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RS-GIS Based Delineation of Spatio-Temporal Crop Rotation Patterns in Hisar-II Block Using Unsupervised Classification

Tanu Sharma[1], Ashok Kumar[2*]
[1]*Department of Agricultural Meteorology, CCSHAU (HISAR)*
[2*]*Department of Geography, Guru Gorakhnath Government Post Graduate College, Hisar*
*(*Corresponding Author)*

ABSTRACT
The Hisar-II Block, situated in the arid agricultural landscape of Hisar District, Haryana, faces significant challenges to environmental sustainability primarily due to the widespread dominance of water-intensive crop rotation systems, notably Rice-Wheat and Cotton-Mustard. These practices have resulted in excessive pressure on the region's finite groundwater reserves and declining soil health. This research aims to accurately delineate and map the spatial distribution of these prevalent crop rotation patterns using advanced Remote Sensing (RS) and Geographic Information System (GIS) technologies, thereby providing essential data for developing evidence-based, sustainable agricultural management strategies. The study employed a multi-temporal data integration approach, utilizing high-resolution imagery from Landsat-9 (August 9, 2025, for Kharif) and Sentinel-2 (February 5, 2025, for Rabi). The core methodology involved a distinctive K-Means, Unsupervised Classification technique: non-agricultural areas were initially masked, followed by the application of the K-Means algorithm to both seasonal images to identify spectrally distinct crop classes (e.g., Rice, Cotton, Wheat, and Mustard). Subsequently, the classified Rabi and Kharif vector layers were merged using a Spatial Union operation within the GIS platform to generate a comprehensive Crop Rotation Pattern Map.
The results clearly establish the spatial dominance of water-intensive cycles across the study area. The Rice-Wheat rotation emerged as the single most prevalent pattern, encompassing 13,293.00 hectares, which accounts for 36.41% of the total geographical area. The Cotton-Mustard rotation follows, covering a substantial area of 7,910.87 hectares (21.66%). This explicit spatial mapping of current practices is crucial. It empowers local policymakers and agricultural extension agencies to effectively target vulnerable areas and promote the adoption of water-saving crops and diversified rotation systems, ultimately enhancing the regional agro-ecological balance and ensuring long-term agricultural resilience.
Key words: *Remote Sensing & Geographic Information System, Unsupervised Classification, Cropping Rotation*

I. INTRODUCTION

A cropping pattern reflects the proportional land distribution dedicated to various crops with in a region over a annual cycle, while crop rotation is a planned strategy involving the sequential change crops on the same field across successive seasons(such as Rabi and Kharif). This cyclical practice is essential for maintain soil health and fertility and for effective pest management.

The cropping pattern of Hisar-II Block predominately features intensive Rice-Wheat or Cotton- Mustard sequences, defining its Kharif-Rabi Seasons. The overwhelming prevalence of crops like Wheat/Rice in the observed pattern is heavily influenced by factors such as canal irrigation, Government Minimum Support Prices (MSP) and deep-rooted farming tradition. Consequently, this sequence drives the cultivation oh high-value, water-intensive cash crops, directly escalating the agricultural intensity and resource burden on the area.

Agriculture remains the primary source of income for a large majority India’s rural population. This deep reliance makes farming the fundamental occupation sustaining countless families in the country’s villages. The shift in agriculture from ancient to modern mechanized production is profound. Modern farming practice, including motorized machinery and improved seeds, have drastically enhanced efficiency. This technology leap enables a very small segment of the population to produce sufficient food, which efficiently supplies the Global Market. This signifies a profound transformation in the scale and output of agriculture compared to past eras. (Agnihotri N. & Priyanka 2017).

