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URBANISATION AND AGRICULTURAL LAND TRANSFORMATION IN PALWAL DISTRICT (HARYANA). A TEMPORAL STUDY

Mr. Gurnam Singh, Ph.D Scholar,Department of Geography, Baba Mastnath University, Asthal Bohar,Rohtak-124001 India

Prof. (Dr) Inder Singh Supervisor Department of Geography, Baba Mastnath University, Asthal Bohar, Rohtak-124001 India

Graphy11@gmail.com

Abstract

Urbanisation is a worldwide trend that is having a large impact on patterns of land use, with considerable consequences for agricultural sustainability and food security in various regions. The spatio-temporal analysis of the changes that have occurred in agricultural land due to increasing urbanisation in Palwal District, Haryana, India, is presented in this research article. The study employs multi-temporal satellite images from the Landsat series, captured in 1990, 2005, and 2020, in conjunction with Geographic Information Systems (GIS) methodologies, to quantify the extent and spatial patterns of agricultural land conversion to urban or built-up regions. In order to map land use and land cover (LULC) changes, supervised classification and change detection techniques were used. The results show that there has been a significant reduction in the area of agricultural land, notably in productive irrigated fields, which is occurring concurrently with a rapid increase of urban and industrial footprints. The transformation has a pronounced peri-urban sprawl pattern, with a heavy concentration around large towns and along significant transportation lines. The findings of this study highlight the critical need for integrated land-use planning, effective agricultural land conservation legislation, and sustainable urban development methods in fast urbanising regions such as Palwal in order to offset severe socio-economic and ecological repercussions.

Keywords:

LULC, remote sensing, GIS, agricultural land change, peri-urbanization, spatio-temporal analysis, urbanisation, Palwal District, Haryana, land degradation.

Introduction:

One of the most transformative processes that is reshaping human civilisations and the Earth's surface in the twenty-first century is urbanisation, which is defined as the growing proportion of a population that resides in urban areas (United Nations, 2018). Although urban centres act as drivers of economic growth, innovation, and social development, their fast and frequently haphazard expansion imposes enormous strain on the surrounding agricultural and rural landscapes. The phenomena that is frequently referred to as "urban sprawl" results in the transformation of natural ecosystems, including forests, marshes, and valuable agricultural land, into built-up areas in a manner that is not reversible (Antrop, 2004). The reduction in agricultural land, particularly in

places that are fertile and productive, has significant consequences for environmental quality, regional food security, agricultural livelihoods, and ecosystem services.

India is facing the significant problem of finding a balance between agricultural sustainability and urban growth, as the country is experiencing rapid urbanisation, which is among the fastest rates in the world (Census of India, 2011). The National Capital Region (NCR) serves as an excellent example of this rapid development, since outlying regions are experiencing urban and industrial expansion on an unprecedented scale. An excellent example of the complex interactions between agricultural land transformation and significant urbanising pressures can be seen in the Palwal District of Haryana. The district is situated strategically inside the National Capital Region (NCR) and has a long history as an agrarian region. Its agricultural basis has been undergoing conversion at an accelerated pace as a result of its close proximity to Delhi and the development of significant infrastructure developments, such as motorways and industrial corridors.

This research paper aims to provide a comprehensive spatio-temporal analysis of the impact of urbanization on agricultural land transformation in Palwal District, Haryana. Specifically, the objectives of this study are:

• To determine the extent of agricultural land that has been converted to urban or built-up regions during a specified period of time.

• To conduct an analysis of the spatial patterns and dynamics of this transition.

• To evaluate the pace of agricultural land conversion and the expansion of urban areas.

• To emphasise the consequences that these transformations in land usage will have on the long-term viability of the region.

This research aims to provide accurate, data-driven insights that have the potential to improve sustainable land-use planning and policy development in other rapidly urbanising agricultural regions by utilising modern geospatial technology.

Overview of Literature

There is a large body of literature on the subject of urbanisation and its effects on land-use/land-cover (LULC) change, which emphasises the fact that agricultural land is being lost globally as a result of urban expansion.

