

Temporal and Spatial Dynamics of Cropping Pattern, Crop Diversification and Irrigation in Hamirpur District, Uttar Pradesh (2011-12 to 2023-24): A Geo-Statistical Analysis

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Abstract

Cropping pattern in semi-arid, drought-prone Bundelkhand undergoes continuous re-adjustment in response to irrigation expansion, market signals and agro-climatic stress. This paper examines change in the area under principal crops of Hamirpur district, Uttar Pradesh, between 2011-12 and 2023-24 using official block-wise agricultural statistics (Directorate of Economics and Statistics / UPDES). Two complementary objectives are pursued: (i) the temporal change and growth rate of major crops at the district level, and (ii) the spatial variation in cropping structure, crop diversification and irrigation intensity across the seven development blocks. Percentage change, Compound Annual Growth Rate, the Coefficient of Variation, Simpson's Index of Diversification, Location Quotients and Pearson correlation are used as analytical tools. Results show that wheat area rose by 27.4 per cent (CAGR 2.04% per annum) and now occupies about 44 per cent of the gross cropped area considered, while pulses stagnated (-2.1%) and sugarcane disappeared entirely from the district. Oilseeds recorded the sharpest expansion (+39.7%), led by mustard and til. Irrigation intensity rose by 18-29 percentage points in every block, and this expansion is strongly and negatively associated with the pulses area ($r = -0.91$), indicating a shift from rainfed pulses toward irrigated wheat and oilseeds. Crop diversification, measured by the Simpson Index, increased marginally in six of the seven blocks. The findings have implications for irrigation planning, pulses revival programmes and drought-proofing strategy in the Bundelkhand region.

Keywords: *cropping pattern; crop diversification; Location Quotient; Simpson's Index; Bundelkhand; Hamirpur; irrigation intensity*

1. Introduction

Agricultural land use is among the most dynamic elements of the rural cultural landscape,

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continuously re-shaped by irrigation development, technology, market access and government price policy. In drought-prone Bundelkhand, where rainfall is erratic and groundwater is limited, the choice between food-grain security crops (wheat, gram) and low-water pulses and oilseeds is a critical adaptive decision for cultivators. Hamirpur, one of the seven districts of the Bundelkhand region of southern Uttar Pradesh, presents a compact and data-rich case in which to examine how cropping structure has responded over a twelve-year interval bracketed by two comparable cross-sections of official block-level statistics, 2011-12 and 2023-24.

Studies of cropping pattern in India have traditionally relied on measures of crop concentration and diversification (Weaver, 1954; Bhatia, 1965; Jasbir Singh & Dhillon, 1984) and on the Location Quotient to identify regional crop specialisation (Kendall, 1939; Thomas, 1963). More recent work stresses the role of irrigation intensity, minimum support price and agro-climatic risk in shifting the balance between food grains, pulses and oilseeds (Vaidyanathan, 2010; Government of India, Agricultural Statistics at a Glance, various years). This paper situates Hamirpur within that literature, applying standard geo-statistical techniques to two officially published cross-sections that together allow both a temporal (district-level, 2011-12 vis-à-vis 2023-24) and a spatial (block-wise) reading of change.

2. Study Area

Hamirpur lies in the south of Uttar Pradesh between roughly 25°30' and 26°15' N latitude and 79°30' and 80°15' E longitude (Fig. 1). The district is divided into seven development blocks: Kurara, Sumerpur, Sarila, Gohand, Rath, Muskara and Maudaha. Gohand and Rath occupy the south-western upland, Sarila and Muskara the central belt, Kurara and Sumerpur the north, and Maudaha the south-east.