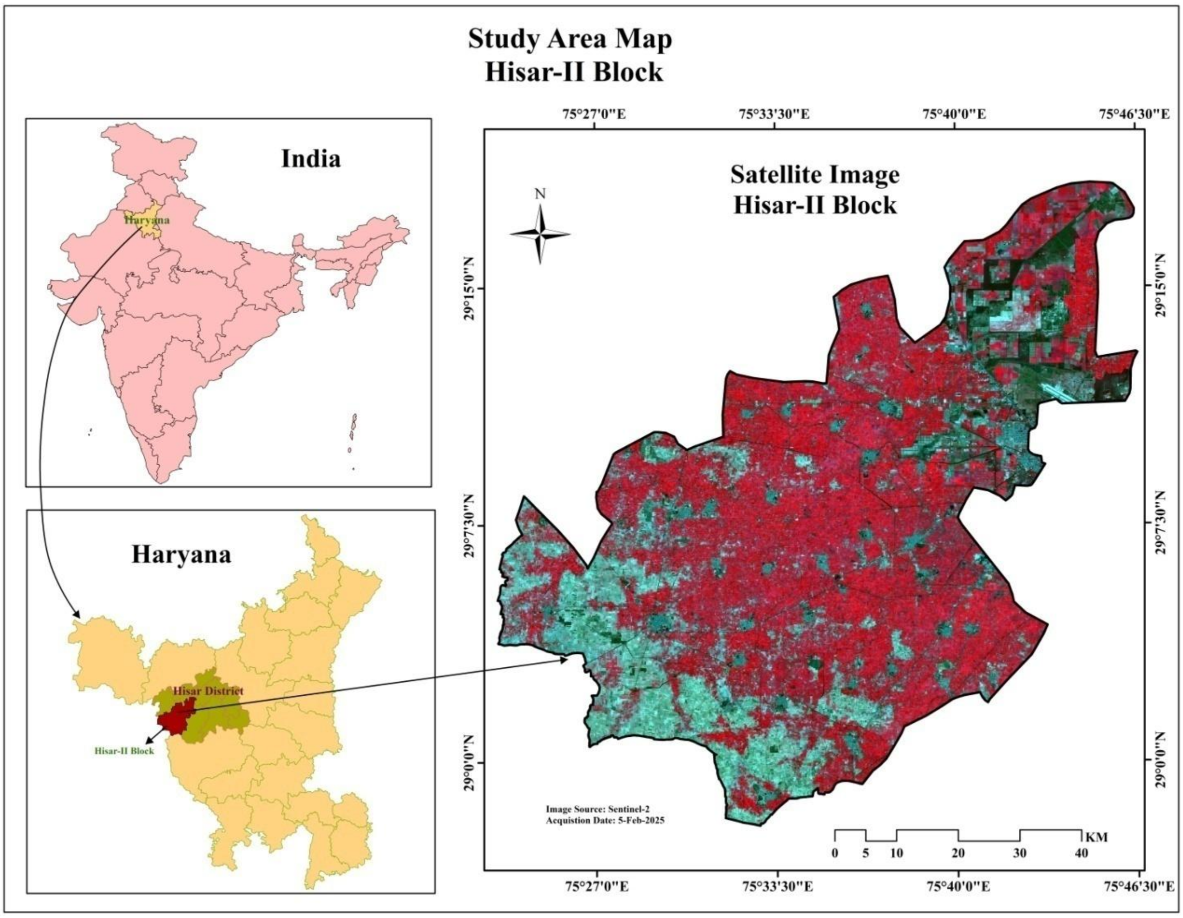
The agricultural framework of the Hisar district has undergone fundamental transformation since the Green Revolution, transitioning its focus from a subsistence – based economy to a highly commercialized, profit oriented enterprise. This pivotal change led to decisive reallocation of cultivated land, where traditional, less-remunerative crops like pulses and coarse grains were significantly displaced. Consequently, the district’s present day cultivation system is firmly established upon the profitable, triadic combination of Wheat, Rice and Cotton.

These dominance establishers a critical historical baseline for the subsequent analysis of contemporary land-use patterns and projected future Rabi- Kharif rotation pattern in specific areas such as Hisar. (Punia V. et.al 2021). This satellite-based evaluation used high-resolution Sentinel-2B data for 2020-2021 to map Rohtak district's field usage. The study confirmed an intensive agricultural system where Wheat and Rice form the principal food crops in their respective Rabi and Kharif seasons. It concludes that local farmers prioritize maximizing productivity using expanded irrigation and a wide range of seeds and fertilizers. (Devi J, et al. 2022)

Haryana's agricultural viability is increasingly challenged by the scarcity of water and chronic oil depletion, necessitating evidence-based decision making. The application of Geo-informatics provides the crucial spatial intelligence required to accurately track cropping shifts and inform effective regional conversation planning. (Devi J, et al. 2023)

STUDY AREA:

Location: - Hisar-II block is one of the nine community development blocks situated within the Hisar district of Haryana, India. It's generally located in the central-western part of the district. The geographical coordinates for the district are 28°56' to 29°38' N latitude and 75°21' to 76°18' E longitude. As an important administrative and agricultural unit Hisar-II covers a significant part of the rural settlements and is important for the agrarian economy of the region. It makes a considerable contribution to the total geographical area of the Hisar district.



