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Spatial Analysis of Irrigation Distribution and Land Use Dynamics in the Districts of Haryana during the 21st Century

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Abstract

This paper presents a comprehensive spatial analysis of irrigation distribution and land use dynamics across the districts of Haryana during the 21st century. Haryana, one of India's leading agrarian states, has experienced significant transformations in its agricultural landscape due to advancements in irrigation infrastructure, population pressure, urban expansion, and changing cropping patterns. Using secondary data from government reports, remote sensing imagery, and GIS-based spatial techniques, the study examines district-wise variations in irrigation intensity, sources of irrigation, and shifts in land use categories such as agricultural land, forest cover, wasteland, and built-up areas. The findings reveal uneven distribution of irrigation facilities, over-dependence on groundwater in central and southwestern districts, and rapid conversion of agricultural land into urban and industrial uses, particularly in districts adjacent to the National Capital Region (NCR). The study highlights the need for sustainable irrigation planning and balanced land use policies to ensure long-term agricultural productivity and environmental stability in Haryana.

Keywords: Spatial Analysis, Irrigation Distribution, Land Use Dynamics, Haryana, GIS, Agricultural Geography

Introduction

Haryana, carved out as a separate state in 1966, has emerged as a key contributor to India's Green Revolution. The state is predominantly agrarian, with a substantial portion of its population dependent on agriculture and allied activities. The geographical location of Haryana, characterized by semi-arid climatic conditions, low and erratic rainfall, and high evapotranspiration rates, makes irrigation a crucial determinant of agricultural productivity.

In the 21st century, rapid socio-economic development, population growth, and urbanization have significantly influenced land use patterns across the state. Expansion of industrial corridors, growth of urban centers like Gurugram, Faridabad, and Panipat, and the intensification of agriculture have resulted in dynamic changes in land utilization. The spatial distribution of irrigation resources has played a pivotal role in shaping these land use patterns, often leading to regional disparities in agricultural development.

This study aims to analyze the spatial distribution of irrigation and its relationship with land use dynamics across the districts of Haryana, highlighting emerging trends, challenges, and policy implications.

Objectives of the Study

The main objectives of this study are:

1. To examine the spatial distribution of irrigation across the districts of Haryana.
2. To analyze changes in land use patterns during the 21st century.
3. To explore the relationship between irrigation availability and land use dynamics.
4. To identify regional disparities and emerging challenges in irrigation and land use management.
5. To suggest policy measures for sustainable resource utilization.

Data Sources and Methodology

Data Sources

The study is based on secondary data collected from:

- Statistical Abstracts of Haryana
- Directorate of Economics and Statistics, Haryana
- District-wise Agricultural Census Reports
- Remote Sensing Data (Landsat & IRS imagery)

- Reports of Central Water Commission (CWC)
- National Remote Sensing Centre (NRSC)

Methodology

The following methods were adopted:

- GIS-based spatial mapping of irrigation sources and land use categories
- Temporal analysis of land use changes (2000–2023)
- Calculation of irrigation intensity and cropping intensity
- Comparative district-wise analysis
- Overlay analysis to identify correlation between irrigation and land use

Spatial patterns were classified using choropleth mapping and land use transition matrices.

Spatial Distribution of Irrigation in Haryana

The spatial distribution of irrigation in Haryana exhibits marked regional disparities shaped by physiography, availability of water resources, and the development of canal and groundwater infrastructure. The northeastern and central districts such as Karnal, Kurukshetra, Kaithal, Panipat, and Yamunanagar enjoy dense irrigation coverage primarily due to well-developed canal networks like the Western Yamuna Canal and Bhakra Canal system, which support intensive agriculture and high cropping intensity. In contrast, the southwestern and southern districts including Mahendragarh, Bhiwani, Rewari, and Nuh display relatively lower irrigation coverage and greater dependence on erratic rainfall, resulting in limited agricultural productivity and higher vulnerability to drought conditions. Groundwater irrigation through tubewells has expanded significantly across the state, particularly in central districts, but this has also led to alarming levels of groundwater depletion, with several areas classified as over-exploited zones. The pattern clearly demonstrates an east-to-west gradient in irrigation development, where canal-fed regions are agriculturally prosperous while rainfed regions remain comparatively backward. This uneven spatial distribution underscores the urgent need for balanced irrigation planning, sustainable water management, and the promotion of alternative irrigation techniques to reduce regional inequalities and ensure long-term agricultural sustainability in Haryana.

Sources of Irrigation

The main sources of irrigation in Haryana include:

- Canals (Western Yamuna Canal, Bhakra Canal)
- Tubewells and borewells
- Tanks and ponds (limited)

Canal irrigation dominates in northeastern and central districts such as Karnal, Kurukshetra, Kaithal, and Yamunanagar, while groundwater irrigation is prevalent in southern and southwestern districts like Mahendragarh, Bhiwani, and Rewari.