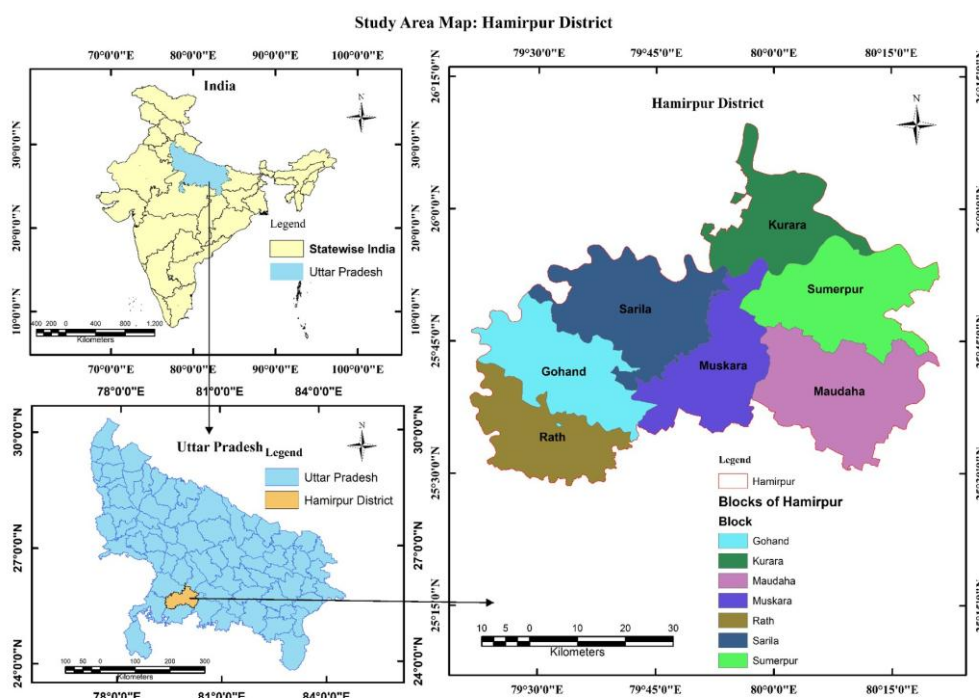


Fig. 1: Study area map showing the location of Hamirpur in India and Uttar Pradesh, and its seven development blocks

The district is predominantly rural. In 2023-24 urban areas accounted for only 803 ha of wheat out of 134,879 ha (0.6%) and just 2,470 ha of the 308,082 ha of food grains (0.8%), so nearly the whole agricultural system can be treated as rural and farm-household based. Agriculture in Hamirpur is largely dependent on the south-west monsoon; canal and tube-well irrigation has expanded appreciably over the study period (Section 5.4), but rainfed cultivation of pulses and coarse cereals still characterises the more upland blocks of Gohand and Rath.

3. Research Objectives

The study draws on two officially published cross-sections of (Block-wise Area under Main Crops) one centred on 2011-12 (with 2009-10 and 2010-11 as lead-in years) and one centred on 2023-24 (with 2021-22 and 2022-23 as lead-in years). Corresponding to these two data sets, two specific objectives are framed:

- Objective 1 (Temporal): To examine the district-level change in the area, composition and growth rate (percentage change and Compound Annual Growth Rate) of the principal food-grain, pulse, oilseed and cash/vegetable crops of Hamirpur between 2011-12 and 2023-24.
- Objective 2 (Spatial): To analyse the block-wise variation in cropping structure, crop diversification (Simpson's Index) and crop specialisation (Location Quotient) across the seven development blocks in 2011-12 and 2023-24, and to relate the observed change to the parallel expansion of irrigation intensity in each block.

4. Data Source and Research Methodology

4.1 Data Source

The study is based entirely on secondary data extracted from UPDES, 'Block-wise Area under Main Crops in the District (in Hectares)', published by the Directorate of Economics and Statistics, Government of Uttar Pradesh, through the UPDES SPIDER Reports portal (updes.up.nic.in). Two report cross-sections were retrieved: (a) the 2011-12 report, which also carries district totals for 2009-10 and 2010-11, and (b) the 2023-24 report, which carries district totals for 2021-22 and 2022-23. Each report gives, for every crop, the Total sown area and the Irrigated area, both at the district level and disaggregated for the seven rural development blocks plus a residual urban category.

4.2 Data Refinement

The raw tables list more than forty individual crop and sub-season (Kharif/Rabi/Zayad) entries, many with negligible or zero area at the block level (e.g., turmeric, sunn hemp, mint). For the purpose of this study the crops were re-grouped into nine analytically meaningful categories that together capture the great majority of the gross cropped area in every block: Rice, Wheat, Barley, Bajra, Total Pulses (urd + moong + lentils + gram + pea + pigeon pea), Total Oilseeds (mustard + linseed + til + peanut + sunflower + soyabean), Sugarcane, Potato and Total Other Vegetables. District-level analysis additionally reports Total Grains (cereals), Total Food Grains and the individual pulse/oilseed crops so that within-group shifts (e.g., gram losing area to pea) are not masked by the aggregate.

Rows for 'Total Rural', 'Total Urban' and 'Total District' provided in the original tables were used only to check internal consistency (block totals were verified to sum to the district total in every instance); the analysis proper uses the seven rural block figures, since the urban residual is agriculturally negligible (Section 2).

