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An Insight into Application of Land Use Land Cover Analysis towards Sustainable Agriculture within Jhajjar District, Haryana

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Land Use and Land Cover (LULC)

Remote sensing

Sustainable agriculture

ABSTRACT

The increasing population, depletion of natural resources, semi-arid climatic and poor soil health conditions in Jhajjar district of Haryana have drawn major attention towards the changes in Land Use/Land Cover (LULC). The region's increasing population is mainly dependent upon the agrarian economy; thus, sustainable agricultural production is a major thrust area of research. The present study analyses the LULC changes in the area during two decades 2000 – 2020, using remote sensing and Geographic Information System (GIS). Landsat satellite images (Landsat-7 and Landsat-8 satellites) for 2000 and 2020 were analyzed for mixed classification based on unsupervised classification followed by supervised classification. The study area has experienced an increase in agricultural land, surface water bodies and built-up land by 16.89%, 79.73% and 56.41%, respectively. There is a decrease in barren land and fallow land by 48.53% and 36.97%, respectively, as per the five major LULC classes. The LULC analysis indicates an increase in built-up land, which is responsible for controlling agricultural productivity and unsustainable agricultural activities. The study provides a comprehensive understanding of the land use trajectory in a specific region in two decades and associated unsustainable changes in the agrarian economy through pressure on the increase in agricultural production and conversion of land mass into croplands. It also signifies climate-resilient agriculture and the management of sustainable agriculture.

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1 Introduction

The dynamics of the earth's surface are attributed to the utilization of land by living and non-living components. In contrast, the land cover denotes what covers the earth's surface (Suzanchi and Kaur 2011), which can be associated with various natural and anthropogenic factors (MohanRajan et al. 2020). Land Use Land Cover (LULC) changes can be accessed by analyzing earth observation datasets using Geographic Information System (GIS). The change detection in LULC is of utmost scientific importance for a comprehensive understanding of the relationship between nature and human beings. The various satellite images as primary data sources provide vast opportunities with different algorithms using GIS tools (Chughtai et al. 2021).

India is a developing country where the agricultural sector plays a pivotal role in establishing a stable economy, providing the main source of livelihood, particularly in the rural sector. An agricultural field is sustainably cultivated when it protects the environment and produces a sufficient quantity of superior-quality food while conserving environmental components (Reganold et al. 1990). However, the burgeoning population pressure in many countries, such as India, has compelled them to use unsustainable methods to increase the farm yield to meet the ever-increasing demand, resulting in continuous depletion in natural resources required for agriculture, such as inadequate availability of cultivable land and water resources (Yadav et al. 2013). This has increased the cost of crop inputs, all indicative of the ongoing unsustainable agriculture practices that are putting the agrarian population of India at risk.

Land and water are the crucial natural resources that directly impact agriculture. In particular, the unethical management and overexploitation of land resources can transform productive land into impervious land (Rahman et al. 2012). Further, continuous overexploitation of the available cultivable land renders the soil infertile (Murungweni et al. 2016). There is supportive evidence proving the rapid change in LULC may make the land unsuitable for agriculture in future. Along with fertile land in arid and semi-arid regions of the world, water is another major limiting factor in crop production. In India's arid to semi-arid areas, climate change has a declining trend in the average rainfall, forcing farmers to use groundwater for irrigation (CGWB, Haryana 2015-16). The increasing number of tube wells, inappropriate cropping patterns, irrigation techniques, and lack of proper planning of systematic groundwater extraction have resulted in excessive exploitation of the available surface and groundwater resources (Kumar 2019). As per WHO estimation, 97 million ha of Indian land is facing freshwater scarcity today (Kumar 2019). Additionally, the adverse effects of the green revolution, extensively practised during the 1970s, are now seen in terms of seasonal mono-cropping of wheat and paddy in rabi and kharif seasons. There is also supportive evidence regarding water logging conditions in fields, increased water and soil salinity, and decreased farmers' income (Rena et al. 2021, Singh et al. 2012). Maintaining land fertility with high water retention capacity, ensuring high crop productivity for extended periods, and utilizing the resources must be scientifically planned and managed without compromising future needs (Singh and Amrita 2017).

Tracking the changes in LULC through Remote Sensing (RS) and Geographic Information Systems (GIS) can help manage sustainable agriculture practices and aid in adopting planning strategies. LULC classification is crucial for understanding the interactions between human activities and the environment. This enables convenient monitoring and detection of changes bringing negative and positive environmental impacts (Ali 2006; Güler et al. 2007; Anil et al. 2011; Arowolo and Deng 2018). The observed changes can further help to monitor and maintain suitable land use practices for achieving the goal of sustainable farming practices within agricultural-dominated regions (Suzanchi and Kaur 2011; Pawar and Singh 2021; Szarek-Iwaniuk 2021).

