

Spatial Structure and Restructuring of Agricultural Support Infrastructure in a Semi-Arid Agrarian District: A Block-Level Statistical Analysis of Hamirpur, Bundelkhand (Uttar Pradesh)

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Abstract

Agricultural support infrastructure input retailing, storage, marketing and institutional service mediates the translation of agrarian potential into realised farm output, yet its internal spatial organisation is rarely subjected to formal statistical scrutiny at the sub-district scale. This paper analyses ten facility indicators for the seven development blocks of Hamirpur district, Bundelkhand, for 2024–25, together with a three-year district time series (2022–23 to 2024–25). Descriptive dispersion measures, chi-square tests of spatial uniformity, Gini coefficients and Lorenz curves, a Pearson correlation matrix, principal component analysis, a composite z-score index (CAII) and Ward's hierarchical clustering are applied. Three findings stand out. First, the district has undergone a rapid ownership transition: private and non-departmental outlets now supply 88.0% of seed, 89.9% of fertiliser and 97.6% of pesticide retailing, while cooperative seed centres halved (47→23) and warehouse numbers fell by 75.9%. Second, facility distribution across blocks is significantly non-uniform for six of eight count indicators ($p < 0.05$), with inequality greatest for institutional rather than commercial facilities (Gini = 0.360 for FPOs against 0.080 for warehouses). Third, PCA isolates two orthogonal dimensions — a commercial input-retailing axis (34.4% of variance) and an institutional-storage axis (29.5%) — that are essentially uncorrelated, implying that market-led and state-led provisioning follow independent geographies. The CAII identifies Rath as the sole high-infrastructure block (100.0) and Gohand, Muskara and Kurara as a contiguous deficit cluster (0.0–6.1). Urban areas, holding only 0.8% of the district's food-grain area, concentrate 38.3% of fertiliser outlets a disparity ratio of roughly 48. The paper argues that aggregate district-level growth in facility counts has concealed, and may have intensified, intra-district polarisation.

Keywords: agricultural infrastructure; Bundelkhand; composite index; principal component analysis; spatial inequality; Farmer Producer Organisations; Hamirpur.

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1. Introduction

The productivity of an agrarian economy depends not only on land, water and biotic inputs but on the density and accessibility of the institutional and physical apparatus that surrounds cultivation¹. Seed and fertiliser outlets determine whether recommended inputs reach a farmer within a feasible travel radius; warehouses and godowns determine whether a harvest can be withheld from a depressed post-harvest market; regulated mandis and their electronic extensions determine the price a cultivator can realise; and collective institutions such as Farmer Producer Organisations (FPOs) determine whether smallholders can access these systems on terms comparable to larger operators. Where this apparatus is thin or unevenly placed, agronomic potential is systematically under-realised².

Bundelkhand, the semi-arid plateau-fringe region straddling southern Uttar Pradesh and northern Madhya Pradesh, is among the most persistently distressed agrarian tracts in India. Erratic and declining rainfall, shallow and gravelly soils over the Vindhyan and Bundelkhand granite formations, limited assured irrigation, and a mono-dominant rabi wheat–pulse cycle combine to produce high inter-annual yield variance. In such an environment the buffering role of support infrastructure — particularly storage and market access — is proportionately more important than in assured-irrigation tracts, because the marginal value of the ability to store, to wait, and to access timely inputs rises with production risk³.

Research on Indian agricultural infrastructure has largely operated at state or district resolution. This is analytically convenient but geographically blunt: the district is not the unit at which a farmer experiences accessibility. A cultivator in a block with no regulated mandi is, for practical purposes, outside the regulated marketing system even if the district as a whole reports five mandis. Sub-district (block-level) analysis is therefore not merely a finer-grained version of district analysis; it addresses a different and more policy-relevant question, namely whether provision within an administrative unit is spatially equitable⁴.

This paper pursues four objectives: (i) to document the direction and magnitude of change in the district's agricultural facility stock between 2022–23 and 2024–25; (ii) to measure the degree of inter-block inequality in facility provision and test whether observed distributions depart significantly from spatial uniformity; (iii) to identify, through multivariate reduction, the latent dimensions along which facility provision is organised; and (iv) to construct a composite index and a typological regionalisation that can be used directly for targeting. The guiding hypothesis is that rapid aggregate expansion of privately owned input retailing has not been matched by expansion of publicly provided storage and institutional infrastructure, and that the two categories obey different and spatially divergent locational logics⁵.

1.2 Related works:

Agricultural support infrastructure plays a fundamental role in improving agricultural productivity, resource efficiency, market integration, and rural livelihoods, particularly in semi-arid regions such as Bundelkhand. Jain et al. (2021)⁶ examined agricultural infrastructural suitability in Bundelkhand and emphasized the importance of irrigation, agricultural markets, roads, storage, institutional credit, and extension services in strengthening agricultural development. Their work demonstrates that agricultural infrastructure varies spatially and can

be assessed through statistical and spatial approaches. Garg et al. (2020)⁷ further demonstrated the importance of water-related infrastructure in Bundelkhand, showing that interventions such as rainwater harvesting, check dams, field bunding, and groundwater-recharge measures can improve water availability, cultivated area, agricultural productivity, and rural livelihoods.

