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# Satellite-Based Analysis of Land Use and Land Cover Pattern in District Kurukshetra, Haryana: Insights from Landsat 8 Imagery for February 2020.

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**Abstract**:

This study investigates land use and land cover (LULC) patterns in Kurukshetra District, Haryana, India, using Landsat 8 satellite imagery and data from local sources. Employing supervised classification with the Maximum Likelihood Algorithm, five LULC categories were identified: water bodies, vegetation, cropland, bare land, and built-up areas. Results indicate that cropland dominates at 58.89% of the area, reflecting the district's agrarian economy. Bare land constitutes 34.54%, largely due to agricultural/crop harvested farms and urban development. Built-up areas cover 3.64%, showing urban expansion, while vegetation and water bodies are limited, comprising 2.22% and 0.7% respectively. These findings highlight significant ecological and socio-economic implications, such as sustainability challenges in agriculture, environmental concerns due to inadequate vegetation, and the importance of water bodies in rural ecosystems. The study emphasizes the need for sustainable land management, balancing agricultural productivity, urban development, and ecological conservation to ensure the district's sustainable future.

**Keywords:** *Landsat 8 imagery, Land use and land cover (LULC), Agricultural Practices and Sustainability, Urban Expansion and Ecological Impact.*

## Introduction:

Land use (LU) and land cover (LC) are critical yet distinct concepts that are essential for understanding the changes occurring on the Earth's surface. Land cover refers to the physical manifestation of the Earth, including aspects like vegetation, water bodies, and built-up areas. In contrast, land use investigates the human dimension and changes made by human, revealing how these land covers are utilized for activities such as agriculture, infrastructures, residential development, or recreation. Land Cover is defined as observed physical features on the Earth's Surface. When an economic function is added to it, it becomes Land Use. (FAO, 2005).

In the current era, the world is experiencing rapid transformations, particularly from natural landscapes to human-modified built environments, and India is a prime example of this trend. The rapid population growth and urban expansion are driving significant changes in land use and land cover patterns, necessitating a deeper understanding of these changes for effective urban and regional planning, environmental conservation, and assessing impacts on climate. Knowledge of land use and land cover is also vital for sustainable resource management, biodiversity conservation, and ensuring the provision of essential ecosystem services like clean water and food.

Traditionally, land use data was primarily sourced from government revenue records, which, were informative, but lacked spatial accuracy. Topographical maps from survey institutions provided a more comprehensive view but were often not updated regularly, leading to outdated information. Soil maps, though useful, were limited in scope and relevance to specific projects.