Presently, more focus is laid on satisfying the short-term supply needed for a growing population without considering the harm caused to the ecosystem services and environmental components (Duraisamy et al. 2018). This negligence can lead to long-term damage and permanent resource loss. Therefore, regular monitoring of LULC change over time can help to effectively apply methods for reduction in degradation of land and water resources and allow sustainable resource maintenance.

The present work is focused on the study of LULC change dynamics within the Jhajjar district in Haryana to monitor and assess possible degradation by the current methods of practising agriculture and the probable remedial measures that can be taken to promote sustainable agriculture in future. To analyze the dynamics of LULC for agricultural sustainability in the Jhajjar district, the important objectives undertaken in this study are (i) Study of the proportion of areas under major LULC classes in different time scales, (ii) the analysis of LULC change to assess the possible drivers of land-use change and (iii) dynamics of LULC change to evaluate the impact on agriculture.

2 Materials and Methods

2.1 Study Area

Haryana (Figure 1) is an arid to semi-arid landlocked state in the North Western region of India with an area of 44,212 sq. Km. It lies between 27°39' - 30°35' N latitude and 74°28' - 77°36' E longitude (Malik 2012). Haryana serves as India's frontline state regarding food grain production. Jhajjar district's economy heavily depends on agriculture (Kumar and Gaur 2015). The district covers the state's southeast region with a total area of 1,834 sq. Km lying

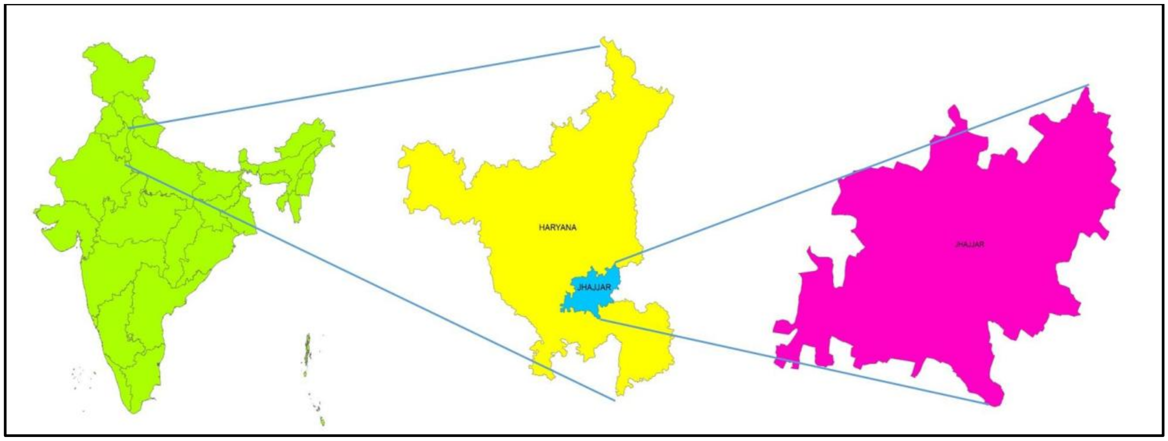

Figure 1 Map showing the location of the study area (map not to scale)