4.3 Analytical Techniques

- Percentage Change and Compound Annual Growth Rate (CAGR): $CAGR (\%) = [(V_t / V_0)^{(1/n)} - 1] \times 100$, where V_0 and V_t are the crop area in 2011-12 and 2023-24 and $n = 12$ years. CAGR is not defined where the initial or terminal value is zero; such cases are marked 'n.a.' in Table 1.
- Coefficient of Variation (CV): $CV (\%) = (\text{Standard Deviation} / \text{Mean}) \times 100$, computed across the seven blocks for each crop in each year, as a measure of inter-block (spatial) disparity in the distribution of a crop; a rising CV indicates increasing spatial concentration, a falling CV indicates spatial convergence.
- Simpson's Index of Diversification (SID): $SID = 1 - \sum p_i^2$, where p_i is the share of the i -th crop group in the nine-crop total of a block. SID ranges from 0 (complete specialisation in a single crop) to a maximum of $(1 - 1/9) \approx 0.89$ for the nine categories used here; higher values denote a more diversified cropping structure (Simpson, 1949).
- Location Quotient (LQ): $LQ = (\text{block's share of a crop in the block's nine-crop area}) / (\text{district's share of that crop in the district's nine-crop area})$. $LQ > 1$ denotes relative specialisation of the block in that crop; $LQ < 1$ denotes relative under-representation.
- Pearson's Product-Moment Correlation Coefficient (r): used to test the association, across the seven blocks, between the change in irrigation intensity (percentage points, 2011-12 to 2023-24) and the percentage change in pulses and oilseeds area over the same period.

All computations were carried out in Python (NumPy/pandas) on the digitised block-wise matrices; charts were produced with Matplotlib. Because the two cross-sections are twelve years apart with no intervening block-wise observation, the study reports a two-point (not a continuous time-series) comparison for the spatial analysis, supplemented by an unbroken three-year lead-in trend (2009-10 to 2011-12 and 2021-22 to 2023-24) at the district level (Fig. 3).

5. Results and Discussion

5.1 Temporal Change in District-level Cropping Pattern (Objective 1)

Table 1 sets out the district-level area under the principal crops in 2011-12 and 2023-24 together with the absolute change, percentage change and CAGR. Wheat, the dominant rabi cereal, increased from 105,840 ha to 134,879 ha, a rise of 27.4 per cent (CAGR 2.04% p.a.), and by 2023-24 accounted for roughly 44 per cent of the nine-crop area considered (Fig. 5). Barley (+54.8%) and pea (+53.4%) recorded still faster growth, while bajra all but disappeared from the district (-71.9%). Total Pulses were essentially stagnant (-2.1%), masking sharply divergent movements within the group: urd rose by 47.0 per cent and pea by 53.4 per cent, but

lentils fell by 18.5 per cent and gram historically the district's leading pulse contracted by 9.3 per cent (Table 1). Oilseeds recorded the most consistent expansion of any crop group (+39.7%, CAGR 2.83% p.a.), driven jointly by mustard, linseed and til, indicating a discernible shift toward oilseeds as a rabi and zayad cash crop. Sugarcane area, already marginal (2,529 ha) in 2011-12, had fallen to zero by 2023-24, and other vegetables also contracted by 42.3 per cent, while potato from a very small base of 43 ha expanded nearly eight-fold.

Crop / Crop-Group	2011-12 (ha)	2023-24 (ha)	Abs. Change (ha)	% Change	CAGR (%/yr)
Wheat	105,840	134,879	+29,039	+27.44	2.04
Barley	2,615	4,048	+1,433	+54.80	3.71
Bajra	317	89	-228	-71.92	-10.04*
Total Grains (cereals)	126,909	150,525	+23,616	+18.61	1.43
Total Urd	13,493	19,828	+6,335	+46.95	3.26
Total Moong	4,037	3,454	-583	-14.44	-1.29
Lentils (Masoor)	37,051	30,214	-6,837	-18.45	-1.69
Gram (Chana)	78,464	71,205	-7,259	-9.25	-0.81
Pea (Matar)	10,668	16,367	+5,699	+53.42	3.63
Pigeon pea (Arhar)	17,275	16,489	-786	-4.55	-0.39
Total Pulses	160,988	157,557	-3,431	-2.13	-0.18
Total Food Grains	287,897	308,082	+20,185	+7.01	0.57
Mustard (Lahi/Sarson)	12,281	16,628	+4,347	+35.40	2.56
Linseed	3,475	4,877	+1,402	+40.35	2.86
Til (Sesame)	31,104	43,451	+12,347	+39.70	2.82
Total Oilseeds	47,085	65,785	+18,700	+39.72	2.83
Sugarcane	2,529	0	-2,529	-100.00	n.a.
Potato	43	347	+304	+706.98	19.01*
Total Other Vegetables	2,273	1,312	-961	-42.28	-4.48

Table 1: District-level Area under Principal Crops, Hamirpur, 2011-12 and 2023-24 (* short growth spells from a very small base; interpret CAGR with caution)

Fig. 2: District-level Area under Major Crop Groups, Hamirpur, 2011-12 vs 2023-24