Studies specifically concerning Hamirpur provide additional evidence of infrastructural and technological constraints. Raaj and Vishnoi (2024)⁸ identified water scarcity, soil degradation, climate variability, limited access to modern agricultural technologies, inadequate credit, and weak market linkages as important challenges to sustainable agriculture in Hamirpur. They also emphasized advanced irrigation, precision farming, renewable-energy technologies, policy support, and capacity building as important components of agricultural transformation. Their methodological use of statistical analysis and GIS for examining the spatial distribution of agricultural resources provides relevance for block-level research. Raaj et al. (2026)⁹ examined land-use change in Hamirpur and identified changes in agricultural and built-up areas through Landsat and GIS-based analysis, demonstrating the significance of spatial and temporal approaches in understanding agricultural transformation. Katiyar et al. (2026)¹⁰ additionally highlighted the importance of training, credit, technology, and extension support in agricultural participation.

2. The 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-east¹¹.

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 under food grains (0.8%), so nearly the whole agricultural system can be treated as rural and farm-household based. This near-total rurality of the production base is analytically important: it means that any concentration of facilities in urban settlements represents a genuine spatial mismatch between where crops are grown and where services are located, rather than a rational response to the distribution of demand. The seven blocks are of broadly comparable administrative standing, which justifies treating them as comparable observational units, while the north–south physiographic gradient (alluvial Yamuna–Betwa interfluvium in the north, dissected upland in the south-west) provides a plausible physical basis for expecting locational differentiation¹².

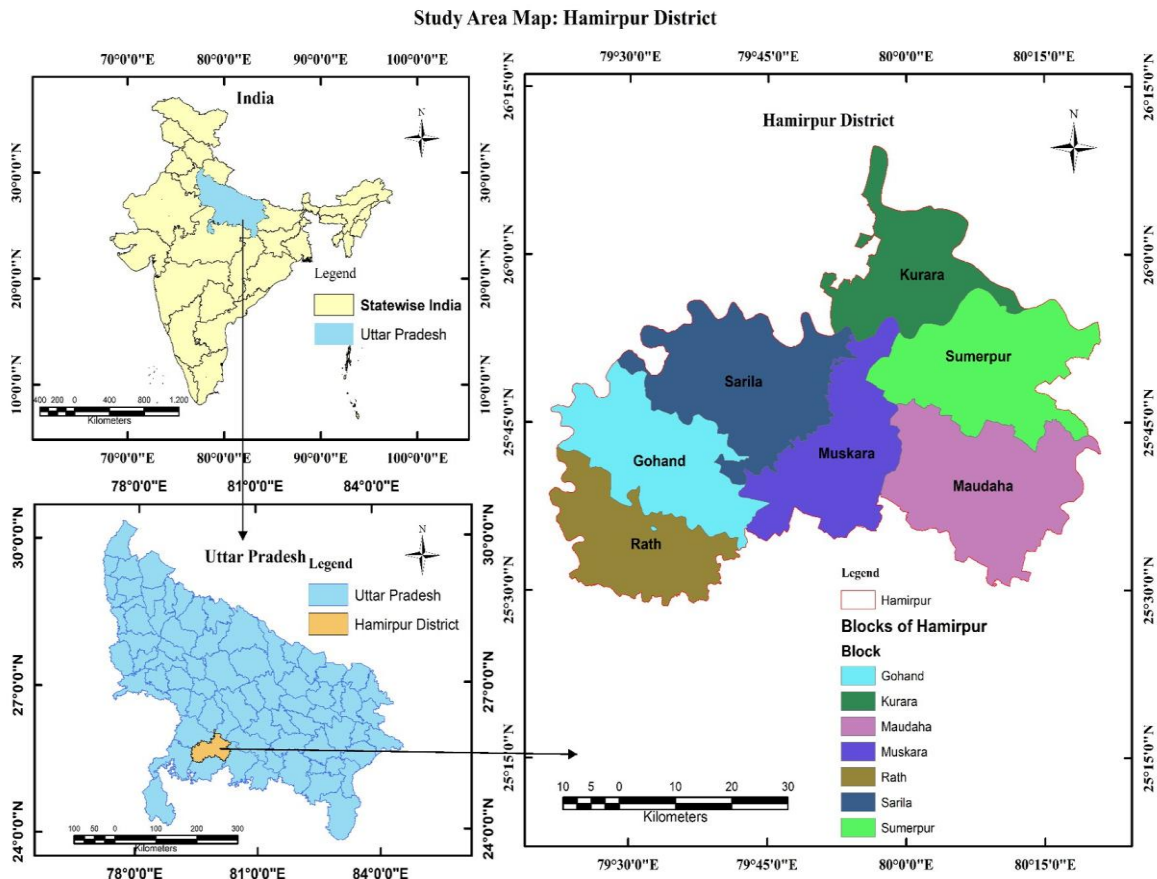


Fig. 1. Study area: location of Hamirpur district within India and Uttar Pradesh, and its seven development blocks.