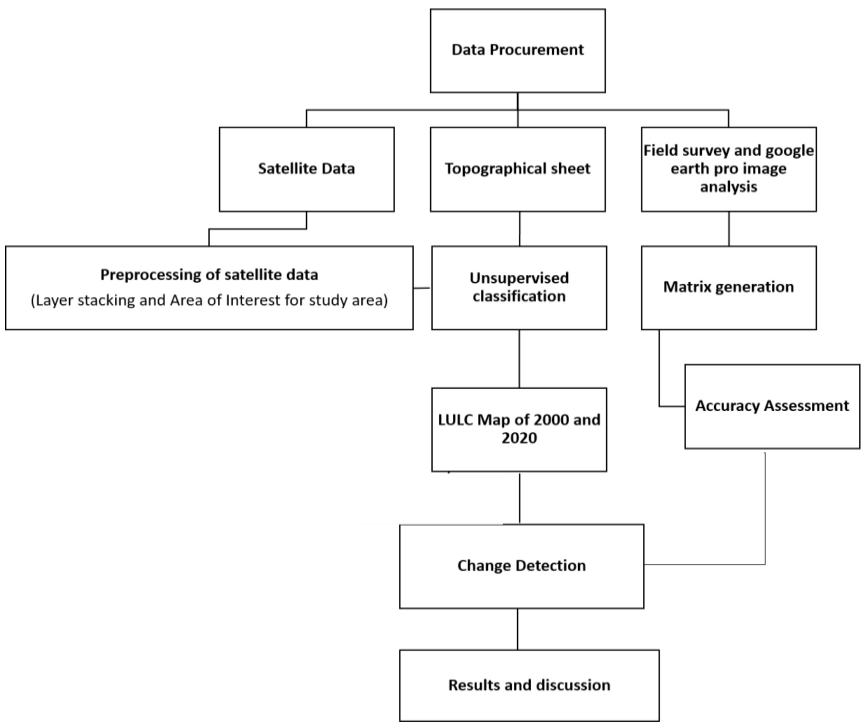

Figure 2 Methodological framework for LULC analysis

between 28°22': 28°49' north latitudes and 76°18': 76°59' east longitudes (Yadav et al. 2009). The topography of the eastern part of the district is considerably even, but some areas are uneven, making it prone to inundation and water logging during the monsoon season. The elevation lies about 222 meters above sea level with a gentle slope from North to South (Arya et al. 2015). The district is classified as an arid to semi-arid area, with the main climatic regime showing a hot and dry summer, cold winter and sparse rainfall during the monsoon (Krishnan 2013). The average annual rainfall received within the district is 532 mm. The maximum and minimum temperatures range from 45°C and 4°C during June and January, respectively (Krishnan 2013). The major crops in the study area are wheat and mustard in winter (Rabi), sugarcane and vegetables in summer (Kharif). The chemical-based fertilizers to augment crop yield and pesticides to protect the crop from harmful pests and diseases are quite common in the study area. With the limited water resources in the region, the primary irrigation methods are tube wells, bore wells and canals to irrigate the crops in the dry season.

2.2 Methodology

For the analysis, both primary and secondary data sources were used (Figure 2).

Table 1 Metadata of Landsat series

Year	Date of Acquisition	Satellite (sensor)	Path / Row	Spatial Resolution
2000	18/2/2000	Landsat 7 (ETM +)	147/40	30 m/ pixel
2020	1/2/2020	Landsat 8 (OLI)	147/40	30 m/ pixel

2.3 Primary Data

The Landsat satellite data of February month were used for the years 2000 and 2020 for LULC change analysis (Table 1). Satellite images were downloaded from USGS Earth Explorer – GLOVIS (https://earthexplorer.usgs.gov/).

To start with the analysis of satellite images, the satellite images of no cloud cover and terrain-corrected images were downloaded from the open data source interface of NASA. The images consisted of different spectral bands with specific spectral information in each band. Layer stacking was carried out in ERDAS Imagine software to utilize the data from the spectral bands. After the layer stacking, the Area of Interest (AOI) corresponding to the study area was clipped from the composite satellite image. Further, image corrections (radiometric correction) were done for Landsat 7 and Landsat 8 images for the years 2000 and 2020 respectively, using ERDAS Imagine software.

2.4 Secondary Data

Secondary data were collected from two methods viz., Google Earth Images and Survey of India topographical sheets of Jhajjar district Toposheet number 53 D/6, 53 D/7, 53D/9, 53D/10, 53 D/11, 53 D/13, 53D/14, 53 D/15 (Map-Scale: 1:25,000)

2.5 Software Used

The software used in this study are (i) ERDAS IMAGINE 2015 for classification, (ii) ArcGIS 10.2 software was used for final map creation, and (iii) ENVI 5.2 software for thematic change detection analysis

2.6 Land Use/Cover Classification Scheme

Based on literature studies and field-based surveys, the LULC analysis for five major classes was carried out for agricultural land, barren land, built-up land, fallow land and water bodies. Unsupervised classification was done through ERDAS Imagine software on satellite images of the years 2000 and 2020 using the K-means classifier method. The supervised classification followed by unsupervised classification has provided the hybrid classification images.

2.7 Field survey and accuracy assessment

Field verification was carried out in different parts of Jhajjar, covering all the LULC classes. Photographs taken during the field survey are shown in Figure 3. The accuracy assessment for LULC classification was done using the quantitative confusion matrix method (Table 2).

2.8 Statistical Analysis

The statistical analysis based on ArcGIS and ERDAS imagines GIS software tools have resulted in significant accuracy in creating thematic maps for LULC classes for 2000 and 2020 satellite images. The accuracy assessment used the quantitative confusion matrix method (Asthana et al. 2020). The statistical comparison for the satellite images has suggested a significant change in various LULC classes, revealing the increasing population and the associated anthropogenic implications creating unsustainability in agricultural practices. The results related to the statistical analysis have been discussed in detail in the Results and Discussion section.