Map-1: Location map of Study Area

Climate- The region experiences a semi-arid, continental climate, characterized by extreme temperature variations. Summers are intensely hot with maximum temperatures frequently exceeding 45°C during May and June. Winters are mild to cold, with temperatures occasionally dropping close to 3°C. Rainfall is limited and erratic, largely concentrated during the southwest monsoon season (July to September). The annual average rainfall is low, contributing to the semi-arid conditions.

Topography and Soil- The physical landscape of Hisar-II is largely level to gently sloping, typical of a plain formed by riverine deposits. While generally flat, the topography includes minor dune-like features or gentle undulations in its western sections. The dominant soil texture is sandy loam, which is workable but possesses low moisture retention capacity. The key soil challenges involve susceptibility to wind erosion and the presence of salinity and alkalinity in areas where natural drainage is insufficient, necessitating careful land management practices.

Land Use and Agriculture-Agriculture overwhelmingly dictates the land use pattern and economic activity in the block. The cropping system is highly intensive and relies heavily on external water sources. The primary Rabi (winter) crops include wheat and Mustard, while Kharif (monsoon) cultivation focuses on Cotton and Rice. This reliance on a few major crops underscores the need for effective resource management. In addition to cultivation, animal husbandry is deeply integrated into the livelihood strategy of the rural populace.

Water Resources- Water management presents a critical challenge due to the semi-arid climate. The main source of surface water for irrigation is the **Western Yamuna Canal (WYC) system,** which acts as the primary life-support for agriculture. However, the erratic nature of canal releases forces farmers to rely heavily on groundwater extraction via tube-wells. This widespread and intensive pumping has resulted in a substantial and ongoing decline in the water table. Consequently, ensuring the sustainable use and equitable distribution of canal water is a paramount concern for the block's future.

II. Methodology:

Satellite Data collection and Secondary source:

The foundational remote sensing data employed in this study draws from two primary high-resolution satellite missions: Sentinel-2 and Landsat 9.

Specifically, the Sentinel-2 component was utilized for its detailed 10-meter resolution imagery, with a focus on the visible spectrum (blue, green, and red bands) alongside the near-infrared (NIR) band. Launched on June 23, 2015, Sentinel-2A forms a critical element of the European Space Agency's (ESA) Copernicus Programme; provide the essential high-resolution multispectral data needed for applications like agriculture, land cover mapping, and broad environmental monitoring. The satellite is equipped with a Multispectral Instrument (MSI) that captures data across 13 distinct spectral bands, offering spatial resolutions of 10m, 20m, and 60m. Although Sentinel-2A initially had a 10-day revisit cycle, the launch of its twin, Sentinel-2B, in 2017 improved the combined revisit frequency to every five days. This valuable data is made freely available through platforms such as the Copernicus Open Access Hub.

The Landsat-9 mission, launched on September 27, 2021, is the continuation of the core partnership between NASA and the USGS (United States Geological survey), dedicated to extending the consistent, multi-decade land observation data at a 30-meter resolution. The satellite is equipped with two highly sensitive sensors, the OLI-2 (captures reflected light imagery) and the TIRS-2 (records emitted heat information). A critical capability is the collection of essential data across visible and near-infrared channels, including Bands 2 (Blue), 3 (Green), 4 (Red), and 5 (Near Infrared), which are foundational for applications like creating true-color images and calculating vegetation indices.