3. Database and Methodology

3.1 Data

The analysis rests on block-wise administrative returns of “main facilities related to agriculture” for Hamirpur district¹³. Two data structures are used. The first is a district-level time series for 2022–23, 2023–24 and 2024–25, permitting measurement of short-run change. The second is a block $\times$ indicator matrix for 2024–25 (7 blocks $\times$ 10 indicators), which supports the cross-sectional spatial analysis. Facility counts are disaggregated by provider Department of Cooperation, Agriculture Department, and “other” (effectively private and non-departmental) which permits a direct test of ownership restructuring. Because block figures sum exactly to the reported rural totals, the block-level analysis is strictly an analysis of the *rural* facility stock; urban facilities are handled separately in Section 4.8.

The ten indicators retained are: seed sales centres, fertiliser sales centres, pesticide sales centres, warehouses, rural godown capacity (MT), agricultural service centres, FPOs, FPO membership, regulated mandis, and biogas plants. Two indicators reported in the source agricultural defence unit centres (uniformly one per block) and cold storage (uniformly zero) are excluded from multivariate work because zero variance renders them uninformative; their constancy is itself reported as a substantive finding.

3.2 Statistical methods

Seven procedures are applied, chosen to move from description through inference to synthesis.

1. **Dispersion analysis¹⁴**. The coefficient of variation, $CV = (\sigma/\mu) \times 100$, is used to compare variability across indicators measured in different units. Following conventional thresholds, $CV < 15\%$ denotes low, $15\text{--}33\%$ moderate and $> 33\%$ high inter-block variability.
2. **Chi-square test of spatial uniformity¹⁵**. For each count indicator the null hypothesis is that facilities are distributed equally across the seven blocks, giving expected frequency $E_i = \Sigma O_i / 7$ and $\chi^2 = \Sigma (O_i - E_i)^2 / E_i$ with 6 degrees of freedom. The test is applied only to genuine counts; godown capacity and FPO membership are magnitude variables for which the chi-square statistic has no valid frequency interpretation, and for these only CV and Gini are reported.
3. **Concentration analysis¹⁶**. The Gini coefficient, computed as $G = [2 \Sigma_i i \cdot x_{(i)}] / (n \Sigma x) - (n+1)/n$ on block values sorted ascending, and its graphical counterpart the Lorenz curve, quantify how unequally each facility type is shared among blocks. $G = 0$ denotes perfect equality; higher values denote concentration in few blocks.
4. **Correlation analysis¹⁷**. A Pearson product-moment matrix over the ten indicators identifies co-location and substitution relationships. Given $n = 7$, the critical value of $|r|$ at $\alpha = 0.05$ (two-tailed, $df = 5$) is 0.754; relationships weaker than this are treated as suggestive only.
5. **Principal component analysis¹⁸**. Indicators are standardised to zero mean and unit variance and decomposed into orthogonal components. Components with eigenvalues exceeding unity (Kaiser criterion) are retained; loadings are reported as component–variable correlations.
6. **Composite Agricultural Infrastructure Index (CAII)¹⁹**. Each block's mean standardised score across the ten indicators, $\bar{Z}_j = (1/k) \Sigma_i z_{ij}$, is rescaled to a 0–100 range by min–max normalisation. Equal weighting is adopted deliberately, so that the index remains transparent and does not embed a prior judgement about which facility matters most; the PCA-derived PC1 score is reported alongside as a data-driven alternative, and the two rankings are compared by Spearman's ρ .
7. **Hierarchical clustering²⁰**. Ward's minimum-variance method applied to the standardised matrix with squared Euclidean distance groups blocks into infrastructure types, providing a regionalisation independent of the index.

Growth is summarised both as simple net percentage change and as the compound annual growth rate, $CAGR = [(V_t/V_0)^{1/n} - 1] \times 100$, over the two-year interval.

4. Results

4.1 Temporal dynamics of the facility stock:

The district's facility stock changed dramatically over the three reference years, but in two opposite directions (Table 1, Fig. 2). Input retailing expanded explosively. Seed sales centres rose from 63 to 259, fertiliser outlets from 101 to 494, and pesticide outlets from 61 to 339 — net increases of 311%, 389% and 456% respectively, corresponding to compound annual growth of roughly 103%, 121% and 136%. Almost the entire increase occurred between 2022–23 and 2023–24 and then continued more moderately, suggesting a discrete regulatory or registration event (most plausibly a licensing drive that brought previously unrecorded dealers onto the register) rather than a purely organic proliferation of new businesses.