Table 2 Confusion Matrix for accuracy assessment of LULC classification

Sum of Area (Hectares)	Column Labels					
Classes	Water Body	Agricultural Field	Fallow land	Settlements	Bare land	Grand Total 2020
Water Body	1114.96	2720.3	1748.47	862.357	236.542	6682.629
Agricultural land	456.142	63455.4	39868.9	2124.25	3482.53	109387.222
Fallow land	1260.97	16319.2	16496	5821.74	2756.34	42654.25
Settlements	815.985	8645.02	8219.86	8961.28	1332.79	27974.935
Bare land	69.93	2434.66	1347.1	115.177	105.818	4072.685
Grand Total 2000	3717.987	93574.58	67680.33	17884.804	7914.02	190771.721

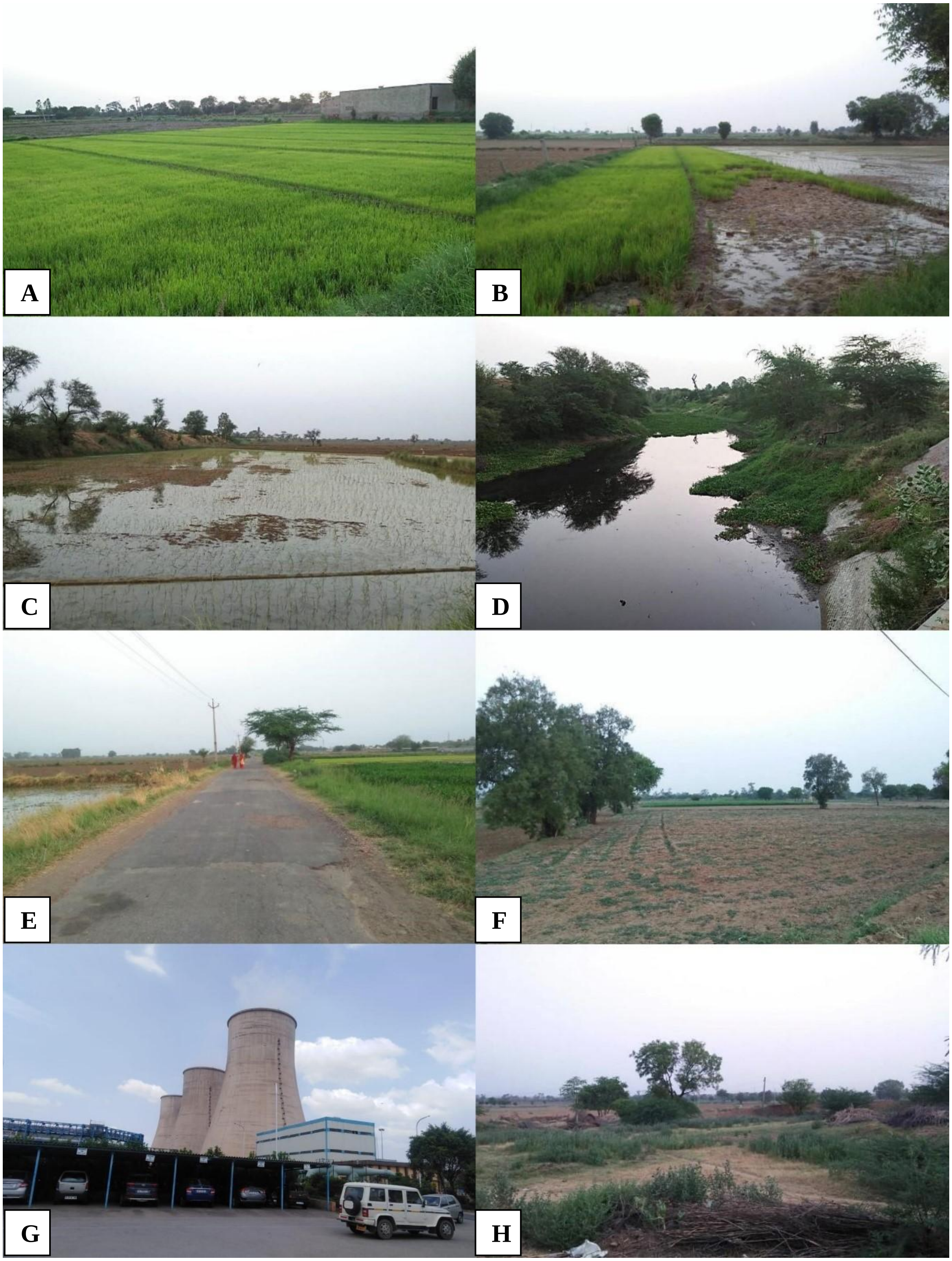

Figure 3 Field photographs of different sites of the study areas A, B & C; Paddy fields, D; Drain No. 8, E; Road passing through the district, F; Fallow lands, G; Jharli Power Plant, H; Barren land.