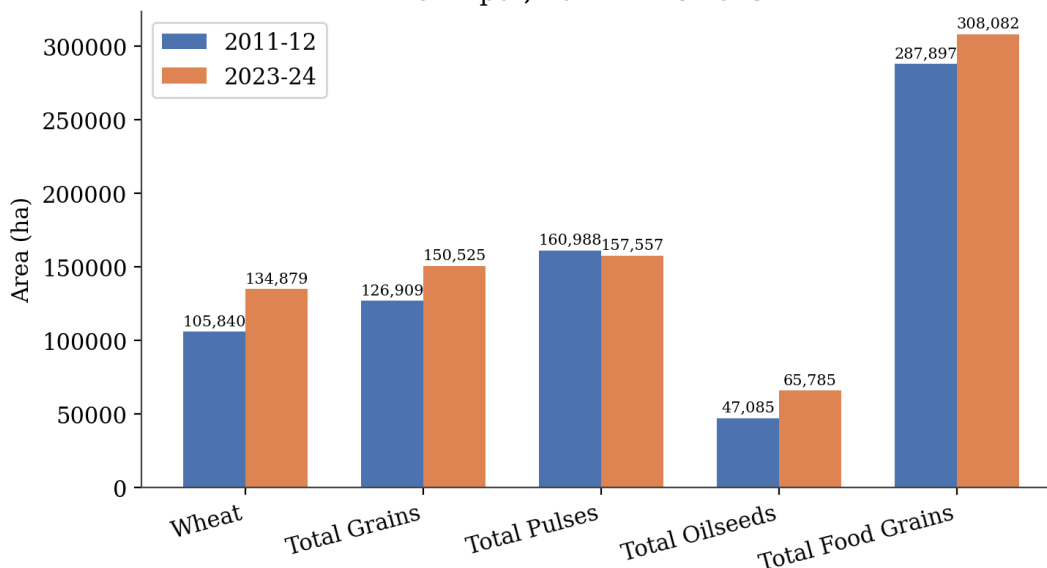


Fig. 2: District-level Area under Major Crop Groups, 2011-12 vs 2023-24

Fig. 3: Trend in Total Food Grain Area, Hamirpur District

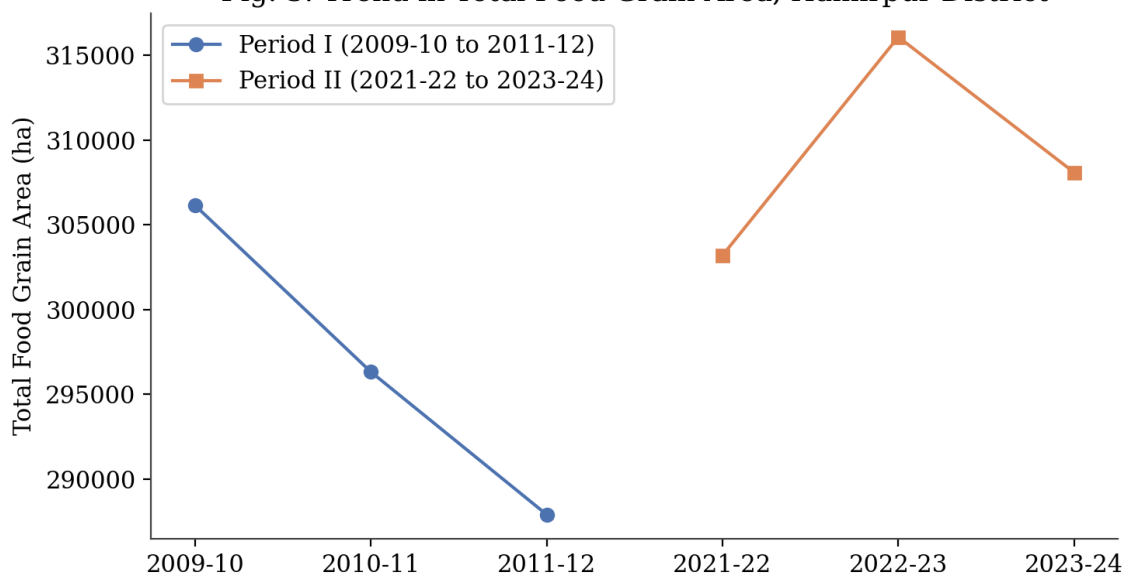


Fig. 3: Trend in Total Food Grain Area- Three-Year Lead-in Windows around the Two Reference Years

The three-year lead-in trends (Fig. 3) show that the two reference years were reached by contrasting short-run paths: total food-grain area was actually declining in the run-up to 2011-12 (2009-10 to 2011-12: -6.0%), whereas it rose, with an intervening spike in 2022-23, in the run-up to 2023-24 (2021-22 to 2023-24: +1.6%). This means 2011-12 was, if anything, a relative trough rather than a peak, so the positive change reported for Total Food Grains in Table 1 (+7.0%) is a conservative, not an inflated, estimate of the underlying long-run gain.