Storage moved in the opposite direction. Reported warehouses collapsed from 187 to 45, a fall of -75.9%, driven entirely by the disappearance of the 132 “other” and 8 departmental warehouses recorded in 2022–23, leaving only the cooperative sector's 45 units. Rural godown capacity nevertheless remained fixed at 10,370 MT across all three years, as did the biogas stock at 2,180 plants and the government agricultural farm at a single 8-ha unit. This combination falling facility counts with unchanged capacity indicates consolidation or reclassification rather than physical loss of storage volume, but it also demonstrates that no net storage capacity was added during a period when input retailing more than tripled.

Marketing infrastructure improved modestly: regulated mandis rose from two to five, of which three are e-NAM-integrated, and agricultural service centres increased from 23 to 62 before contracting to 53. FPOs and their membership (60 organisations, 15,080 members) were first reported in 2023–24 and remained unchanged thereafter.

Table 1. Change in agricultural facility stock, Hamirpur district, 2022–23 to 2024–25

facility	2022-23	2023-24	2024-25	Net change (%)	CAGR (%)
Seed sales centres	63	206	259	+311.1	+102.8
Fertiliser sales centres	101	456	494	+389.1	+121.2
Pesticide sales centres	61	293	339	+455.7	+135.7
Warehouses	187	45	45	-75.9	-50.9
Godown capacity (MT)	10370	10370	10370	+0.0	+0.0
Agricultural service centres	23	62	53	+130.4	+51.8
FPOs	n.a.	60	60	n.a.	n.a.
FPO membership	n.a.	15080	15080	n.a.	n.a.
Regulated mandis	2	5	5	+150.0	+58.1

Biogas plants	2180	2180	2180	+0.0	+0.0
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n.a. = not reported in that year. CAGR computed over the two-year interval.

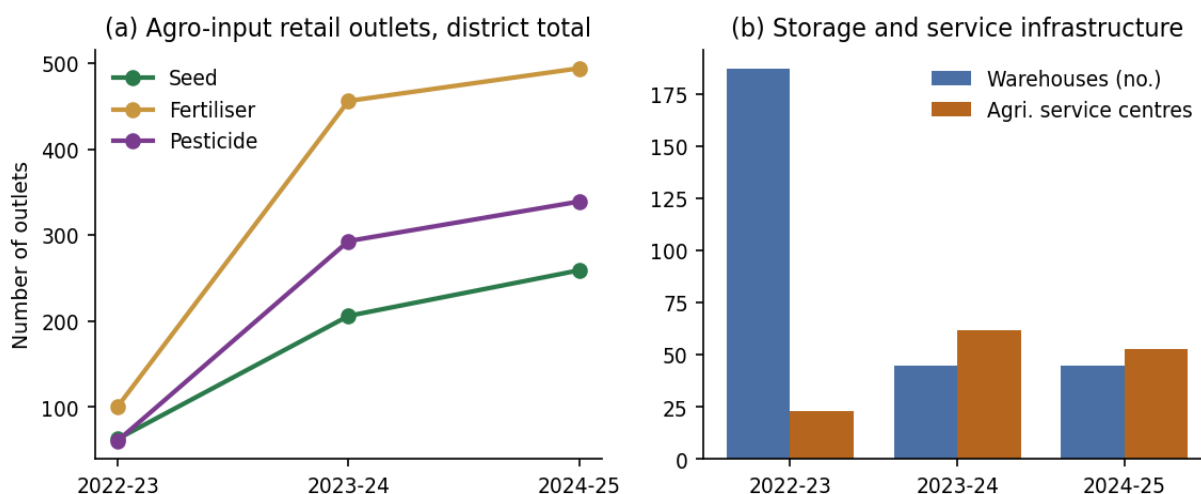


Fig. 2. Divergent trajectories of (a) agro-input retail outlets and (b) storage and service infrastructure, Hamirpur district.

4.2 Ownership restructuring of input provisioning

The expansion described above was almost wholly private. Table 2 shows that by 2024–25 private and non-departmental outlets accounted for 88.0% of seed centres, 89.9% of fertiliser centres and 97.6% of pesticide centres. A chi-square test of independence across the three input types confirms that the provider mix differs significantly between inputs ($\chi^2 = 48.86$, $df = 4$, $p < 0.001$): pesticides are the most fully privatised channel, seeds the least, reflecting the residual role of the Department of Cooperation in certified seed distribution.

The public retreat is absolute as well as relative. Cooperative seed centres fell from 47 to 23, a halving, and the Agriculture Department's direct fertiliser retailing ceased entirely (4 outlets in 2022–23, none thereafter), while private fertiliser outlets rose from 42 to 444. The department now retains a token presence of eight outlets each in seed and pesticide retailing precisely one per block plus one urban unit which is best read as a demonstration or quality-reference function rather than a supply function.