Table 3 Summary of land use/ land cover classification statics for 2000 and 2020

Land Use	2000 Area (ha)	(%)	2020 Area (ha)	(%)	Change	Relative change (%)
Water body	3717.987	1.94	6682.629	3.50	2964.642	79.73
Agricultural land	93574.58	49.05	109387.222	57.33	15812.642	16.89
Fallow land	67680.33	35.47	42654.25	22.35	−25026.08	-36.97
Built-up land	17884.804	9.37	27974.935	14.66	10090.131	56.41
Barren land	7914.02	4.14	4072.685	2.13	−3841.335	-48.53

3 Results and Discussions

The data analysis for LULC change detection (Table 3) depicts that the area covered by water bodies in Jhajjar district has increased from 3717.987 ha (1.94%) in 2000 to 6682.629 ha (3.50%) in 2020, from close observation of the spatial distribution of the water bodies in the maps (Figure 4, 5) it can be inferred that the increase in the area is primarily due to the construction of the reserve pond close to the Mahatma Gandhi and Indira Gandhi thermal power plant in the southeastern part (Figure 3G). Further waterlogged areas and paddy cultivation having inundated fields with water are also inferred to have contributed to the increase in the area of water bodies (Figure 3, B & C). Surface water bodies in the Jhajjar district include ponds, lakes, reservoirs, water canals, waterlogged agricultural fields, etc., covering the second largest land use (Figures 4 and 5).

During the last 50 years, large investments have been made worldwide in arid and semi-arid regions to increase agricultural production, particularly for its diversification (Ram et al. 2008). Jhajjar also lies in the arid to semi-arid belt, where the water requirement for irrigation is fulfilled through groundwater extraction or canal irrigation to improve and stabilize yields. Major canals in the district are the Western Yamuna Canal and the Jawaharlal Nehru Lift Canal. Water from the Western Yamuna Canal is used for drinking, irrigation, industrial sector, domestic purposes, etc.

The groundwater level increased due to the arrival of the Jawaharlal Nehru Canal in the 1970s, and people saw a golden opportunity to grow water-intensive paddy crops. Increased cultivation of paddy and wheat leads to the problem of water logging in several parts of the district (Figure 3, B & C), further

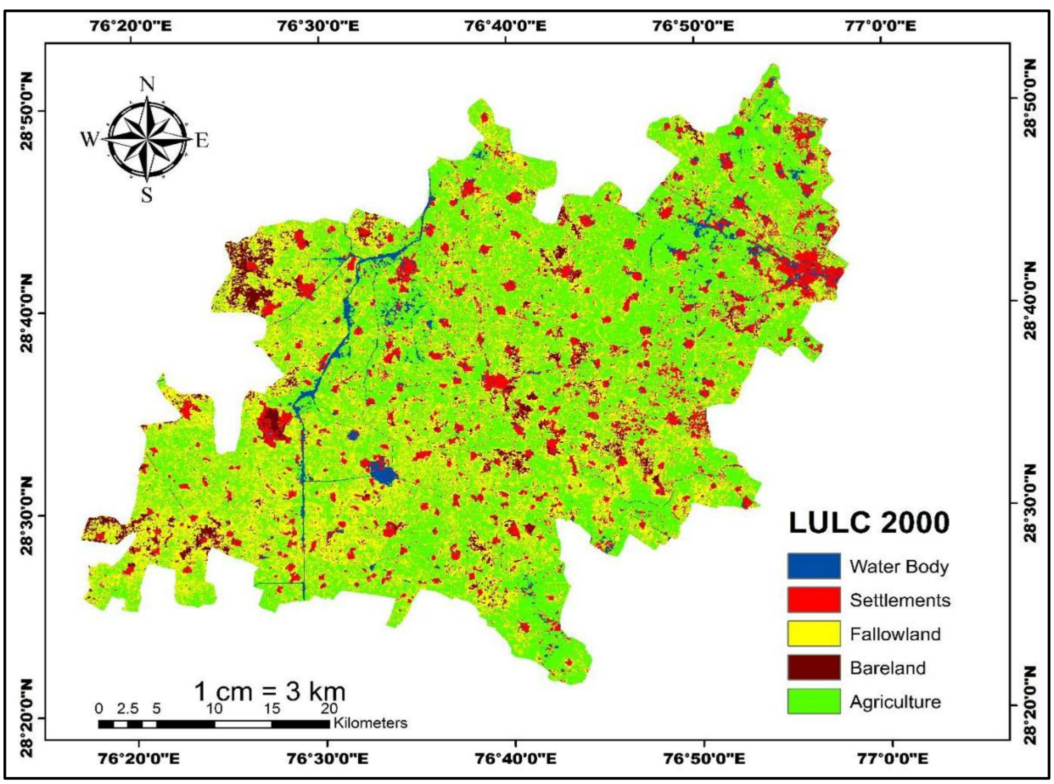

Figure 4 Land use/ land cover of Jhajjar district in different categories during the year 2000