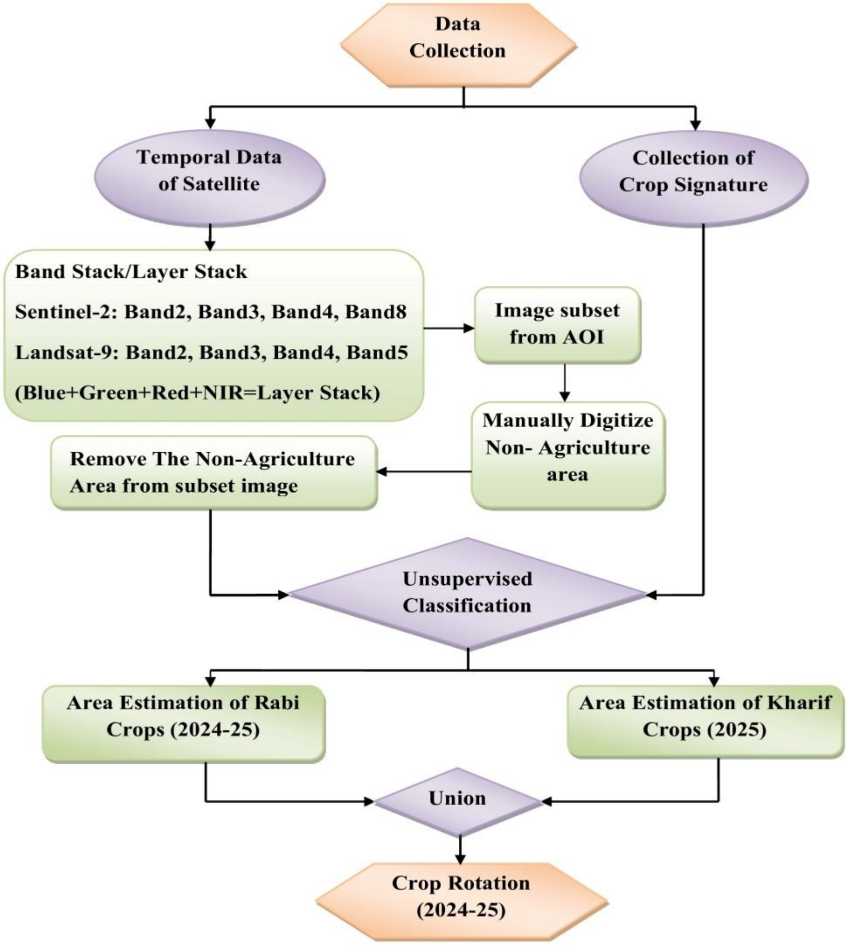


Fig-1: Flow chart of Methodology

Operating jointly with Landsat 8, the mission achieves a high revisit frequency, delivering fresh images of any global location every 8 days. This free and open data stream is indispensable for long-term monitoring in fields like agriculture, water resource planning, and climate science.

Image Acquisition:

- **Sentinel-2=** 5-Feb-2025 (for Rabi Crops)
- **Landsat-9=** 8-Aug-2025(for Kharif Season)

Band Stack: Band Stacking/Layer Stacking is the requisite data integration step where several single-band raster files, which record distinct wavelength reflectance values from the Earth's surface, are precisely aligned and combined. This operation constructs a unified, multi-spectral image file, thereby creating the complex digital structure necessary for subsequent quantitative analysis, such as thematic classification and index computation.

- Sentinel-2: Band2 (Blue), Band3 (Green), Band4 (Red), Band8 (NIR).
- Landsat-9: Band2 (Blue), Band3 (Green), Band4 (Red), Band5 (NIR).

Image subset and FCC creation: The composite spectral image stack is first subjected to a geospatial cropping operation. This process rigorously extracts the data corresponding solely to the predefined Area of Interest (AOI), discarding vast amounts of extraneous pixels outside the study region. This crucial step minimizes the dataset size, optimizing computational efficiency for all downstream processing and analysis.

Digitize and masking of Non- agriculture areas: Manually digitize Non- Agriculture areas in the subset allowed them to be excluded, as agricultural land will only be relevant in the further procedures. Non-Agriculture areas were then masked out of the subset images using the digitized layers, generating a more specific dataset focused solely on croplands.

Unsupervised classification:

In the initial stage of processing, the refined satellite image data is subjected to a clustering algorithm such as K-Means. This technique operates automatically, examining the spectral reflectance of every pixel within the designated crop area. It groups pixels that have similar spectral 'colors' or characteristics into a set number of spectral clusters. Crucially, the process happens without any prior knowledge or training data from the user, it simply identifies the most naturally occurring spectral groups in the image.

Cropping Pattern:
The separate seasonal classification results are geometrically combined using attribute-based logic to resolve the complete crop rotation pattern. This final, integrated product serves as a spatial database where each land unit is explicitly coded with its two-season crop history, thereby providing the foundation for analyzing agricultural intensity and yearly land utilization.

