological continuity of the systems land use planners strive to preserve and efficiently manage.

4.3.3 | State in LULC Change

Land use change is a primary driving force leading to land deterioration. Many LULC changes, such as deforestation, can result in land degradation and cause serious worldwide damage. Urbanization, road development, declining water supplies, and human disturbance are all factors that contribute to land degradation (Dou and Chen 2017; Oelbermann and Raimbault 2015). Destruction of agricultural lands is a visible and tangible phenomenon that has a direct impact on the livelihood of the study area's residents. Soil loss is the most common kind of land degradation because the most fertile upper section of the soil is removed, exposing the less fertile and more erosive component of the soil (Keesstra et al. 2021; Li et al. 2022). Water erosion may remove soil down to bedrock in shallow soils. As a result, erosion results in the loss of agricultural land's potential productivity. Soil structure can be significantly degraded, causing it to become more acidic and less fertile or nonproductive (Liaqat et al. 2021). In this study, farmers recognized and reported the status of the land in terms of changing land cover conditions. In this research, farmers frequently mentioned forest land cover change, variability of rainfall, decline in soil fertility, soil erosion, rising prices of land, land fragmentation, loss of soil fertility, and changes in biodiversity as showing the current status of land because of LULC change.

4.3.4 | Impacts of LULC Change

As mentioned by farmers, increasing migration from rural areas to cities was seen as the primary impact of LULC change, which was mentioned by about 82.1% of the participants. This is related to population growth, and people, particularly the youth, are migrating to metropolitan areas, owing to rising agricultural land costs, over-consumption of irrigable water, and rising food prices. As a result, land has become scarce and expensive. According to the findings, most of the farmers believed that LULC changes had a major impact on soil erosion that reduces soil quality (Borrelli et al. 2021; Kavian et al. 2017) and decrease crop and livestock productivity. Moreover, farmers and focus groups stated that fast population growth, along with a loss in agricultural productivity (mostly due to soil erosion caused by LULC change) and unpredictable economic development, has led to the serious problem of migration followed by social and political instability. Also, the results of the study conducted by Tayyebi et al. (2010) showed the various socio-economic effects of LULC changes in the Metropolis of Shiraz, Iran. In the research area, 52.2% of respondents believed LULC change had a negative influence on biodiversity. In line with these findings, Sharma et al. (2018) noted that LULC dynamics considered the most important factors influencing biodiversity preservation. In addition, several research teams (e.g., Sharma et al. 2018; Mantyka-Pringle et al. 2015; Masum et al. 2017; Kalivodová et al. 2021) have investigated the adverse effects of LULC change on biodiversity loss across the world.

4.3.5 | Response in LULC Change

Growing environmental and sustainability concerns have pushed many governments to change their land use policies to balance different uses of land resources (Azadi et al. 2011). Changes in agricultural land and its spatial distribution have resulted from these policies. Various environmental purposes are included in agri-environmental measures, which include macro and microeconomic policies, training agendas, supporting investments in farmlands, environmental and landscape protection in relation to agriculture, improving agricultural processing and marketing, conservation and rehabilitation, land policies and strategies, and commitment to international conventions. As a strategy, integrated land resource planning provides an opportunity to develop sustainable land resource utilization (Salehpour Jam et al. 2021).

In this study, responses are considered as activities that the government will take to decrease the negative effects of LULC Change. The most important measures reported by participants, in both the questionnaire survey and the focus groups, to overcome the challenges of LULC changes include increasing farmers' awareness in land management, resource conservation and restoration, using proper land use planning and investment, and proper management of land resources. Despite ongoing actions by the government and major investment, farmers do not believe the challenges have been resolved. According to international land resource management norms, the state must present an appropriate management strategy (Rasool et al. 2021). Responses are often feedback or actions by society, people, and governmental organizations to take appropriate remedial measures in response to unanticipated land use changes. Land managers can use specific methods at the individual level to assist in mitigating the impacts of the status of land as a result of the demands placed on it by certain drivers. However, the scope of such measures is limited to a specific area of the individual's land. As a result, responses must come from the highest levels of decision-making, with the potential to meet both people's needs and unplanned land use changes. Thus, a proper land use policy may be an effective solution for dealing with and ending these

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changes while also positively influencing the frameworks D-P-S-I-R. Therefore, more studies should be done in this field, and the government should provide an appropriate management strategy for land resources management based on international conventions.

5 | Conclusion and Policy Implications

In this study, the pattern of spatio-temporal LULC changes and its characterization were assessed for the metropolis of Tehran during four time periods including 1990, 2000, 2010, and 2020. The findings of this study indicated that forest land was depleted by 43.06 km^2 (5.9%), bare land declined by 282.42 km^2 (33.52%), and farmland was depleted by 61.05 km^2 (8.02% of total land), whereas urban and built-up areas expanded by 384.94 km^2 (47.15%) from 1990 to 2020.