5.2 Block-wise Variation in Food Grain Area (Objective 2, part i)

At the block level, Total Food Grain area increased in every block between 2011-12 and 2023-24 (Table 2, Fig. 4), but the rate of increase was markedly uneven. Gohand (+12.9%) and Rath (+12.4%) — the two upland, historically less-irrigated blocks in the south-west of the district recorded the fastest growth, while Kurara (+1.5%) and Maudaha (+3.2%) grew only marginally. This pattern is consistent with a process of spatial convergence: blocks that started from a comparatively lower irrigated base in 2011-12 (Section 5.4) show the largest subsequent gains, narrowing though not eliminating inter-block disparity.

Block	Food Grain Area 2011-12 (ha)	Food Grain Area 2023-24 (ha)	% Change
Kurara	33,308	33,807	+1.50
Sumerpur	48,248	51,132	+5.98
Sarila	40,828	42,690	+4.56
Gohand	35,028	39,547	+12.90
Rath	33,804	38,001	+12.42
Muskara	42,780	47,383	+10.76
Maudaha	51,393	53,052	+3.23

Table 2: Block-wise Total Food Grain Area, 2011-12 and 2023-24

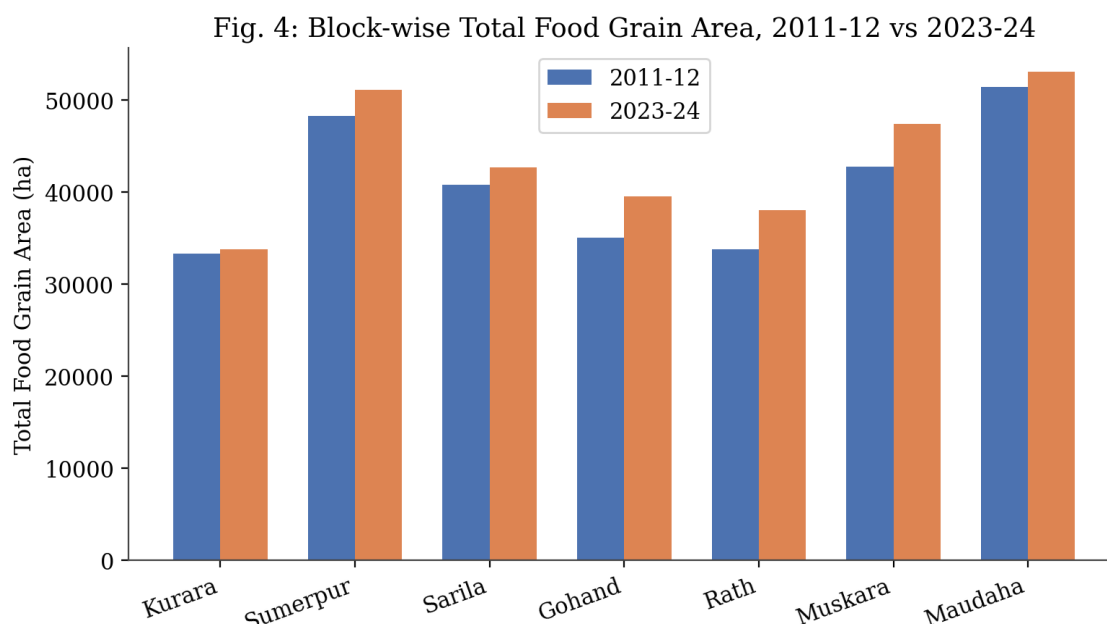


Fig. 4: Block-wise Total Food Grain Area, 2011-12 vs 2023-24

5.3 Cropping Pattern, Spatial Disparity (CV) and Crop Diversification (SID)

Figure 5 presents the percentage composition of the nine-crop area in each block for both years. The broad structure wheat and pulses together accounting for 75-90 per cent of cropped area is common to all blocks and both years, but two shifts stand out: the wheat share rose in every block (most sharply in Gohand, from 42.3% to 44.6%), and the oilseed share rose in six of the seven blocks, most strikingly in Maudaha, where oilseeds already occupied the largest share of any block in 2011-12.