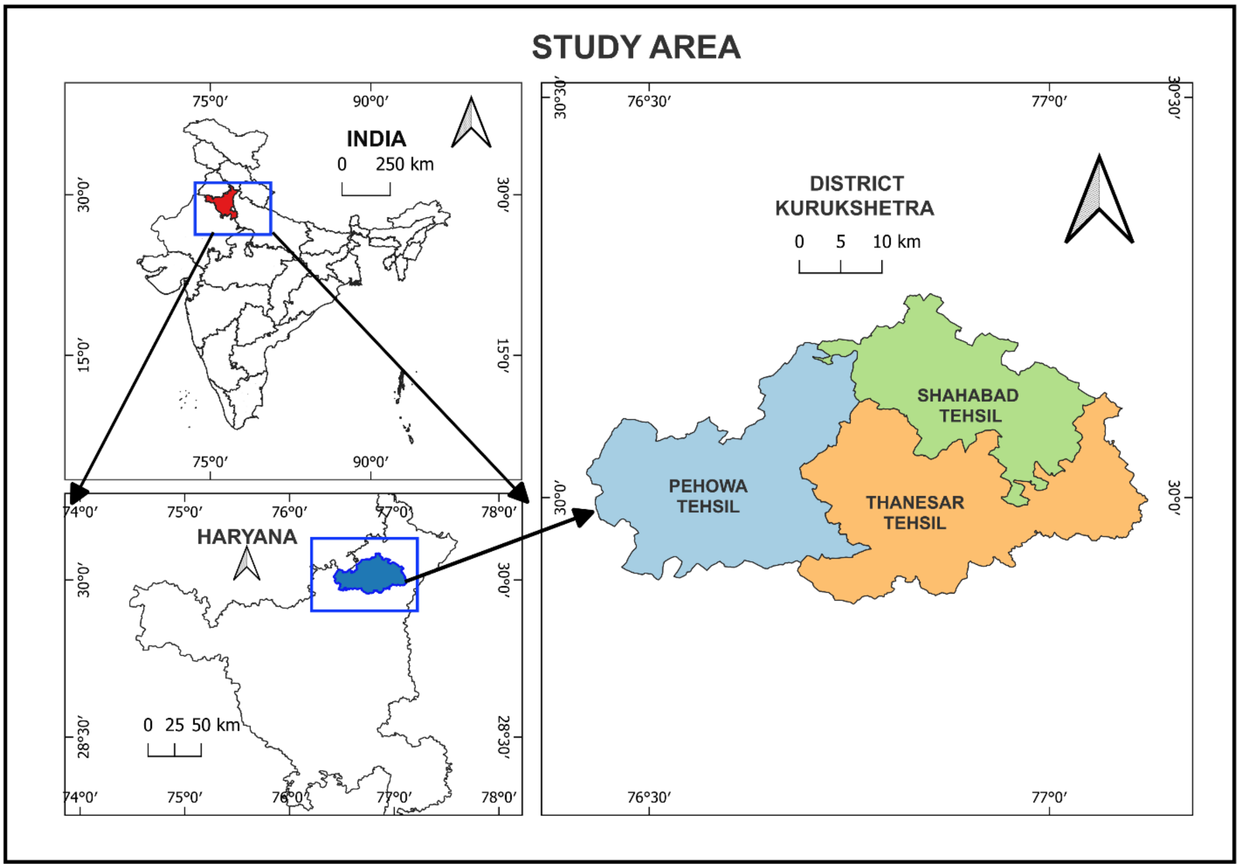
Advancements in technology have positioned remote sensing as the leading method for acquiring land use and land cover data. This technique, utilizing satellites and other aerial platforms, captures detailed, multi-spectral images of the Earth's surface. The broad coverage and frequent revisits by these platforms enable precise, current, and comprehensive classifications of land cover. Geographic Information Systems (GIS) further enhance this data by enabling detailed spatial analyses and intricate map creation.

One of the challenges in land cover and land use studies is the inconsistency in classification terminologies across various organizations. Terms like "forest" can vary in definition depending on the criteria used by different entities. To address these variations, this research adopts a hierarchical classification system that allows for both broad and detailed categorizations. This study aims to explore land use and land cover at the hierarchical Level 1, utilizing remote sensing technology.

In summary, a thorough understanding of land use and cover is critical in addressing the complexities of our rapidly changing world. Modern technologies, especially remote sensing, and GIS, have significantly improved our ability to track and analyze these changes with greater accuracy and detail.

**Study Area:**

The present study is focused on the Kurukshetra district, located in the northeastern part of Haryana, India. This district is geographically positioned within the coordinates of North latitudes 29°53'00" to 30°15'02" and East longitudes 76°26'27" to 77°07'57". Predominantly lying within sections of the Survey of India Topo-sheets numbered 53B and 53C, Kurukshetra covers an approximate land area of 1676 square kilometers, constituting about 3.46% of Haryana's total land area.




**Geographical Boundaries and Administrative Divisions:** Kurukshetra shares its borders with several adjacent districts within Haryana, namely Karnal to the south and southeast, Kaithal to the southwest, and Ambala to the north. Additionally, it borders Patiala district in Punjab to the northwest. Administratively, Kurukshetra is a part of the Ambala division and is subdivided into three tahsils (Thanesar, Pehowa, and Shahabad), three sub-tahsils, and six blocks (Ladwa, Pehowa, Shahabad, Thanesar, Babain, and Ismailabad). The district's infrastructure includes a well-developed network of roads and railways, with significant townships such as Shahabad, Babain, Ladwa, and Pehowa complementing its administrative center in Kurukshetra.

**Population and Demographics:** Based on the 2011 census, Kurukshetra has a total population of 964,231, yielding a population density of 630 individuals per square kilometer. This figure surpasses the average population density of Haryana, which stands at 573 persons per square kilometer.

**Hydrogeology and Environmental Challenges:** Geographically, the eastern part of Kurukshetra falls within the Upper Yamuna Basin, while the western part is situated in the Ghaggar basin. The district is characterized by the absence of perennial rivers, with the Markanda river flowing in its northwestern part. The district's reliance on surface water sources and groundwater reservoirs for agricultural irrigation is significant, with the over-extraction of groundwater emerging as a major environmental concern.