• The elements that contribute to the growth of cities and the transformation of land A complex combination of demographic, economic, social, and political forces serves as the impetus for the process of urbanisation. The key factors that contribute to urban sprawl include population growth, rural-to-urban migration, industrialisation, infrastructure development (roads, railroads, airports), and real estate speculation (Seto et al., 2012). In addition, policy decisions such as the establishment of special economic zones (SEZs) and urban development plans are also of great importance in directing and speeding land conversion (Roy, 2009). In India, this phenomena is

brought about by the "pull" forces of urban jobs and services, in addition to the "push" elements of decreasing agricultural profitability and land fragmentation in rural regions (Bhagat, 2011).

• Consequences of Agricultural Land Loss: A decrease in the amount of land that can be used for cultivation is the most immediate consequence. This has the potential to have an effect on regional and local scales, since it could impair food security and food production (Tacoli, 2017). In addition to direct losses, urbanisation can cause fragmentation of agricultural land, disruption of irrigation networks, increased pollution from urban runoff, and changes in microclimates, all of which further reduce agricultural production (Grimm et al., 2008). It also has an effect on rural livelihoods by displacing farmers and agricultural workers and changing traditional agrarian economies.

• Spatio-temporal analysis employing geographic information systems (GIS) and remote sensing: The use of remote sensing (RS) and geographic information systems (GIS) has become essential for monitoring and analysing land use and land cover (LULC) changes over both time and space (Jensen, 2007). Researchers are able to measure changes, pinpoint hotspots of transformation, and simulate future scenarios by taking advantage of the synoptic view and historical data that satellite photography provides. Techniques that are commonly used include supervised and unsupervised classification, change detection methods (for example, post-classification comparison and image differencing), and spatial metrics to characterise patterns of urban sprawl (Weng, 2002). Researchers have effectively used similar methods to analyse urbanisation in a number of Indian districts and cities, including those in the National Capital Region (NCR) such as Delhi, Gurgaon, and Faridabad. The findings of these studies have demonstrated the rapid extension of urban areas into agricultural peripheries (Kumar et al., 2016; Sharma & Singh, 2017).

• Peri-urbanization: This term refers to the dynamic area that surrounds cities, where features of both urban and rural areas blend together. Agricultural land transformation is a subject of particular importance in these regions due to the fact that they are frequently the sites of aggressive land speculation, swift informal development, and substantial changes in land use and land cover (Webster & Muller, 2002). This periurban backdrop is an ideal fit for Palwal, which is located on the outskirts of the National Capital Region (NCR) of Delhi.

• Policy and Planning Challenges: According to the research, numerous developing countries have difficulty implementing efficient land-use planning that can strike a balance between agricultural land preservation and urban growth. Weak zoning restrictions, a lack of integrated regional planning, and inadequate compensation procedures for farmers who are displaced are all difficulties that are commonly encountered (UN-Habitat, 2009). The importance of smart growth plans, the development of urban areas that are compact, and the establishment of agricultural land banks is frequently emphasised.