This transition has ambiguous welfare implications. Density of provision has unquestionably improved, which shortens farmer travel distances. But private outlets are subject to weaker price and quality discipline than cooperative channels, and the cooperative share of input outlets now ranges from only 6.9% in Rath to 10.0% in Sumerpur, leaving little institutional counterweight in any block.

Table 2. Ownership structure of agro-input retailing, 2024–25 (district totals)

Facilities	Cooperative Dept.	Agriculture Dept.	Private / other	Total	Private share (%)
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Seed sales centres	23	8	228	259	88.0
Fertiliser sales centres	50	0	444	494	89.9
Pesticide sales centres	0	8	331	339	97.6

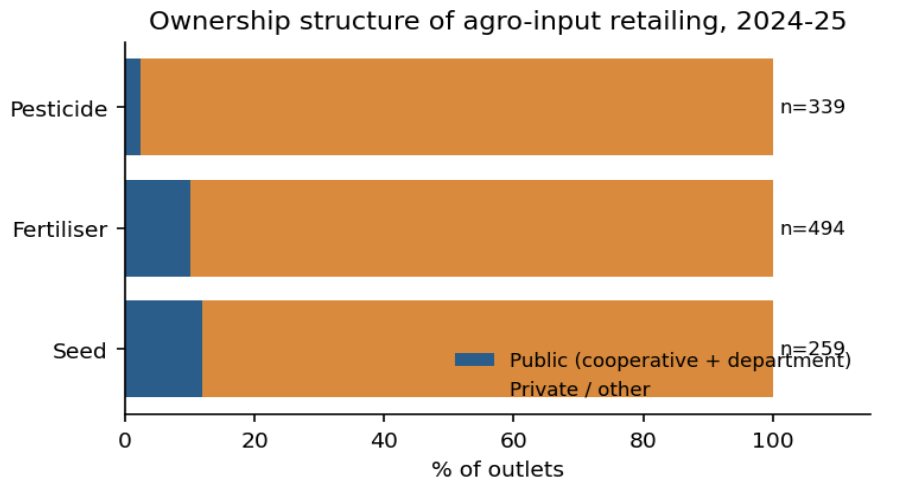


Fig. 3. Public (cooperative and departmental) versus private shares of agro-input retail outlets, 2024–25.

4.3 Block-level profile and variability:

Table 3 presents the full block $\times$ indicator matrix for the rural stock, and Table 4 its statistical summary. Rath emerges immediately as an outlier, holding the largest share of seed (40 of 176), pesticide (53 of 204) and fertiliser (52 of 305) outlets, the most FPOs (12) and the largest FPO membership (2,500), and the district's only government agricultural farm. Gohand is consistently the weakest commercial node, with the fewest seed (15), fertiliser (23) and pesticide (16) outlets, yet holds the second-largest number of FPOs (10) — an inversion discussed below.

Variability differs sharply by facility type (Fig. 4). Three indicators exceed the 33% high-variability threshold: FPOs (CV = 73.57%), regulated mandis (68.31%) and agricultural service centres (63.42%), with FPO membership close behind (57.06%). At the opposite extreme, godown capacity (CV = 14.15%) and warehouses (15.36%) are distributed with remarkable evenness, and agricultural defence units are perfectly uniform at one per block. The pattern is systematic rather than incidental: *administratively allocated* facilities are near-uniformly distributed, while *market-determined and voluntarily-formed* facilities are highly concentrated. Administrative allocation in this district has evidently followed a norm of one-per-block equality, which guarantees formal equity but ignores differences in cropped area and farm population.

Table 3. Block-wise agricultural facilities, rural Hamirpur, 2024–25 (indicators in rows, blocks in columns)

Indicators	Kurara	Sumerpur	Sarila	Gohand	Rath	Muskara	Maudaha	Rural total
Seed sales centres	16	25	28	15	40	26	26	176
Fertiliser sales centres	41	49	49	23	52	41	50	305
Pesticide sales centres	19	26	27	16	53	27	36	204
Warehouses	6	7	7	5	5	5	6	41
Godown capacity (MT)	700	1075	900	900	850	850	1050	6325
Agricultural service centres	6	3	8	3	8	0	9	37
FPOs	2	3	2	10	12	4	5	38
FPO membership	800	900	700	2000	2500	1000	800	8700
Regulated mandis	1	1	0	0	1	1	1	5
Biogas plants	310	303	259	319	310	246	433	2180

Table 4. Descriptive statistics, concentration and tests of spatial uniformity (n = 7 blocks)