The Coefficient of Variation across the seven blocks (Table 3) indicates the direction of spatial convergence or divergence for each crop. Wheat, barley and pulses show mild convergence (falling CV), consistent with the broadly uniform adoption of high-yielding wheat-pulse rotations across the district. Bajra and oilseeds remain highly concentrated in a few blocks (CV of 133.9% and 47.7% respectively in 2023-24), though the oilseed CV has fallen appreciably from 54.7 per cent, implying that oilseed cultivation, while still led by Maudaha, has diffused somewhat into other blocks. Other vegetables show the opposite tendency: CV rose sharply from 26.2 to 44.7 per cent, indicating growing spatial concentration of vegetable cultivation in a smaller number of blocks (chiefly Gohand and Rath).

Crop / Crop-Group	CV 2011-12 (%)	CV 2023-24 (%)
Rice	96.8	97.5
Wheat	18.6	18.2
Barley	20.5	20.4
Bajra	143.8	133.9
Total Pulses	21.3	18.3
Total Oilseeds	54.7	47.7
Sugarcane	154.3	n.a. (0 in all blocks)
Potato	23.6	25.4
Total Other Vegetables	26.2	44.7

Table 3: Block-wise Coefficient of Variation (Spatial Disparity), 2011-12 and 2023-24

Simpson's Index of Diversification (Table 4, Fig. 6) rose in six of the seven blocks between 2011-12 and 2023-24, indicating a modest but consistent broadening of the cropping base away from wheat-pulse mono-dominance. Kurara recorded the largest gain (+0.052), moving from the least to a middling level of diversification, while Rath already the most diversified block in 2011-12 (SID = 0.649) showed a marginal decline (-0.001), remaining the most diversified block in 2023-24 as well (SID = 0.647). Maudaha combines the highest SID (0.664) with the strongest oilseed specialisation (Table 5), showing that diversification and specialisation in a particular high-value crop are not mutually exclusive at the block scale.

Block	SID 2011-12	SID 2023-24	Change
Kurara	0.585	0.636	+0.052
Sumerpur	0.614	0.638	+0.023
Sarila	0.593	0.622	+0.029
Gohand	0.610	0.623	+0.013
Rath	0.649	0.647	-0.001
Muskara	0.606	0.629	+0.023
Maudaha	0.637	0.664	+0.027

Table 4: Simpson's Index of Crop Diversification by Development Block

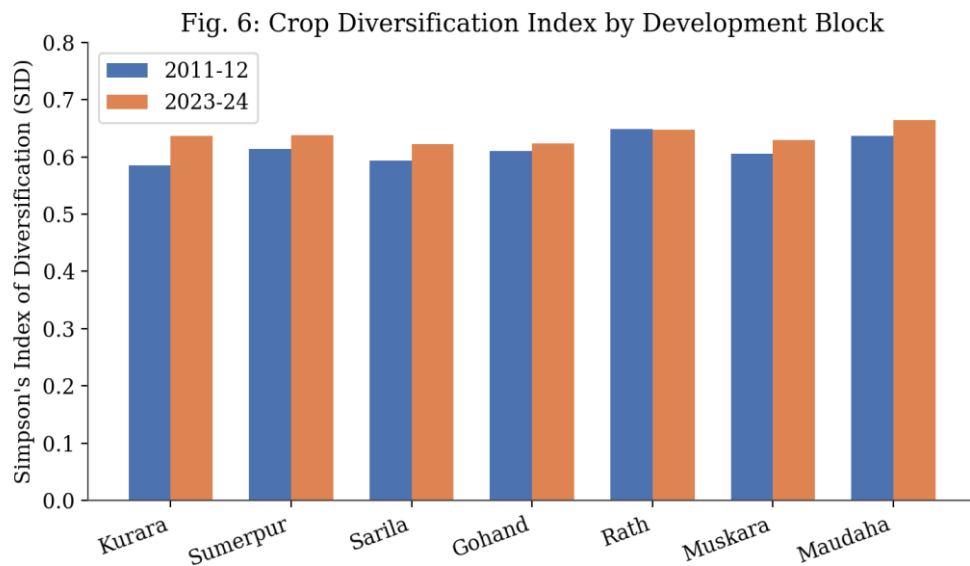


Fig. 6: Crop Diversification Index (SID) by Development Block, 2011-12 vs 2023-24