**Climatic Conditions:** Kurukshetra's climate is predominantly dry, with hot summers and cold winters. The monsoon season brings humid conditions due to oceanic air influx. The district receives an average annual precipitation of 582 millimeters, predominantly during the southwest monsoon from late June to September, which accounts for about 81% of the total annual rainfall. The non-monsoon season, influenced by western disturbances and thunderstorms, contributes the remaining 19% of the rainfall.

**Geomorphology and Soil Composition:** Kurukshetra is part of the Indo-Gangetic alluvial plains, characterized by a nearly flat terrain with an average elevation ranging from 274 to 241 meters above mean sea level. The land generally slopes from northeast to southwest. The district's soil profile is dominated by tropical arid brown soils, which are pale brown in color, deep, and imperfectly drained, with low to moderate permeability and medium to high moisture holding capacity.

**Agricultural Practices and Irrigation:** In Kurukshetra, 81% of the net irrigated area (123,000 hectares) depends on groundwater, while canal systems irrigate only 28,000 hectares. This heavy reliance on groundwater for irrigation highlights the pressing need for sustainable water resource management. The gross irrigated area of 271,000 hectares represents a mere 4.9% of the state's land area, yet the irrigation intensity is significantly high at 179.5. The main crops include paddy during the kharif season and wheat in the Rabi season, reflecting the agricultural cycle of the region.

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**Geological Profile:** The district, falling within the Upper Yamuna and Ghaggar Basins, consists of Quaternary geological formations. The Recent alluvial deposits, part of the extensive Indus alluvial plains, define the district's geological landscape. Groundwater in the area is present at varying depths, occurring under unconfined, semi-confined, and confined conditions in the aquifers.

This comprehensive overview of Kurukshetra district encompasses its geographical, administrative, demographic, hydrogeological, climatic, geomorphological, agricultural, and geological characteristics, thus providing a detailed context for the current research study.

**Data Used:**

For the analysis conducted in this study, the primary satellite data was sourced from the Landsat 8 Operational Land Imager (OLI). This data is available on the Earth Explorer portal, accessible via https://earthexplorer.usgs.gov.

The Landsat 8 OLI dataset encompasses several bands, each with specific characteristics. The bands employed in this study, along with their respective specifications, are listed below:

- Band 2 (Blue): This band operates within the 0.450 - 0.51 µm wavelength range and has a spatial resolution of 30 meters.
- Band 3 (Green): With a wavelength range of 0.53 - 0.59 µm, this band also boasts a spatial resolution of 30 meters.
- Band 4 (Red): This band captures wavelengths ranging from 0.64 to 0.67 µm and maintains a spatial resolution of 30 meters.
- Band 5 (Near-Infrared): Operating in the 0.85 - 0.88 µm wavelength range, this band similarly has a 30-meter spatial resolution.
- Band 6 (SWIR 1): With a wavelength range of 1.57 - 1.65 µm, it also has a spatial resolution of 30 meters.
- Band 7 (SWIR 2): This band functions in the 2.11 - 2.29 µm wavelength range, again with a spatial resolution of 30 meters.

The dataset selected for this research was specifically chosen from cloud-free images taken in February 2020. This time frame aligns with the end of the Rabi agricultural season, providing an optimal window for analysis. Additionally, to accurately delineate the boundaries of Kurukshetra District and its tehsils, an administrative map from the Survey of India was downloaded from its official website and incorporated into the study.

**Methodology:**

The methodology employed in this study for satellite image analysis begins with an essential step: preprocessing of the imagery. This phase is critical to ensure the accuracy and validity of the data, considering the complexities associated with satellite imagery acquisition.

**a. Radiometric Calibration:** The first preprocessing step involves radiometric calibration. Satellite sensors capture reflected or emitted radiation from the Earth's surface as digital numbers (DNs). However, for these DNs to accurately reflect the intensity of the radiation received, they must be converted into actual radiance values. This conversion is accomplished using calibration constants, which are typically provided in the satellite sensor's metadata. The process ensures that the imagery accurately represents the radiation intensities as detected by the satellite sensor.

**b. Atmospheric Correction:** Another crucial preprocessing step is atmospheric correction. The Earth's atmosphere can significantly alter the spectral signatures recorded by satellite sensors, primarily due to the scattering and absorption of electromagnetic radiation. To mitigate these atmospheric effects and ensure the imagery accurately represents ground conditions, various algorithms and techniques are applied. These methods are often tailored to the specific satellite sensor and prevailing atmospheric conditions, with the aim of retrieving accurate surface reflectance values.