Indicators	Mean	SD	Min	Max	CV (%)	Gini	χ^2 (df=6)
Seed sales centres	25.14	8.34	15	40	33.15	0.16	16.58*
Fertiliser sales centres	43.57	10.06	23	52	23.10	0.11	13.95*
Pesticide sales centres	29.14	12.32	16	53	42.28	0.20	31.25***
Warehouses	5.86	0.90	5	7	15.36	0.08	0.83 ns
Godown capacity (MT)	903.57	127.83	700	1075	14.15	0.07	—
Agricultural service centres	5.29	3.35	0	9	63.42	0.32	12.76*
FPOs	5.43	3.99	2	12	73.57	0.36	17.63***

FPO membership	1242.86	709.12	700	2500	57.06	0.26	—
Regulated mandis	0.71	0.49	0	1	68.31	0.29	2.00 ns
Biogas plants	311.43	60.47	246	433	19.42	0.09	70.46***

*** $p < 0.01$; * $p < 0.05$; ns = not significant. χ^2 not computed for magnitude variables (godown capacity, FPO membership).

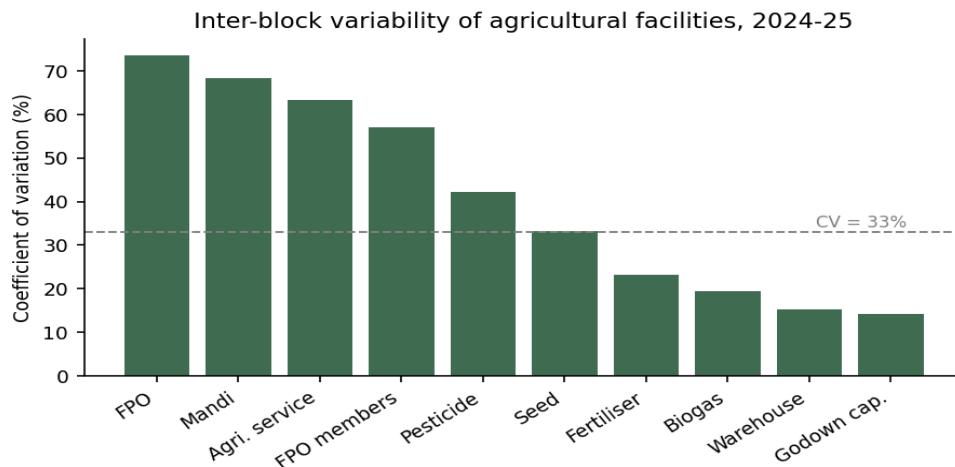


Fig. 4. Coefficient of variation of facility indicators across the seven blocks. Institutional and market-determined facilities vary far more than administratively allocated ones.

4.4 Spatial concentration and inequality

Chi-square tests reject the hypothesis of uniform distribution for six of the eight count indicators (Table 4). Departures are highly significant for pesticide outlets ($\chi^2 = 31.25$, $p < 0.001$) and biogas plants ($\chi^2 = 70.46$, $p < 0.001$), significant for seed outlets, fertiliser outlets, FPOs and agricultural service centres, and non-significant only for warehouses ($\chi^2 = 0.83$, $p = 0.99$) and regulated mandis ($\chi^2 = 2.00$, $p = 0.92$). The near-perfect fit for warehouses is itself informative: it confirms that cooperative storage was allocated on a fixed per-block basis.

Gini coefficients order the indicators consistently with the chi-square results but allow direct comparison of magnitudes (Fig. 5). Inequality is highest for FPOs ($G = 0.360$), agricultural service centres (0.320), regulated mandis (0.290) and FPO membership (0.260); it is lowest for godown capacity (0.070), warehouses (0.080) and biogas plants (0.090). The Lorenz curves make the practical consequence visible: the three weakest blocks hold only about 21% of the district's FPOs but close to 40% of its warehouse capacity.

The mandi case deserves separate emphasis because a low Gini here is misleading. With only five mandis for seven blocks, two blocks Sarila and Gohand have none at all, and only three mandis are e-NAM enabled. Expressed against the cropped base, the district supports roughly one regulated mandi per 61,600 ha of food-grain area. For cultivators in Sarila and Gohand, regulated marketing is a service that must be reached by crossing a block boundary, with the attendant transport cost falling entirely on the producer.