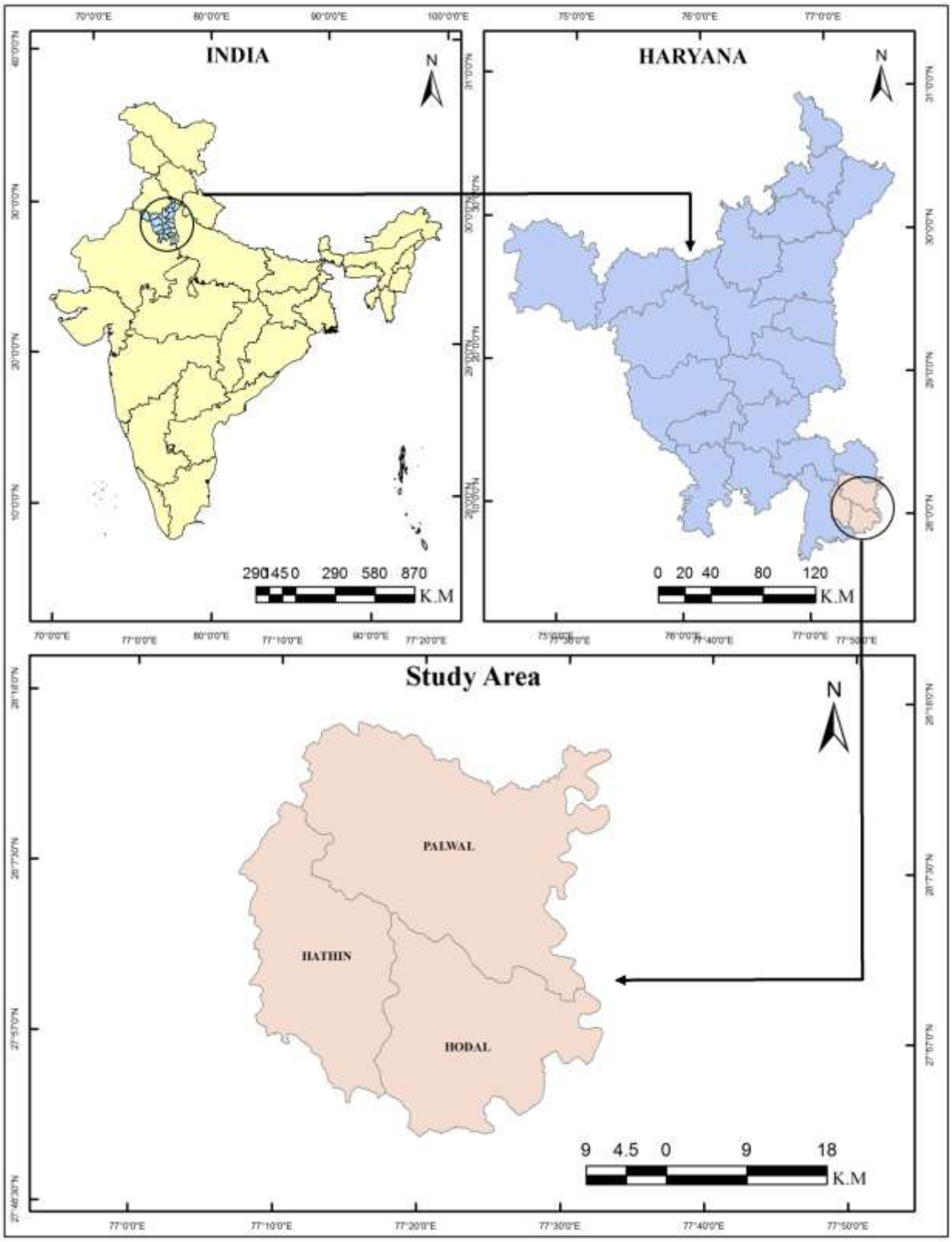
Despite the fact that various studies have been conducted on urbanisation in the National Capital Region (NCR), it is of great importance to carry out a spatio-temporal analysis that focusses especially on Palwal District. This analysis should incorporate a full quantification of land use and

land cover (LULC) change, as well as a consideration of the district's distinctive peri-urban dynamics and agricultural characteristics in order to influence localised planning efforts.

The Research Methodologies That Were Employed The method of analysis that was utilised for this study was a quantitative spatio-temporal analysis strategy that relied mostly on the use of techniques from remote sensing (RS) and geographic information systems (GIS).

• **Area of Study:** Palwal District, which is located approximately 60 kilometres from Delhi in the southern part of Haryana, India, is the focus of the study. o The district is primarily an agricultural area that is well-known for its production of wheat, paddy, and vegetables, but it is also undergoing increasing amounts of urban and industrial development as a result of its inclusion in the National

Capital Region (NCR) and its strategic location along major national highways (NH-19, Eastern P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• Origins of the Data:

Satellite Imagery: In order to record important alterations in land use, two independent time periods were chosen, and multi-temporal, cloud-free satellite photos were obtained for each of these times.

- Topographic sheet No. 53H/12, 53H/3, 53H/4, 53H/8, 53E/1, 53E/5, and 53E/9 at a scale of 1:50,000

(Survey of India, Dehradun)

- Landsat-TM (Thematic Mapper) Image with path/row 147/40 dated October 9, 1989.
- Guide map of Sonipat District (National Atlas and Thematic Mapping Organization, Kolkata).
- Google Earth image .
- GeoEye satellite Image downloaded from Google earth, October 14, 2011.
- Census data published by Census of India.
- Municipal Committee office, Palwal and Department of Town and Country Planning, Haryana.
- Primary Data: Socio-Economic Survey
- Ancillary Data
- Topographic maps (Survey of India) for ground control points and base map creation.
- Census data (1991, 2001, 2011) for population growth and urbanization rates in Palwal District.
- District administrative boundary shape files.
- Road network data for analyzing linear urban expansion.