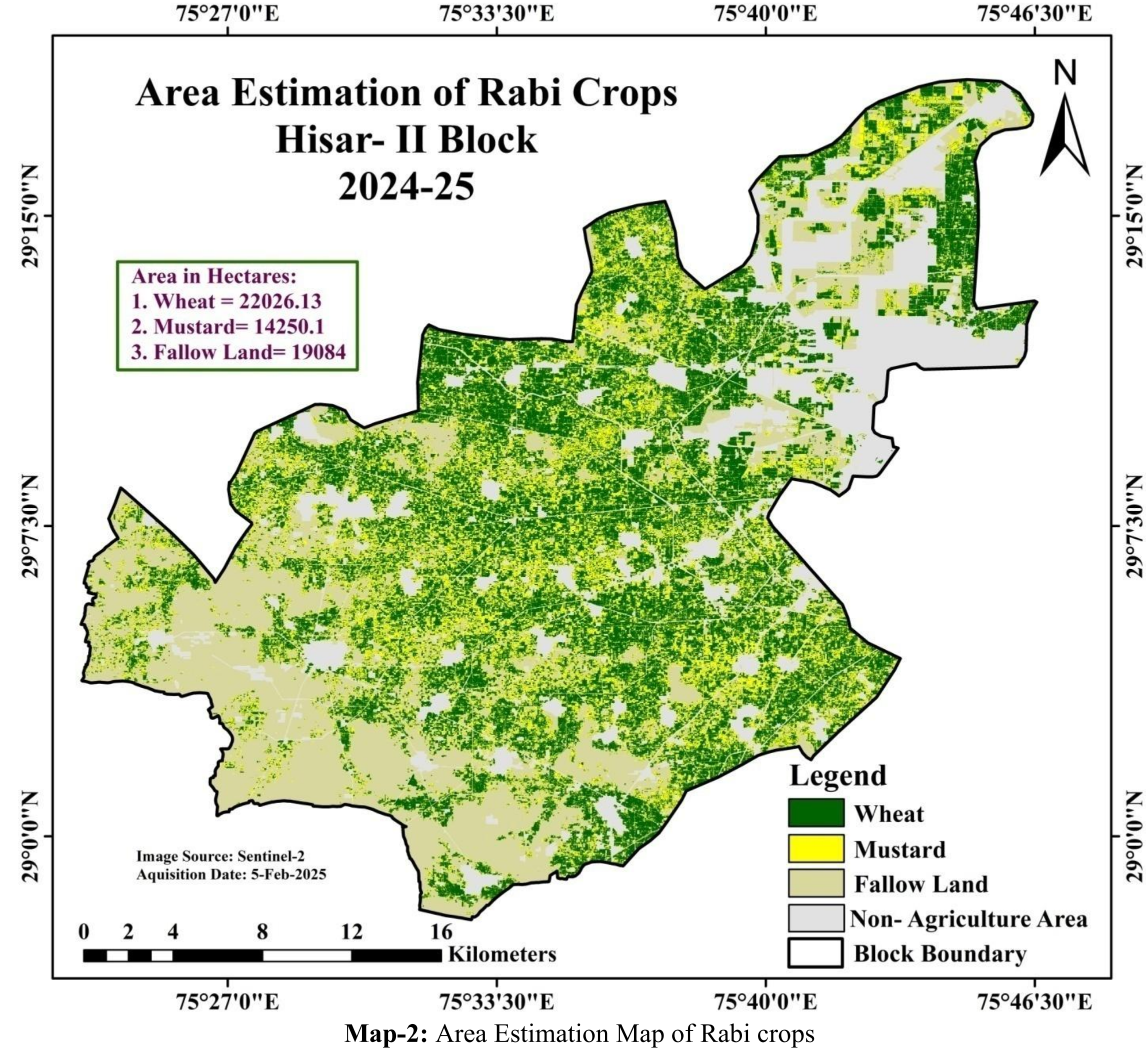
- **Rabi Season Crop (November-April):** This map spatially details the complete distribution of every classified crop (e.g., Wheat, Mustard, Fallow land) cultivated during the Rabi season.
- **Kharif Season Crop (June-October):** This map provides the corresponding spatial layout of all crops (e.g., Rice, Cotton, Pearl Millets) grown throughout the subsequent Kharif season.

Union: A Spatial Union operation is executed within the GIS environment, serving to geometrically merge the two distinct seasonal layers: the Rabi Crop and the Kharif Crop. This function combines all features from both input maps, resulting in a single output layer. The resultant polygons inherit the combined attribute data from both the original Rabi and Kharif features, effectively linking the crop grown in the first season with the crop grown in the second season for every specific land parcel. This process is fundamental to revealing and mapping the explicit crop rotation pattern.

III. Result and Discussion

The analysis of remote sensing data for the Hisar-II block provides a quantitative and spatial foundation for understanding agricultural land use during the 2024-25 cropping year. The total geographical area studied is 67057.13 hectares. This section focuses on the seasonal crop distribution and the resulting patterns crops rotation, highlighting the intensive nature of cultivation in the region.

Rabi Season Crops: The Rabi (winter) cropping pattern is characterized by the clear dominance of two major crops: Wheat and Mustard.