The DPSIR framework provides qualitative tools for analyzing LULC changes. It also establishes a framework for explaining the complexities of this field. This study is novel in combining quantitative approaches for detecting land cover change, such as ground observations and remote sensing, with qualitative studies, such as FGDs and surveys, to gain knowledge of the community and their responses to LULC change. Growing population was highlighted as a main factor of LULC change driver, while agricultural land demand was indicated as a main pressure. Diminished forest cover was the most common state seen as a result of LULC changes. Finally, enhancing farmers' knowledge about management of land, conservation plans, restoration of resources, implementation of proper land use planning, and investing in land resources were highlighted as vital responses to all of the factors described above, according to the respondents.

In order to minimize the degradation of land and to enhance the welfare of the region's population, farmers must be provided with knowledge on appropriate agricultural techniques and also on soil and water conservation measures. Traditional rainfed agriculture (bare noncovered channels) is the primary form of farming in the area. Most of the agricultural lands, forest areas, and bare lands were converted into urban and built-up areas. If the current situation continues, land degradation may endanger agricultural viability and the accessibility of natural resources in the region, resulting in reduced agricultural production. Therefore, suitable and integrated approaches to implement land resource management policies and strategies must be adopted. To maximize agricultural yields, productivity must be increased via the use of appropriate technologies.

This study highlights the utility of integrating RS data with the DPSIR framework for LULC change analysis and provides valuable theoretical and policy insights. Theoretically, it demonstrates the power of RS in providing objective, large-scale, and cost-effective analysis, especially in data-poor developing economies. Additionally, combining RS with socio-ecological models can contribute to the understanding of LULC dynamics.

The study emphasizes the necessity of institutionalizing RS technology in urban planning, creating open data policies for broader access, and enhancing stakeholder ability to successfully use RS and GIS tools at the policy level. Moreover, by identifying high-risk regions for deforestation or degradation, RS can guide targeted efforts, encouraging resource conservation and sustainable urban growth. These results highlight RS as an essential part of sustainable land management and well-informed decision-making.

This research contributes to the theoretical understanding of LULC dynamics by demonstrating the efficacy of RS technologies in data-scarce contexts, while also providing actionable policy recommendations, such as institutionalizing RS in urban planning, promoting cross-sector collaboration, and implementing targeted interventions for conservation and land restoration. These contributions not only fill gaps in existing literature but also equip policymakers with tools and strategies to address LULC challenges effectively, making this study a valuable resource for fostering sustainable development in rapidly urbanizing regions.

Considering the aforementioned factors as well as the results of the current research, the following policy implications for effective management of land in the region can be made:

(1) The responsible government officials should make comprehensive efforts to avoid further land degradation and to rehabilitate degraded regions. This includes detailed LULC zoning, which can be part of Master plans, Landscape plans, or other legally binding planning documentation, and which facilitates for example the establishment and protection of green belts, areas of designated farmland, or nature conservation zones; (2) In partnership with nongovernmental organizations, concerned government officials should support annual tree planting to promote land management sustainability in their areas. This support can take for example the form of direct financial or material support, tax incentives, or methodological support, or a combination of these approaches; (3) Local governments should offer incentives and other forms of support to communities for maintaining and restoring natural forests, in addition to managing new planting.

The limitations and suggestions for future research directions of this work have also been determined in this section. A key limitation of this study was the inability to access Landsat satellite data in the specified time-series, since the data was available only for a few specific periods in the case study. Moreover, the cloud-free image was necessary; otherwise, the categorization of LULC would be impossible due to the lack of a true reflective digital number. As a result, cloud-free data selection was critical to do this research. Emerging cities in developed and developing countries can be studied to identify evolving trends for sustainable development, which might be the subject of further research in the future. The DPSIR framework is used in this study to link remotely sensed data to actual ground conditions. There are analyses of the consequences of different LULC changes. The significant decline in the agricultural class, for example, has major consequences for rising poverty and reduced agricultural production. Thus, this research provides a foundation for linking the interactions between the environment and humans and the complex linkages that result from them. However, further research is required to list any land use change drivers including the long chain of pressure, status, impact, and, ultimately, the Responses that involve high-level land use planning decisions.

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Ethics Statement

The authors have nothing to report.

Consent

All authors contributed equally to the preparation of this manuscript. All authors have read the manuscript and agreed to its publication. All authors have read the manuscript and agreed to its submission.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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