**c. Spatial Subsetting:** The final preprocessing step is spatial subsetting, which is performed to improve computational efficiency and focus the analysis on the study's region of interest. In this case, the satellite imagery was subsetted to include only the area corresponding to the Kurukshetra District in Haryana State. This approach ensures that the analysis remains localized and directly relevant to the objectives of the study.These preprocessing steps are integral to obtaining precise land use and land cover classifications from satellite imagery. Neglecting any of these stages could result in inaccurate interpretations in later stages of the analysis.

In this study, the focus was on identifying and categorizing various land use and land cover (LULC) types within a specified area using satellite imagery, a task crucial for applications in urban planning, environmental management, and more. A key method employed for this purpose was supervised classification, a technique heavily reliant on the analyst's pre-existing knowledge about the targeted region.

**Supervised Classification and the Maximum Likelihood Algorithm:** Among various supervised classification methods, the Maximum Likelihood Algorithm (MLA) is particularly noteworthy for its probabilistic approach. This algorithm calculates the likelihood of a pixel belonging to a certain class based on its spectral properties. It considers the mean and variance of spectral values across bands for each class and assigns a pixel to the class where this probability is maximal. The underlying assumption is that pixel spectral values for each class follow a normal distribution in each band.

**Land Use and Land Cover Classes Defined:** Employing MLA in this study allowed for the segmentation of the satellite imagery into distinct LULC classes:

1. **Water Body:** This class encompasses areas predominantly covered by water, such as lakes, rivers, and reservoirs. Water bodies are identifiable due to their unique reflective characteristics, particularly in the near-infrared band.

2. **Vegetation:** This category includes regions rich in flora, such as forests, shrubs, and other plantations. The high reflection in the near-infrared and absorption in the red region due to chlorophyll are characteristic of vegetation.

3. **Cropland:** These areas, under agricultural use, can vary in their spectral signatures based on the crop type and its growth stage.

4. **Bare Land:** This class covers areas with little to no vegetation, including deserts and exposed soils. The lack of vegetation and moisture lends a distinctive spectral quality to these areas.

5. **Built-up Land:** Urban and rural settlements, encompassing buildings, roads, and other infrastructures, fall into this category. The reflective properties of materials like concrete and metal across multiple bands make these areas stand out.

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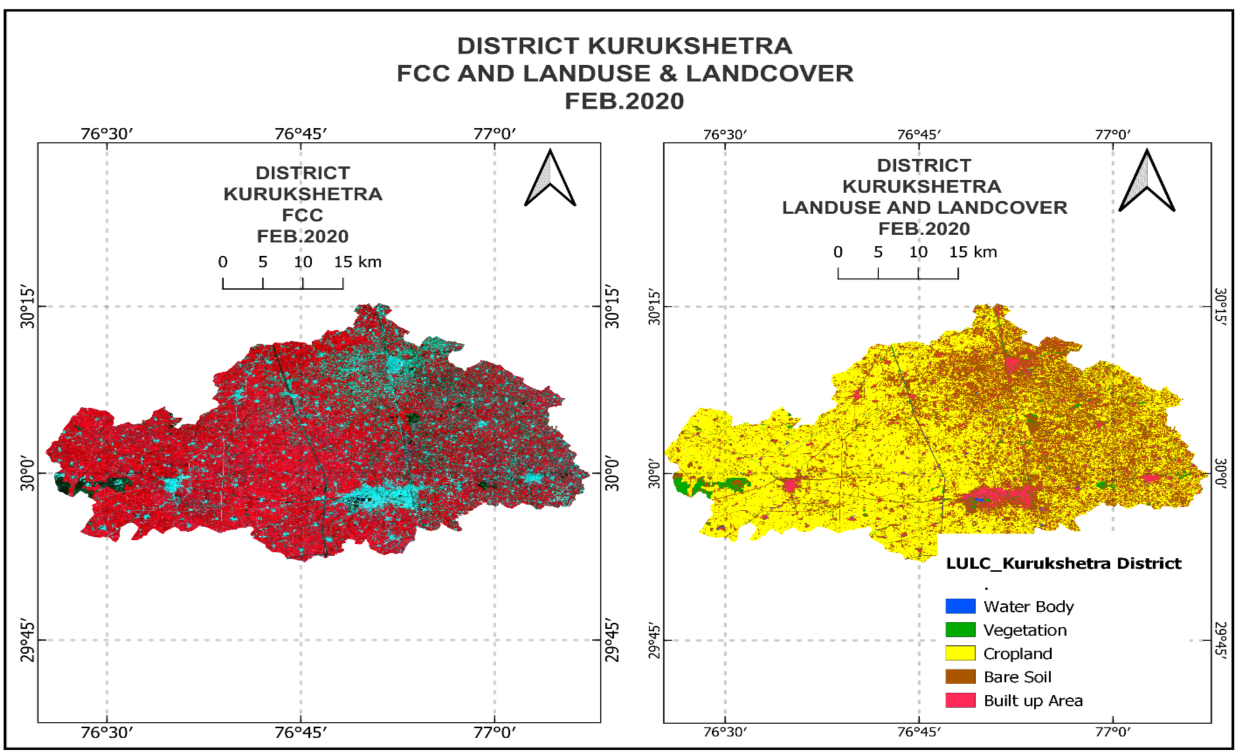
**Importance of Training Sample Selection:** The success of the MLA in supervised classification is highly dependent on the selection of appropriate training samples. Accurate sample selection is crucial for effectively converting the spectral data from the satellite imagery into meaningful LULC categories.