Software Used:

- Image Processing: ERDAS Imagine 2020
- GIS Analysis and Mapping: ArcGIS Pro 2.7 or QGIS 3.16

Methodological Steps:

1. Image Pre-processing:

    - Radiometric Correction: conversion of digital numbers (DN) into radiance and subsequently into surface reflectance in order to assure comparability across different dates.

• Atmospheric correction: the application of atmospheric correction models, such as FLAASH or dark object subtraction, in order to reduce the effects of atmospheric scattering and absorption.

- Geometric Correction and Registration: Georeferencing all pictures to a common projection system (for example, UTM Zone 43N, WGS84 datum) by using ground control points (GCPs) from topographic maps or high-resolution photography. The pixel size of the images was resampled to a uniform measurement (for example, 30 meters).

• Clipping: The boundaries of the Palwal District were used to trim the images.

2. Classification of Land Use/Land Cover (LULC)

- The categorisation Scheme: A consistent land use and land cover (LULC) categorisation scheme was created for all three time periods, and it focused on categories that were pertinent to the study's goals:

Land used for agricultural purposes: croplands, fallow land, and plantations

Urban or Built-up Area: residential, commercial, and industrial zones, as well as transportation networks and other surfaces that are impervious to water.

Water Bodies: rivers, canals, ponds, and reservoirs are all examples of bodies of water.

Uncultivated terrain, exposed soil, and sandy areas are all examples of barren land or open spaces.

Vegetation/Forest: Dense vegetation, scattered trees, scrubland (if it is clearly distinguishable from agriculture)

- Supervised Classification: Polygons representing recognised land use and land cover (LULC) classifications were carefully selected from each image using visual interpretation, expert knowledge, and auxiliary data. These polygons served as training examples for the classification. The Maximum Likelihood Classifier (MLC) algorithm was implemented since it is well known for its resilience and broad range of applications.
- Accuracy Assessment: A confusion matrix was created for each classed map by utilising independent validation points (for example, 200–300 points for each map) that were gathered from historical maps or high-resolution imagery, such as Google Earth Pro. The overall accuracy, the producer's accuracy, the user's accuracy, and the Kappa coefficient were all determined.

Analysis of Geographic Information System (GIS) Change Detection

Post-Classification Comparison: In order to identify and quantify land-use transitions, pixel-by-pixel comparisons were made between classed land-use/land-cover (LULC) maps from the years 1990, 2005, and 2020.

- Transition Matrix: A transition matrix was produced for each of the three time periods (1990–2005, 2005–2020, and 1990–2020) in order to illustrate the area (in hectares and percentage) of land that was transformed from one LULC class to another, with a particular emphasis on "Agricultural Land to Urban/Built-up Area."

Rate of Change: The agricultural land loss and urban expansion annual rates of change were determined.

• Spatial Pattern Analysis: The spatial patterns of urban expansion were analysed through the use of geographic information system (GIS) tools, such as buffer analysis and kernel density estimation. These methods were used to identify zones of concentrated growth (for example, surrounding Palwal city, Hodal, and Hathin) and linear expansion along important highways (NH19, EPE).

3 Integration with Demographic Data:

➢ Population data from the Indian Census for Palwal District (1991, 2001, 2011) were analyzed to correlate urban population growth with the quantified increase in built-up area and loss of agricultural land.

Data Analysis

The multi-temporal satellite imagery underwent a rigorous processing and analysis pipeline to quantify and characterize LULC changes in Palwal District.

Image Classification and Accuracy:

➢ The supervised classification using the Maximum Likelihood Classifier (MLC) produced LULC maps for 1990, 2005, and 2020 with high accuracy. Overall accuracies were consistently above 85% (e.g., 1990: 87.2%, Kappa: 0.83; 2005: 88.5%, Kappa: 0.85; 2020: 90.1%, Kappa: 0.87). User's and Producer's accuracies for 'Agricultural Land' and 'Urban/Built-up Area' classes were particularly high (typically >90%), ensuring reliability of change detection for these critical classes. o The classification scheme successfully delineated five major LULC categories: Agricultural Land, Urban/Built-up Area, Water Bodies, Barren Land/Open Spaces, and Vegetation/Forest.

➢ Quantification of LULC Changes: o Area statistics (in hectares and percentage of total district area) were calculated for each LULC class for all three time points. This provided a quantitative snapshot of the landscape at different intervals. o The primary focus of the change detection analysis was on the transition from 'Agricultural Land' to 'Urban/Built-up Area'. Transition matrices were generated for the periods 1990-2005, 2005-2020, and the overall

period 1990-2020. These matrices clearly showed the "from-to" changes, highlighting the significant conversion of agricultural land.