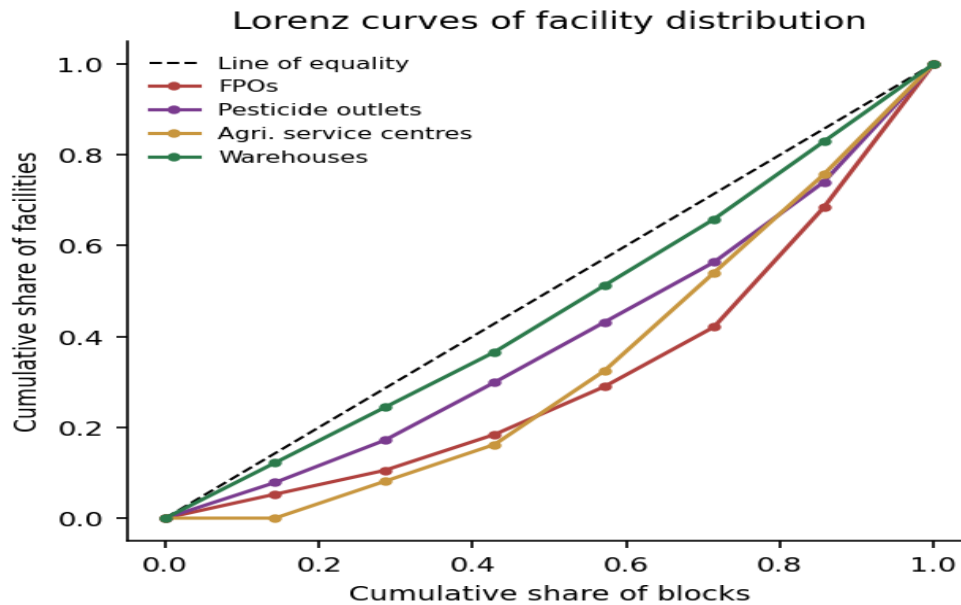


Fig. 5. Lorenz curves of facility distribution across blocks. The greater the departure from the diagonal, the more concentrated the facility.

4.5 Inter-relationships among facilities

The correlation matrix (Fig. 6, Table 5) reveals a structured rather than random pattern of association. Two relationships are statistically significant at $n = 7$. Seed and pesticide outlets are very strongly associated ($r = 0.939$, $p = 0.002$), and FPOs and FPO membership are almost collinear ($r = 0.969$, $p < 0.001$), the latter being definitional. Strong but formally non-significant associations link seed with fertiliser outlets ($r = 0.746$) and, notably, warehouses with FPOs in the *negative* direction ($r = -0.717$).

The clustering of the three input-retail variables at $r > 0.70$ indicates that seed, fertiliser and pesticide dealerships co-locate: they are complementary businesses serving the same customer in the same trip, and they respond to the same underlying demand surface. The inverse warehouse–FPO relationship is more interesting. Blocks well endowed with cooperative storage (Sumerpur, Sarila, Kurara) have few FPOs, while blocks with weak storage (Gohand, Rath) have the most. One plausible reading is functional substitution: where cooperative storage is absent, collective producer organisation emerges as an alternative route to aggregation and bargaining power. An equally plausible reading is that FPO promotion programmes have been deliberately targeted at blocks identified as institutionally underserved. The data cannot discriminate between these, but either interpretation implies that warehouses and FPOs should not be treated as additive components of a single “institutional capacity” construct.

Table 5. Strong bivariate associations among facility indicators ($|r| \geq 0.60$)

Indicator X	Indicator Y	Pearson r	p	Sig.
Seed sales centres	Fertiliser sales centres	0.746	0.0542	ns

Seed sales centres	Pesticide sales centres	0.939	0.0017	**
Fertiliser sales centres	Pesticide sales centres	0.697	0.0819	ns
Warehouses	FPOs	-0.722	0.0668	ns
Warehouses	FPO membership	-0.694	0.0836	ns
FPOs	FPO membership	0.969	0.0003	**