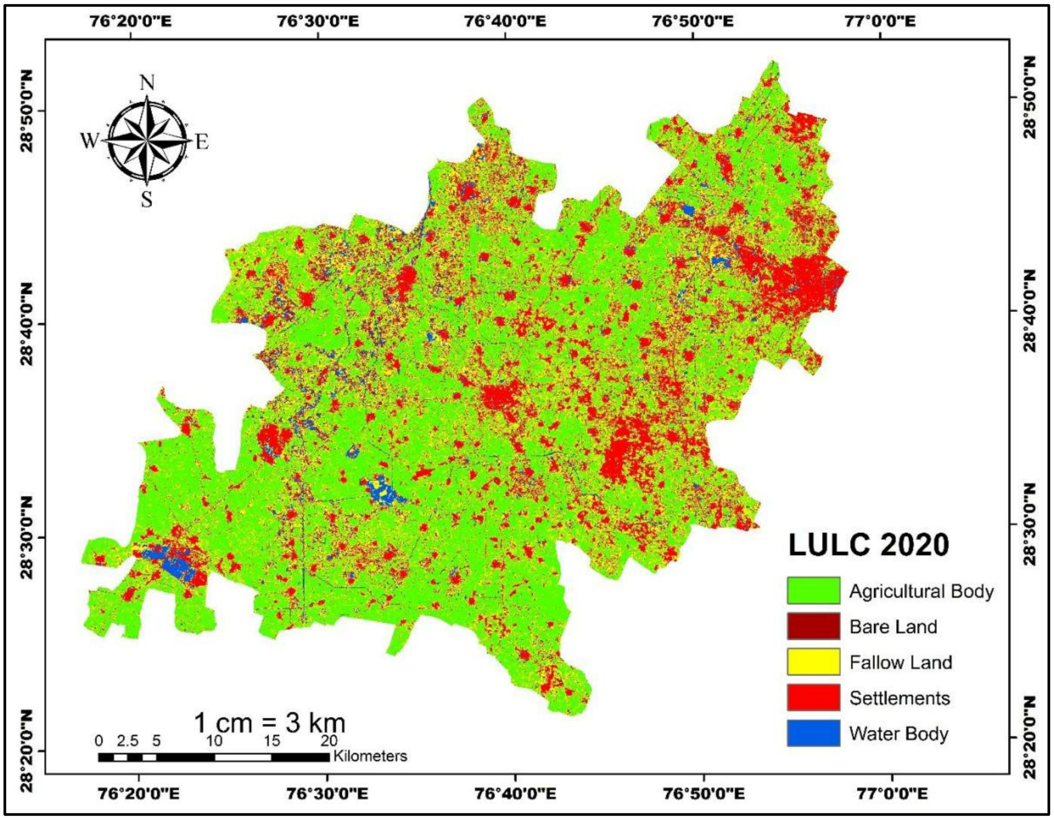

Figure 5 Land use/ land cover of Jhajjar district in different categories during the year 2020

leading to groundwater and soil salinity. Stagnant water in the rice fields decreases the porosity of the soil, affecting the infiltration rate and consequently leading to water logging conditions (Chaudhary and Aneja 1991).

Additionally, the district and the neighbouring areas in the South-West and North-West directions were profoundly exposed to floods due to saucer-like depressions. These parts are situated in low-lying areas and are inappropriate for agriculture. During monsoon season, drain congestion further leads to floods affecting the crops in the villages within the nearby areas. Jawaharlal Nehru Canal flows through the areas of the district where the groundwater table is high, causing severe water logging problems. The rainwater further amplifies this problem, leading to crop damage (Komal 2019).

It has been understood that the characteristic features of an area's soil play a significant role in increasing the water table. The sandy soil in most parts of the Jhajjar district allows water percolation in the deeper subsurface layers. Further, surface runoff is received from Rajasthan through the Sahibi River and other rivers from the South (Rathore et al. 2001). Along with that, runoff from other districts of Haryana, like Rewari and Gurugram, also flows towards Jhajjar (Komal 2019). This increases the water table, causing further soil saturation within the paddy fields. Stagnant water in these fields affects the soil's physical condition, leading to compactness, consequently decreasing the infiltration rate and increasing water logging and soil salinity (Chaudhary and Aneja 1991).

Over the past two decades, groundwater has emerged as one of the principal sources of irrigation (Shah et al. 2006). Development in agriculture and irrigation facilities has led to several complex problems, such as the rise and fall in the groundwater table and its quality deterioration. These problems have threatened the sustainability of agriculture within several regions of the world (Singh and Amrita 2017).

Paddy cultivation should be reduced in the area to rectify the problem of decreasing groundwater levels and address the issue of salinization. Farmers should also be encouraged to plant water-transpiring *Eucalyptus* trees and saline fisheries in some parts of the district for bio-drainage to tackle the problem of increased soil salinity.