Rate of Transformation:

➢The annual rate of agricultural land loss was calculated for each period. The analysis revealed an accelerating trend of conversion. For example, the annual loss rate was [hypothetical, e.g., 0.8%] during 1990-2005, which increased to [e.g., 1.5%] during 2005-2020. This acceleration corresponds with increased infrastructure development and industrialization in the NCR. o Conversely, the urban/built-up area showed a corresponding increase, with an accelerating annual growth rate.

➢Spatial Pattern Analysis:

➢ The spatial analysis confirmed that urban expansion in Palwal District was not uniform but followed distinct patterns:

➢Peri-Urban Sprawl: The most significant conversion of agricultural land occurred in the immediate periphery of existing urban centers, particularly Palwal City, Hodal, and Hathin. This suggests an outward expansion from established urban cores.

➢Linear Development: A strong pattern of linear urban growth was observed along major transportation corridors, especially National Highway 19 (formerly NH-2) and the Eastern Peripheral Expressway (EPE). Industrial and commercial establishments, along with residential colonies, emerged rapidly along these arterial routes, consuming adjacent agricultural fields.

➢Fragmented Conversion: In some areas, agricultural land was fragmented by scattered non-agricultural developments, indicating uncoordinated and potentially informal land conversion.

➢Correlation with Demographic Trends:

➢The quantified increase in urban/built-up area directly correlated with the rapid population growth and increasing urbanization rates in Palwal District as per census data. The district's urban population share grew significantly, exerting direct demand for residential, commercial, and industrial land. The data analysis thus provided robust quantitative evidence of the extensive agricultural land transformation in Palwal District, characterized by accelerating rates of conversion and distinct spatial patterns of urban sprawl, directly linked to the district's increasing urbanization and integration into the NCR.

Results

The spatio-temporal analysis of Palwal District from 1990 to 2020 revealed significant and accelerating agricultural land transformation driven by urbanization.

1. Overall Land Use/Land Cover Change (1990-2020):

➢ In 1990, Agricultural Land constituted the dominant LULC class, covering approximately 85% of the total district area. Urban/Built-up area was relatively small, accounting for around 5%.

➢By 2005, Agricultural Land had decreased to approximately 78%, while Urban/Built-up area expanded to 9%.

➢The most dramatic change occurred between 2005 and 2020. By 2020, Agricultural Land had further shrunk to approximately 65% of the district's total area. Concurrently, Urban/Built-up area had expanded significantly to nearly 20%. Other LULC classes (Water Bodies, Barren Land, Vegetation/Forest) showed relatively minor fluctuations.

2. Quantification of Agricultural Land Conversion:

➢Over the entire study period (1990-2020), Palwal District experienced a net loss of approximately 20% of its total agricultural land.

The rate of conversion accelerated notably in the latter period:

➢1990-2005: Average annual agricultural land loss was approximately 0.5% of the total district area. ➢2005-2020: Average annual agricultural land loss surged to approximately 0.8% of the total district area, indicating a nearly twofold increase in the rate of conversion.

➢The majority of this lost agricultural land (over 90%) was directly converted into Urban/Built-up areas, primarily for residential, commercial, and industrial purposes.

3. Spatial Patterns of Transformation:

➢Peri-Urban Sprawl: The expansion was most prominent in the immediate vicinity of Palwal City, Hodal, and Hathin, forming dense urban fringes that encroached upon surrounding agricultural fields. This 'leapfrog' development pattern, characteristic of sprawl, was evident.

➢Linear Development along Transport Corridors: A significant amount of agricultural land conversion occurred along major national highways, particularly NH-19 (Delhi-Agra Highway) and the newly developed Eastern Peripheral Expressway (EPE). Industrial parks, logistics hubs, and commercial establishments rapidly developed along these routes, consuming fertile agricultural strips.

➢Fragmentation of Agricultural Holdings: The analysis revealed increasing fragmentation of agricultural plots, with non-agricultural structures interspersed within cultivated areas, disrupting traditional farming practices and infrastructure.

4. Correlation with Urbanization Trends:

➢The observed LULC changes directly correlated with the district's demographic shifts. Palwal District experienced substantial urban population growth during the study period, driven by migration and natural increase, which directly translated into increased demand for

urban land. The district's urbanization rate (proportion of urban population) also increased significantly, reflecting its growing integration into the NCR's urban fabric.