**Utilization of QGIS Software:** For the analysis of the LULC data derived from the Landsat 8 satellite imagery, QGIS (Quantum GIS) software was employed. As an open-source GIS application, QGIS enables the viewing, editing, and analytical processing of geospatial data. Its widespread use in geospatial analysis is attributed to its versatility, user-friendly interface, and cost-effectiveness, being free from licensing fees.

**Results and Discussion:**

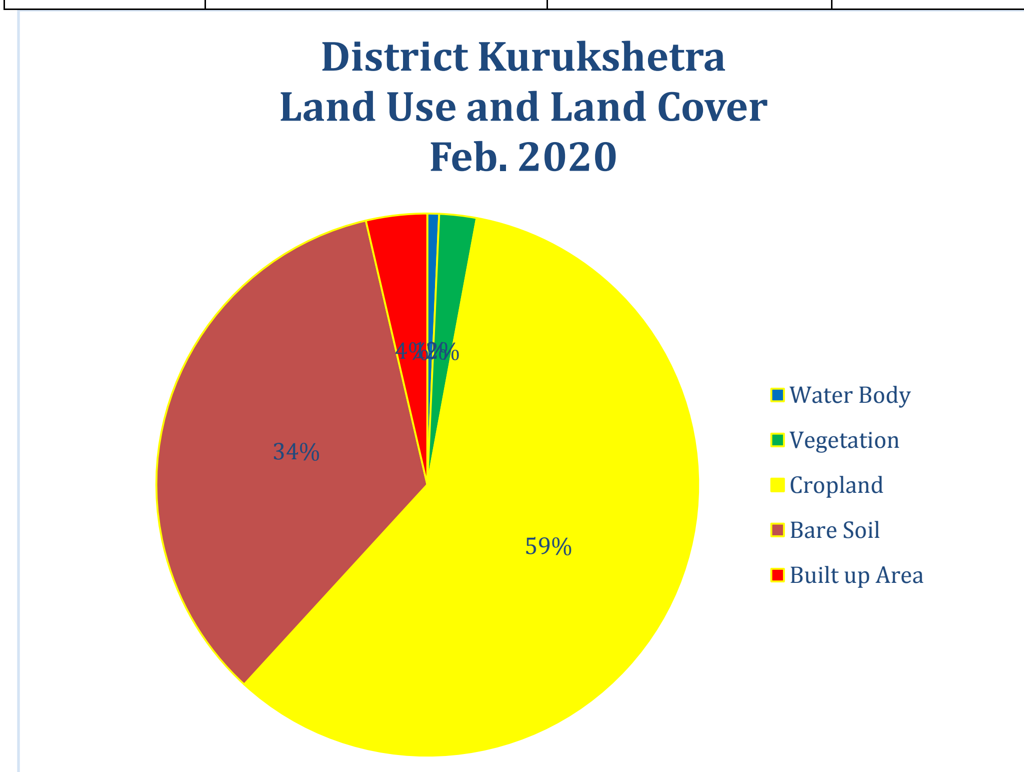
The present study aims to elucidate the land use and land cover patterns of Kurukshetra District, utilizing data from the official website of Kurukshetra (kurukshetra.gov.in) and the Survey of India's district boundary map and data extracted from Landsat 8 satellite imagery of the district. This analysis is critical for understanding the region's ecological and socio-economic dynamics.