Map-2: Area Estimation Map of Rabi crops

This spatial map geographically illustrates the distribution of winter crops across the Hisar-II Block. It highlights the largest area dedicated to wheat and Mustard cultivation, showing their location relative to Fallow land and Non-Agriculture areas.

Table 1: Rabi Crop Area Estimation of Hisar-II Block (2025)

Area Estimation of Rabi Crops			
Sr.No.	**Class**	**Area Estimation (in Hec.)**	**Area Estimation (in %)**
1.	Wheat	22026.13	32.84
2.	Mustard	14250.1	21.25
3.	Fallow Land	19084	28.45
4.	Non-Agriculture Area	11696.9	17.44
	Total	**67057.13**	**100**

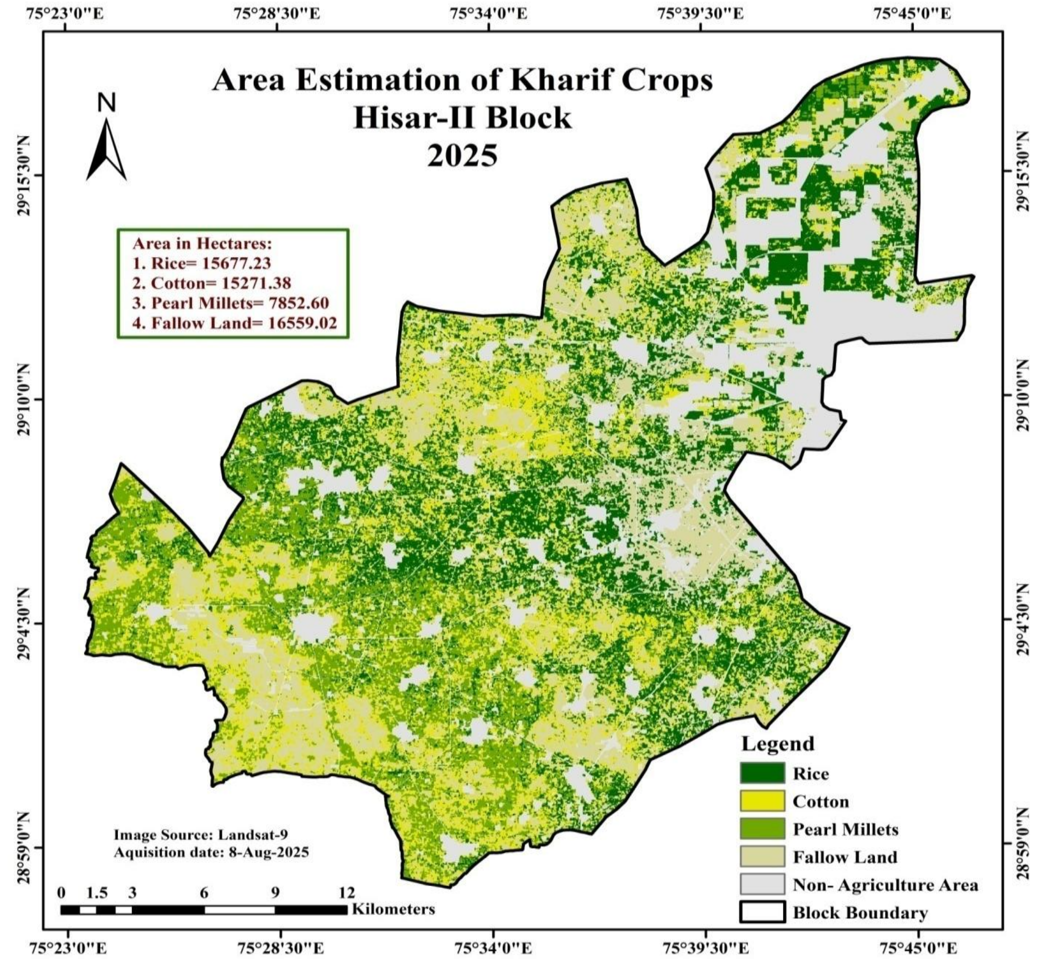
Wheat holds the largest share of the total land area, accounting for 32.84% (22,026.13 Hectares). This extensive cultivation underscores the crop's economic and staple importance in the region. Following Wheat, Mustard is the next most widespread crop, occupying 21.25% (14,250.1 Hectares). Together, these two crops define the winter agricultural landscape, showcasing a significant focus on both cereal food security and oilseed cash crop production. The remaining portions of the land were categorized as Fallow Land (28.45%) and Non-Agriculture Area 17.44%).