From the data obtained, maps (Figures 4 and 5) and a graph (Figure 6) were made to interpret the changes in LULC classes within the Jhajjar district. The LULC analysis also shows an increase in the area covered by agricultural land from 93574.58 ha (49.05%) in 2000 to 109387.222 ha (57.33%) in 2020. This is

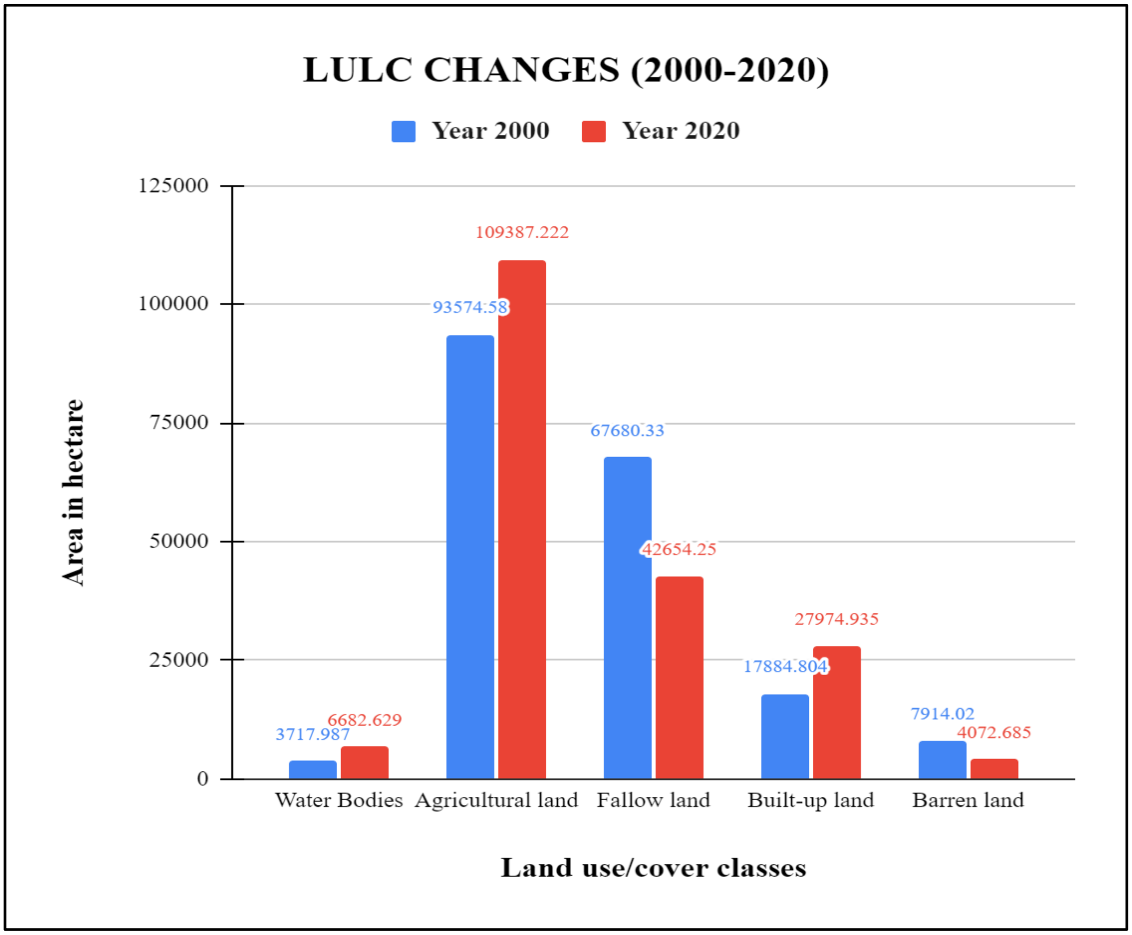

Figure 6 Comparison of Land Use/ Land Cover pattern in Jhajjar district in the years 2000 and 2020

mainly because uncultivable and fallow lands are transformed into agricultural lands (Figure 6). Rather than following traditional cropping methods involving mixed cropping patterns, farmers have shifted to market-oriented approaches by which they can earn more and more profit. There have been perceptible shifts in the type of crop grown from cereals, pulses and oilseeds to rice and wheat to generate high revenue over the past years (Chaudhary and Aneja 1991). The extensive cropping or over-exploitation of the land resource has led to land quality degradation and increasing compactness, soil salinity, water logging, and multiple nutrient deficiencies with low organic carbon content (Deen and Bala 2021). Using fertilizers and pesticides has also increased artificial productivity to make more money and reach the required food production. Furthermore, a steady increase is observed in the net sown area, the yield of wheat and rice after the green revolution. However, despite claims, the suitable land area for crop production is minimal in most developing countries with growing food demand (Young 1999).