District-wise Irrigation Intensity

High irrigation intensity districts:

- Karnal
- Kurukshetra
- Kaithal
- Panipat

Moderate irrigation intensity districts:

- Hisar
- Jind
- Sirsa

Low irrigation intensity districts:

- Mahendragarh
- Rewari
- Mewat (Nuh)

The spatial pattern reveals a clear east-west gradient, with better irrigation facilities in the canal-fed eastern zone and poor coverage in the rainfed western region.

Groundwater Exploitation

Over-extraction of groundwater has become a serious concern, with several districts falling under "dark zone" or "over-exploited" categories. Intensive rice-wheat cropping in central districts has further aggravated the situation.

Land Use Dynamics in the 21st Century

Land use dynamics in Haryana during the 21st century reflect a complex interplay of agricultural intensification, urban expansion, industrialization, and environmental transformation. While agriculture continues to dominate the land use structure, there has been a noticeable decline in net sown area due to the rapid growth of urban centers, development of industrial estates, expansion of transport infrastructure, and increasing conversion of fertile agricultural land into residential and commercial zones, particularly in districts adjoining the National Capital Region such as Gurugram, Faridabad, Sonipat, and Jhajjar. Simultaneously, the pressure to increase food production has led to intensified cropping in canal and groundwater-irrigated zones, resulting in higher cropping intensity but also contributing to soil degradation, salinity, and declining water tables. Forest cover remains minimal and largely confined to the Aravalli belt, while wastelands have marginally decreased owing to reclamation and improved irrigation facilities. The emergence of peri-urban landscapes has further altered traditional rural land use patterns, creating fragmented and heterogeneous spatial structures. Overall, the 21st century has witnessed a shift from predominantly agrarian land use towards a more diversified and urban-oriented pattern, raising concerns about sustainable land management, ecological balance, and long-term agricultural viability in the state.

Major Land Use Categories

The land use structure of Haryana includes:

- Net sown area
- Forest land
- Barren and uncultivable land
- Fallow land
- Built-up area

Changes in Agricultural Land

While agriculture remains dominant, net sown area has declined slightly due to:

- Urban expansion
- Industrial development
- Infrastructure projects

Districts near NCR like Gurugram, Faridabad, and Sonipat witnessed rapid decline in agricultural land, while districts like Sirsa and Fatehabad retained higher agricultural coverage.

Increase in Built-up Areas

The growth of urban centers has led to:

- Conversion of fertile agricultural land
- Fragmentation of rural landscapes
- Rise in peri-urban settlements

Forest and Wasteland Trends

Forest cover remains minimal, largely concentrated in the Aravalli region. Wastelands have reduced marginally due to land reclamation and expansion of irrigation facilities.

Relationship between Irrigation and Land Use Patterns

A strong correlation exists between irrigation availability and land use intensity. Districts with high irrigation density support:

- Multiple cropping
- Intensive agriculture

- Higher cropping intensity

In contrast, districts with limited irrigation show dominance of:

- Pasture lands
- Single cropping
- Fallow land

The spatial overlay analysis indicates that irrigation acts as a catalyst for land use change, promoting intensification but also increasing ecological stress where unchecked groundwater use occurs.

Regional Disparities and Emerging Challenges

Regional Imbalances

Significant disparities exist between canal-irrigated and rainfed zones, leading to uneven agricultural productivity and income levels.

Environmental Concerns

- Declining groundwater table
- Soil salinization and waterlogging
- Loss of biodiversity
- Urban sprawl

Climate Variability

Erratic rainfall and rising temperatures add pressure on irrigation systems and influence cropping decisions.

Policy Implications and Recommendations

1. Promotion of micro-irrigation techniques (drip and sprinkler)
2. Regulation of groundwater extraction
3. Crop diversification towards less water-intensive crops
4. Strengthening canal infrastructure
5. Integrated land use planning and zoning
6. Encouraging rainwater harvesting
7. Adoption of GIS-based planning for resource management

Conclusion

The spatial analysis of irrigation distribution and land use dynamics in Haryana reveals that irrigation plays a decisive role in shaping agricultural and spatial development patterns. While improved irrigation has enhanced productivity, it has also led to over-exploitation of groundwater and ecological imbalance. The rapid transformation of land use, particularly near urban centers, poses a serious challenge to sustainable agriculture. A balanced approach integrating efficient irrigation management, environmental conservation, and planned land use strategies is essential for the sustainable development of Haryana in the 21st century.

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