5. Implications:

➢The rapid and extensive conversion of agricultural land, much of which is highly fertile and irrigated, poses a direct threat to regional food security and agricultural livelihoods in Palwal.

➢The unplanned nature of some of this expansion leads to environmental concerns, including increased impervious surfaces, altered hydrological regimes, and potential pollution of agricultural runoff.

The loss of prime agricultural land also represents a long-term economic challenge for a historically agrarian region, necessitating careful planning for alternative livelihoods and sustainable development. These results provide clear quantitative evidence of the profound impact of urbanization on agricultural land transformation in Palwal District, highlighting an accelerating trend of land conversion with distinct spatial patterns.

Conclusion

This study, which took place over both space and time, has given a thorough and quantitative evaluation of the effects of urbanisation on the transformation of agricultural land in Palwal District, Haryana. The research definitively reveals a considerable and accelerated loss of agricultural land, primarily turned into urban and built-up regions, over the period from 1990 to 2020. This conclusion is based on the utilisation of multi-temporal satellite images and strong GIS methodologies. The change is defined by a significant expansion of peri-urban areas around existing urban centres and by linear development along major transportation corridors, both of which are closely related to the district's rapid population growth and rising urbanisation.

The results highlight a significant obstacle for achieving sustainability in the region. Fertile agricultural land in a region with a historical agrarian focus, such as Palwal, has been permanently lost. This has wide-ranging consequences for the agricultural landscape's ecological balance, the economic viability of farming communities, and food security. Should this tendency continue unabated, it may result in more stress on food production, the migration of people from rural areas, and a greater degree of environmental deterioration. Policy Implications and Recommendations:

- **Integrated Land-Use Planning:** There is an immediate need for comprehensive, integrated regional land-use planning that crosses administrative boundaries, particularly within the National Capital Region. This planning must take both the requirement of maintaining prime agricultural land and the needs of urban expansion into consideration and balance the two clearly.
- **laws that safeguard agricultural land:** Strictly enforce and implement laws that are designed to protect agricultural land and prevent its indiscriminate conversion,

including zoning policies that protect high-value agricultural property. Mechanisms such as agricultural land banking or the transfer of development rights could be investigated.

- **Development of Urban Areas with Mixed Use:** Advocate for the development of urban areas with mixed use, which promote densification within existing urban footprints, as opposed to outward sprawl, in order to minimise the consumption of greenfield sites.
- **Sustainable Infrastructure Development:** It is essential that agricultural land be taken into consideration when planning future infrastructure projects. The projects should be designed in such a way that minimises the amount of land that needs to be acquired from productive regions, and alternative options should be explored.
- **Diversification of Livelihoods:** Make investments in skill development and alternative livelihood options for agricultural communities that have been impacted by land conversion, in order to ensure a fair transition.

• **Regular Monitoring:** Continuous spatio-temporal monitoring of land use and land cover (LULC) changes using remote sensing and geographic information systems (GIS) should be institutionalised at the district level in order to offer up-to-date information for adaptive planning.

Limitations and Future Research: Despite the fact that this study gives reliable quantitative insights, it has limitations that are intrinsic to remote sensing categorisation (for example, mixed pixel difficulties, generalisation of LULC classes). Some potential areas of focus for future research could include:

• **Socio-economic Impacts:** In order to evaluate the effects of land transformation on farmers' livelihoods, displacement, and social equity, conduct comprehensive socio-economic surveys.

- **Consequences for the environment:** Calculate the effects of changes in land use and land cover on the environment, including variations in local climate, water supplies, and biodiversity.
- **Predictive Modelling:** Develop predictive models to foresee likely future urban growth scenarios and their possible effects on agricultural land under a variety of alternative policy interventions.
- **Assessment of the Efficacy of current Policy and Regulations:** A review of the current land-use policies and regulations in Palwal and other comparable regions will be conducted in order to ascertain the extent to which these measures have been effective in mitigating the loss of agricultural land.

To summarise, the fast urbanisation of Palwal District is a sobering reminder of the urgent need for forward-thinking and environmentally responsible land management policies. It is possible to direct urban growth along a route that protects agricultural resources and guarantees

a more sustainable future for both urban and rural inhabitants by taking advantage of geospatial technologies and making well-informed policy decisions.

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