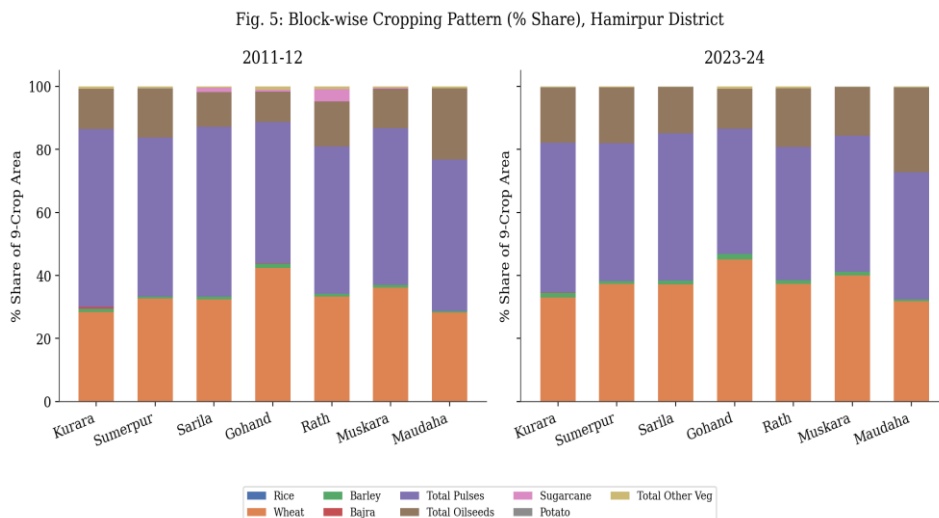


Fig. 5: Block-wise Cropping Pattern (% Share of Nine-Crop Area), 2011-12 vs 2023-24

5.4 Crop Specialisation (Location Quotient) and Irrigation Intensity

Location Quotients for pulses and oilseeds (Table 5) show that Kurara and Sarila remain consistently specialised in pulses ($LQ > 1$ in both years), while Gohand remains persistently under-represented (LQ 0.90 and 0.92). Maudaha is, by a wide margin, the most oilseed-specialised block in both years (LQ 1.53 and 1.47), though its degree of specialisation eased slightly as oilseed cultivation diffused elsewhere; Kurara shows the largest gain in oilseed specialisation (LQ rising from 0.86 to 0.96), consistent with its parallel rise in overall diversification (Table 4).

Block	LQ Pulses 2011-12	LQ Pulses 2023-24	LQ Oilseeds 2011-12	LQ Oilseeds 2023-24
Kurara	1.13	1.10	0.86	0.96
Sumerpur	1.01	1.02	1.05	0.97
Sarila	1.08	1.08	0.75	0.81
Gohand	0.90	0.92	0.66	0.70
Rath	0.94	0.98	0.98	1.02
Muskara	1.00	1.00	0.84	0.84
Maudaha	0.97	0.94	1.53	1.47

Table 5: Location Quotients for Pulses and Oilseeds by Development Block

Irrigation intensity (irrigated share of the food-grain area) rose in every block by between 18 and 29 percentage points over the study period (Table 6, Fig. 7). The largest gains were in Kurara (+28.9 points) and Maudaha (+27.1 points), both starting from a comparatively low irrigated base (34.0% and 37.0% respectively in 2011-12); Gohand and Muskara reached the highest absolute irrigation intensity by 2023-24 (72.1% and 72.0%).

Block	Irrig. % 2011-12	Irrig. % 2023-24	Change (pts)
Kurara	34.0	62.9	+28.9
Sumerpur	40.3	63.4	+23.1
Sarila	43.2	64.5	+21.3
Gohand	53.4	72.1	+18.7
Rath	47.7	65.8	+18.1
Muskara	48.6	72.0	+23.4
Maudaha	37.0	64.1	+27.1