The land use and land cover classification in this study is based on five primary categories: cropland, bare land, built-up area, vegetation, and water bodies. This categorization is essential for assessing the district's ecological balance and its capability to support human activities.

**Land Use and Land Cover Analysis:**

| **Land Use and Land Cover of District Kurukshetra, Haryana Feb. 2020** | | | |
|---|---|---|---|
| **Class Code** | **Class Name** | **Area in sq. km** | **Percentage** |
| 1 | Water Body | 11.70 | 0.7 |
| 2 | Vegetation | 37.24 | 2.22 |
| 3 | Cropland | 987.12 | 58.89 |
| 4 | Bare land | 578.99 | 34.54 |
| 5 | Built-up Area | 61.07 | 3.64 |
| | Total Area | 1676.14 | |



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1. **Water Bodies:** Covering 11.7 square kilometers (0.7% of the total area), water bodies in the district are predominantly situated in rural areas and villages. They primarily consist of johads and ponds, which are crucial for water collection and recharging groundwater. A significant concentration of these water bodies is located in the Thanesar Tehsil, contributing 6 square kilometers. It is primarily composed of the water bodies of ritual and tourists significance such as jyotishar and brahmsarovar areas.

2. **Vegetation:** Vegetation spans 37.25 square kilometers, accounting for 2.22% of the total area. This coverage is significantly below the ideal 10% required for maintaining a sustainable ecosystem in plains. Vegetation in Kurukshetra includes notified forest areas, agroforestry, social forestry, and scattered trees, playing a vital role in ecological balance and biodiversity conservation. Vegetation includes all the notified forests, tree covers which are natural planted.

3. **Cropland:** As of February 2020, cropland occupies the largest portion of Kurukshetra District, encompassing 987.12 square kilometers or 58.89% of the total area. The area under the cropland is largest among the land uses and land covers. This prevalence underscores the district's agricultural prominence, which forms the backbone of its economy. The extensive cropland area reflects both the agrarian lifestyle and occupancy of the region and the dependency of a large population on agriculture for livelihood. The map depicts that the croplands are concentrated around the villages. The towns and cities interspersed the cropland. Cropland in the region encompasses all the crops harvested the rabi season such as food crops, commercial crops, fodder crops etc.

4. **Bare Land:** The second most extensive category, bare land, covers 578.99 square kilometers, amounting to 34.54% of the district's area. This vast expanse is primarily the result of agricultural practices, particularly following the harvest of sugarcane crops and the consequent plowing activities. The regions of Ladwa and Shahbad are especially notable for their sugarcane cultivation. Satellite images from February 2020 reveal that fields previously sown with sugarcane during the Rabi season appear as barren land. This is the biggest limitation of the study based on the information derived from the satellite imagry. Factors contributing to this include the presence of numerous brick kilns, degradation of notified forest areas, and the proliferation of construction colonies and open plots, especially around urban centers.

5. **Built-up Area:** The built-up area, predominantly located in urban locales, constitutes 61 square

kilometers or 3.64% of Kurukshetra's total area. This concentration in urban areas- in and around the towns and cities as opposed to rural ones highlights the district's urbanization patterns, driven by population pressure and economic activities in urban centers.

**Ecological and Socio-Economic Implications:**

The land use and land cover patterns of Kurukshetra District have profound implications on both the ecology and the socio-economic fabric of the region. The dominance of cropland reflects the district's agrarian economy, but it also raises concerns regarding land sustainability and the pressure on agricultural resources. The significant proportion of bare land, a result of agricultural practices and urban expansion, poses challenges for land management and environmental conservation.

Urban areas, though limited in extent, are rapidly expanding, leading to increased pressure on land resources and potential ecological imbalance. The inadequate vegetation cover is a concern for environmental sustainability, emphasizing the need for enhanced forest conservation and tree plantation initiatives. Water bodies, despite their limited coverage, play a pivotal role in sustaining the rural ecosystem and need to be preserved and managed effectively.

**Conclusion:** This study highlights the intricate land use and land cover dynamics of Kurukshetra District. The findings underscore the need for sustainable land management practices that balance agricultural productivity, urban development, and ecological conservation. Future research should focus on developing strategies to enhance vegetation cover, manage bare land areas effectively, and preserve water bodies to ensure a sustainable future for the district.

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