As the groundwater of Jhajjar district is highly saline in some parts, it is unfit to be applied in the fields. The saline regions in Haryana have increased by 35% to 80,000 hectares in the last 20 years (CSSRI 2016). During the rainy season, the saline groundwater spills over the waterlogged agricultural fields, further worsening the condition. The farmers must leave the field uncultivated for a few seasons until the soil is functional and fertile again. Also, mono-cropping over the years has led to a problem of weed infestation, which has become so deleterious that without chemical control measures, it is difficult to harvest any yield (Chaudhary and Aneja 1991).

Although there is an increase in the net sowing area in the district, soil fertility is lost. Judicious use of agricultural land is necessary, along with crop diversification, to maintain the fertile land. The soil may be left unsuitable for cropping in the coming years if remedial measures are not undertaken soon. Fallow land is agricultural land left uncultivated for a certain period, especially during the growing season. The main reasons for land fallowing are low soil fertility, poor or low irrigation facilities, uncertainty of rainfall, and limited economic means of farmers (Malik 2012). The temporary rest for a while compensates for the low nitrogen content and other deficient nutrients, low moisture of the soil and weeds in the field. However, prolonged soil exposure can lead to water and wind erosion.

During the last two decades, the fallow land has decreased from 67680.33 ha (35.47%) in 2000 to 42654.25 ha (22.35%) in 2020 (Table 2). The field survey shows that fallow land is now utilized for agricultural and other developmental activities to house and expand built-up areas (Pawar and Singh 2021). From the data obtained, there has been an increase in agricultural land, built-up land and water bodies. Consequently, there has been a decrease in the fallow and barren land. From this, it can be inferred that the farmers have intensively utilized the fallow land for agricultural purposes. There is an ever-increasing food demand, compelling farmers to overutilize land resources. They are adopting unsustainable methods like chemical fertilizers to convert fallow land into fertile land. Although there is a visible positive impact on overall net production, the loss of soil fertility, erosion, and toxicity can't be neglected simultaneously.

A significant decrease in barren land has also been observed in the district during the twenty-year duration, i.e. 2000-2020 (Figure 5). The area under this category in 2000 was 7914.02 ha, constituting about 4.14% of the geographical area, which decreased to 2.13 ha in 2020, including 2.13% of the geographical area. As the urban population in the area has exceeded the rural population (Suzanchi and Kaur 2011), the barren land has been mainly utilized for urban developmental activities that have ultimately led to the expansion of built-up areas.

Scrubland is present in the central region of the district. Due to excessive salinity or excess availability of salt and sodium, these are prominent in the district's western part (Arya et al. 2015). Mine dumps of brick kilns also contribute to the formation of barren lands. Although these lands can be reclaimed for agricultural use after regular inputs, they lack proper soil conservation and drainage for long-term agricultural use.

The LULC analysis also shows an increase in urbanization since Jhajjar lies in Haryana, which is close to Delhi, the country's capital. According to the population census data, the difference between 2001 and 2021 shows an increase in population in Jhajjar district from 42,305 in 2001 to 1,33,261 in 2021. The land use analysis indicates that during the period 2000-2020, the built-up area has significantly increased by >56%, i.e. from 17884.804 ha (9.37%) to 27974.935 ha (14.66%), adding 10090.131 ha more to the built-up category. The increasing trend shows the impact of rapid urbanization. The commercial use of land has been increased. Since the inclusion of the district in the National Capital Region in 1997, various industries have been relocated from the non-conforming areas of Delhi to the parts of the National Capital Region (NCR), including Jhajjar. Further, a significant rise in industrial development has been reported due to the establishing of an extended railway network within the district, allowing for better transportation and connectivity that has developed Jhajjar as a hub for bigger industrial settlements and projects. On the one hand, the built-up area has increased, but on the other hand, it has affected natural vegetation in the study area. Jhajjar has experienced fluctuating average rainfall, creating problems for the rain-dependent regions. It is also inferred that the haphazard and rapid unplanned infrastructure development may complicate the situation soon.

Conclusion

The present study suggests that the major land-use change factors are rapid urbanization, climate change and agricultural expansion. The agricultural-dominated region of Jhajjar district in Haryana shows that urbanization accompanied by unplanned agricultural development and inappropriate agricultural techniques have severely threatened sustainability. These changes are estimated to enhance further water logging problems, soil salinity, loss of cultivable land and lack of suitable water for irrigation within this semi-arid region. The changes observed using LULC analysis between 2000 and 2020 suggest that major improvements such as crop diversification, sustainable use of groundwater for irrigation, and drainage of waterlogged areas must be introduced broadly to restore the degraded cultivable land.

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Conflict of Interest

There is no conflict of interest.

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