Table 6: Irrigation Intensity (Irrigated Share of Food Grain Area) by Block

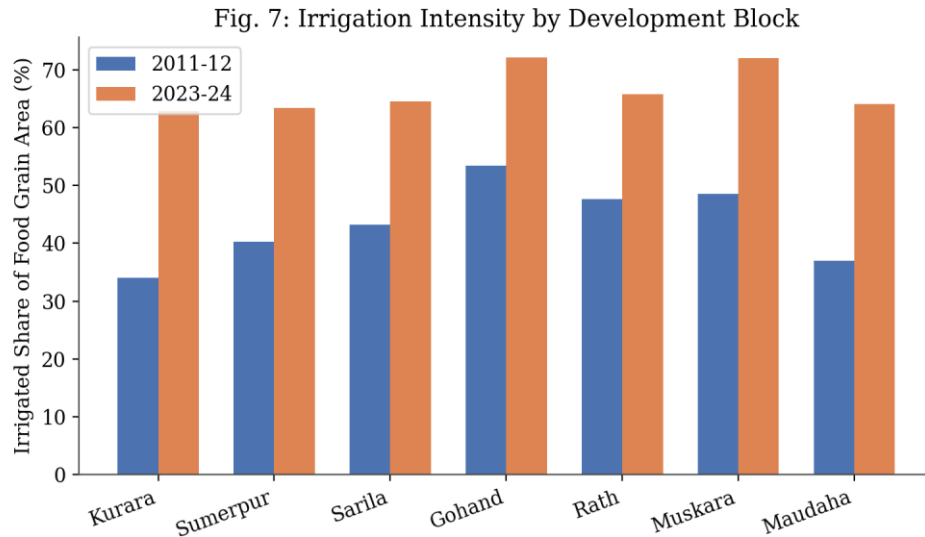


Fig. 7: Irrigation Intensity by Development Block, 2011-12 vs 2023-24

5.5 Association between Irrigation Expansion and Pulses / Oilseeds Area

Pearson correlation across the seven blocks between the change in irrigation intensity (2011-12 to 2023-24) and the percentage change in pulses area yields $r = -0.91$ (Fig. 8a), a strong negative association: blocks with the largest irrigation gains (Kurara, Maudaha) recorded the largest percentage declines in pulses area, while blocks with smaller irrigation gains (Gohand, Rath) recorded pulses area increases. This is consistent with the well-documented substitution of rainfed pulses by irrigated wheat once canal or tube-well water becomes available. The corresponding correlation for oilseeds is weaker and also negative ($r = -0.35$, Fig. 8b): oilseed area rose in every block regardless of the size of the irrigation gain, suggesting that oilseed expansion plausibly driven by mustard's relatively low water requirement, its rabi-season MSP support, and market demand for edible oil has proceeded somewhat independently of the pace of irrigation development.

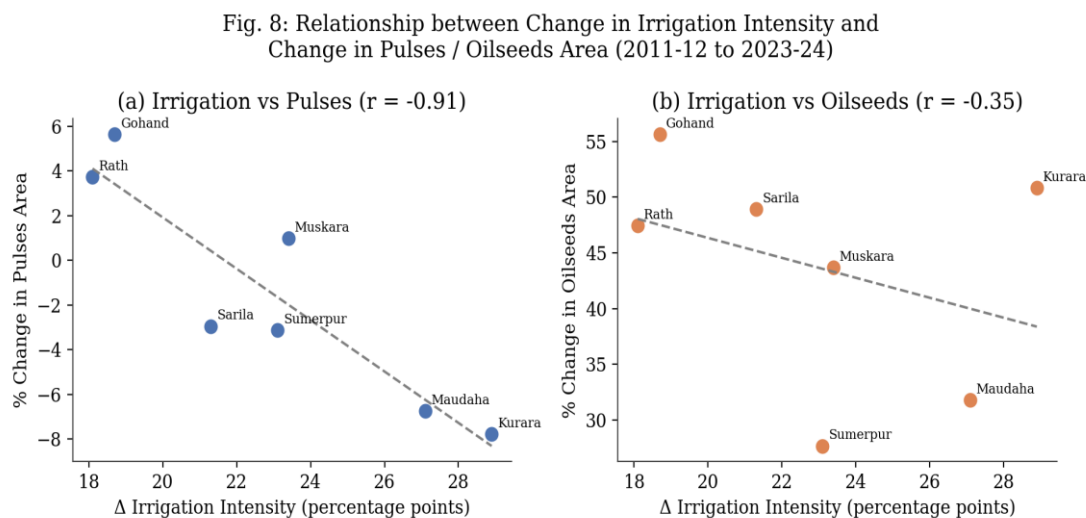


Fig. 8: Change in Irrigation Intensity vs. Percentage Change in (a) Pulses and (b) Oilseeds Area, by Block

6. Conclusion

This paper has combined a temporal (district-level) and a spatial (block-wise) reading of change in the cropping pattern of Hamirpur district between 2011-12 and 2023-24, addressing the two objectives. At the district level, wheat and oilseeds have been the clear gainers (CAGR 2.04% and 2.83% p.a. respectively), pulses have stagnated in aggregate while undergoing significant internal recomposition away from gram and lentils toward urd and pea, and sugarcane has effectively disappeared from the district. At the block level, food-grain area has grown fastest in the historically less-irrigated upland blocks of Gohand and Rath, producing a measurable convergence in food-grain distribution even as bajra and oilseeds remain spatially concentrated. Crop diversification, measured by the Simpson Index, has risen modestly across most blocks, and the strong negative association between irrigation expansion and pulses area ($r = -0.91$) points to irrigation-driven crop substitution as a principal mechanism of change. These findings suggest that targeted revival of pulses through location-specific extension in blocks such as Kurara and Maudaha where the pulses area has contracted most and continued, geographically balanced irrigation investment in Gohand and Rath would help sustain both food security and cropping diversity in this drought-prone Bundelkhand district. The study is limited by the twelve-year gap between the two block-wise cross-sections; a continuous annual block-wise series, where it becomes available, would permit trend rather than two-point analysis and a fuller test of the irrigation-substitution hypothesis advanced here.

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