Kharif Season Crops:
The Kharif (monsoon) season exhibits a more diversified cropping pattern, though it is primarily driven by two key commercial crops: Rice and Cotton. The area dedicated to these crops is nearly equivalent, demonstrating a balanced resource allocation between cereal and fibre production.

Table-2: Kharif Crop Area Estimation of Hisar-II Block (2025).

Area Estimation of Kharif Crops			
Sr.No.	**Class**	**Area Estimation in (Hec.)**	**Area Estimation (in %)**
1.	Rice	15677.23	23.37
2.	Cotton	15271.38	22.77
3.	Pearl Millets	7852.6	11.71
4.	Fallow Land	16559.02	24.69
5.	Non-Agriculture Area	11696.9	17.44
Total		**67057.13**	**100**

Rice cultivation covers 23.37% (15,677.23 Hectares), indicating high reliance on the monsoon rains and irrigation systems for this water-intensive cereal. Simultaneously, Cotton cultivation is almost equally substantial, accounting for 22.77% (15,271.38 Hectares). The presence of these two high-value crops dominates the cultivated Kharif area. Pearl Millets (Bajra) represent the third largest cultivated area, covering 11.71% (7,852.6 Hectares). The inclusion of this hardier, drought-tolerant crop in over (10%)of the block suggests a pragmatic approach to farming, likely mitigating risk in areas with less assured irrigation or poorer soil quality.



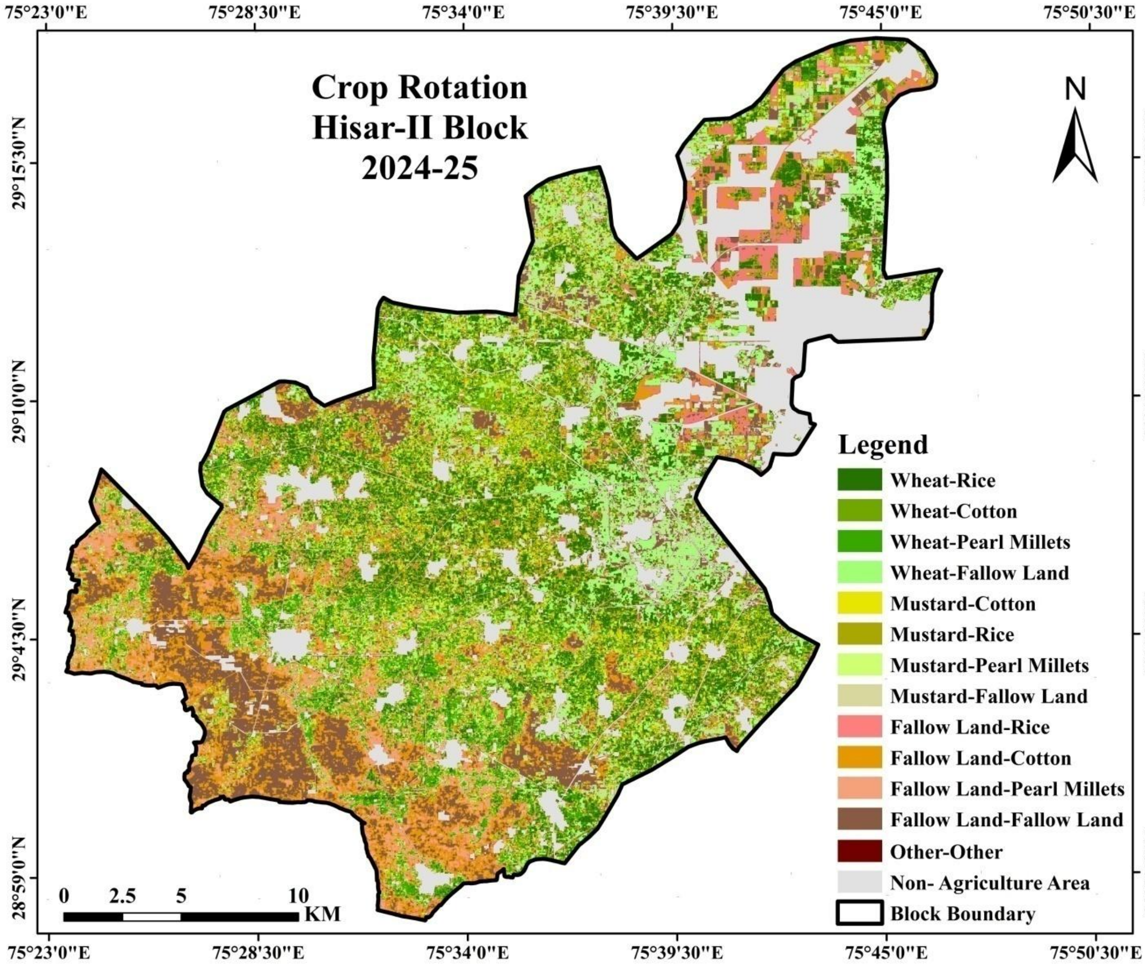
Map-3: Area Estimation of Kharif Crops.

This spatial map geographically illustrates the distribution of Monsoon crops across the Hisar-II Block. It highlights the largest area dedicated to Rice and Cotton cultivation, showing their location relative to Fallow land and Non-Agriculture areas.

IV. Crop Rotation

The crop rotation analysis for the Hisar-II Block reveals a high-intensity agricultural system focused on continuous production across the Rabi and Kharif seasons.

The crop rotation pattern of Hisar-II Block in 2024–25 presents a diverse agricultural landscape influenced by water availability, soil conditions, and market forces. Wheat–Rice rotation dominates the northern and eastern irrigated regions, while cotton-based and bajra-based rotations characterize the semi-arid western and southwestern zones. Fallow-based rotations mark areas of water scarcity. The map highlights the expanding shift towards rice cultivation, raising concerns about groundwater sustainability. Overall, the rotation patterns reflect both traditional cropping practices and emerging shifts driven by climatic and economic pressures.



Map-4: Crop Rotation Map of Rabi- Kharif Seasons of Hisar-II Block (2024-25)

This map visualizes the sequential farming practices across the block by depicting the Rabi- Kharif crop rotations. It shows the spatial contiguity of intensive cycles like Wheat- Rice and Mustard – Cotton, allowing for the assessment of farming intensity across different geographical zones within block.

Table 3: Showing the Crop rotation of Hisar-II Block (2024-25).

Crop Rotation of Rabi and Kharif			
Sr. No	**Crop Rotation**	**Area (in Hec.)**	**Area in %**
1	Wheat-Rice	8082.5	14.4
2	Fallow Land-Fallow Land	6029.8	12.1
3	Wheat-Fallow Land	5796.6	10.3
4	Fallow Land-Cotton	5690.7	10.1
5	Wheat-Cotton	5377.3	9.6
6	Mustard-Rice	4436.9	7.9
7	Mustard-Cotton	3969.4	7.1
8	Mustard-Fallow Land	3692.1	6.6
9	Fallow Land-Pearl Millets	3288.4	5.9
10	Fallow Land-Rice	2965.0	5.3
11	Wheat-Pearl Millets	2587.1	4.6
12	Mustard-Pearl Millets	1936.9	3.4

13	Other-Other	1507.6	2.7
14	Non-Agriculture Area	11696.9	2.7
Total		**67057.1**	**100**

The most critical sequence is the high-input wheat-Rice rotation, which alone accounts for 14.4% (8082.5 Hec.) of the area, forming the backbone of the region's productive economy. This intensive pattern is strongly supported by the Wheat-Cotton rotation, which covers 9.6 %(5377.3 Hec.). Mustard play a major role of diversification, integrated into sequences such as Mustard-Rice (7.9%) and Mustard-Cotton (7.1%), collectively utilizing a significant portion of the cultivated land. These intensive double cropping combinations highlight the strategic use of land for primary food crop and commercial outputs. Furthermore, the inclusion of Pearl Millets (4.6%) and Mustard–Pearl millets (3.4%) introduces essential crop diversify, contributing to system resilience.

V. Conclusion:

This study, utilizing remote sensing and GIS technique, applying the unsupervised classification (K-Means algorithms) to multi-temporal satellite imagery to successfully mapped the complex cropping pattern of Hisar-II Block. The analysis reveals a land-use pattern highly influenced by the profitable, irrigated Wheat-Rice rotation which emerged as the most extensive system. This allows them to effectively target vulnerable areas and promote the adoption of water saving crops and diversified system, thereby enhancing regional agro-ecological balance. This work provides the vital geospatial intelligence needed for evidence-based decision-making, ensuring long-term agricultural resilience in the semi-arid environment of Hisar-II Block. Furthermore, this dataset serves as foundational resource for Ph.D. scholars, researchers, and planners in critical field such as water resource modelling, optimize crop production and policy implementation.

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