** $p < 0.01$; * $p < 0.05$; ns = not significant at $n = 7$ (critical $|r| = 0.754$, $df = 5$).

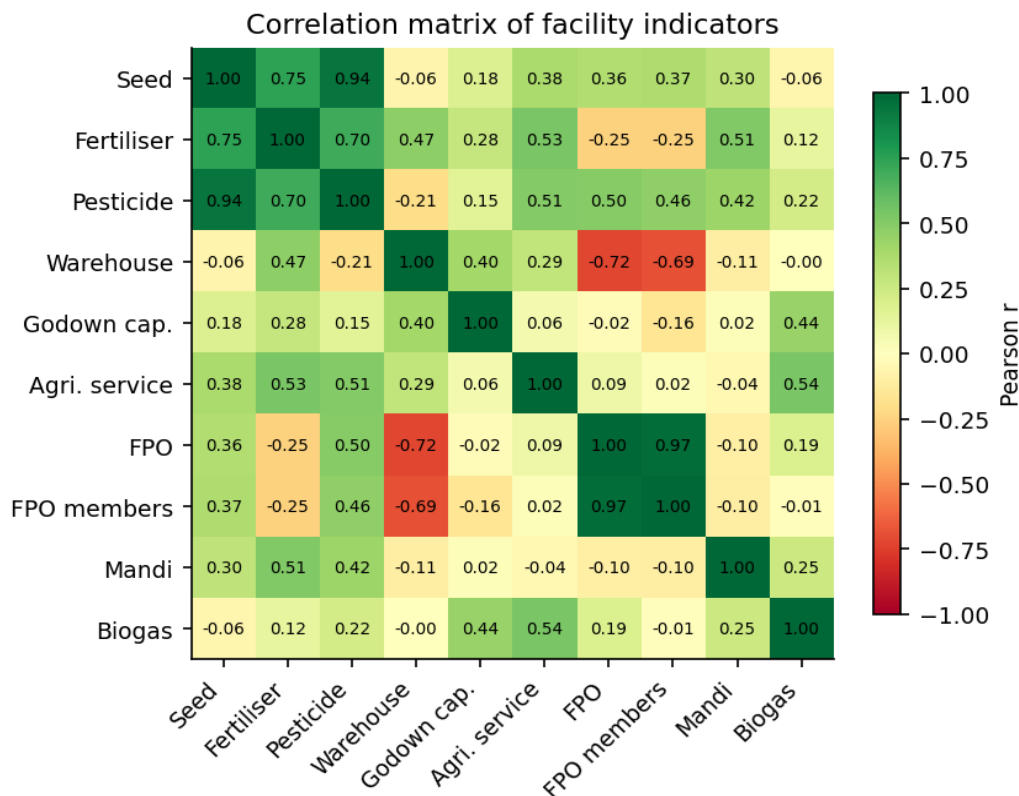


Fig. 6. Pearson correlation matrix of facility indicators across the seven blocks.

4.6 Latent dimensions of provision

Principal component analysis extracts four components with eigenvalues above unity, together explaining 89.11% of total variance (Table 6). The first two are substantively interpretable and account for 63.84%.

PC1 (34.4% of variance) loads heavily and positively on pesticide outlets (1.066), seed outlets (0.958), fertiliser outlets (0.706) and agricultural service centres (0.605), with a weak negative loading on warehouses (-0.223). This is unambiguously a *commercial input-retailing intensity* axis, capturing the market-driven dimension of provision.

PC2 (29.5%) contrasts warehouses (0.941) and fertiliser outlets (0.756) against FPO membership (-0.880) and FPOs (-0.842). This is an *institutional mode* axis, separating blocks served through cooperative storage from those served through collective producer organisation

— the multivariate expression of the negative correlation identified above. PC3 (14.3%) is dominated by biogas plants (0.854) and godown capacity (0.545), representing a residual rural-development-programme dimension.

The crucial result is orthogonality. Because PC1 and PC2 are by construction uncorrelated and of comparable magnitude, commercial and institutional provision in Hamirpur vary independently: knowing that a block is well supplied with dealers tells one nothing about whether it is well supplied with storage or producer organisations. A single-dimensional notion of “agriculturally well-served” is therefore inadequate for this district, and any composite index must be interpreted with that caveat in mind.

Table 6. Eigenvalues and variance explained (components with $\lambda > 1$)

	Eigenvalue	% variance	Cumulative %
PC1	4.01	34.38	34.38
PC2	3.44	29.46	63.84
PC3	1.67	14.33	78.17
PC4	1.28	10.94	89.11

Table 7. Component loadings (component–variable correlations)

	PC1 (34.4%)	PC2 (29.5%)	PC3 (14.3%)
Seed sales centres	0.958	0.102	-0.355
Fertiliser sales centres	0.706	0.756	-0.305
Pesticide sales centres	1.066	0.018	-0.150
Warehouses	-0.223	0.941	0.083
Godown capacity (MT)	0.223	0.458	0.545
Agricultural service centres	0.605	0.390	0.419
FPOs	0.599	-0.842	0.272
FPO membership	0.545	-0.880	0.082
Regulated mandis	0.444	0.279	-0.374
Biogas plants	0.373	0.215	0.854

4.7 Composite index and regionalisation

The CAII and Ward's clustering produce a consistent three-fold regionalisation (Table 8, Fig. 7). The index correlates very strongly with the independent PC1 score (Spearman $\rho = 0.964$, $p = 0.0005$), and the two rankings differ only in the ordering of Kurara and Muskara, which confirms that the equal-weighted index is not an artefact of the weighting choice.

- **High-infrastructure (CAII = 100.0):** Rath alone. It forms a singleton cluster, standing apart on almost every commercial and institutional indicator. Rath is the district's second urban centre and its sub-divisional headquarters, and the concentration of facilities there reflects a classic central-place effect rather than any agronomic superiority of its upland soils.
- **Medium-infrastructure (CAII 30.0–81.7):** Maudaha (81.7), Sumerpur (50.9) and Sarila (30.0). These blocks combine moderate commercial density with adequate cooperative storage; Maudaha is distinguished by the district's largest biogas stock (433) and highest agricultural service centre count (9).
- **Low-infrastructure (CAII 0.0–6.1):** Gohand (0.0), Muskara (4.9) and Kurara (6.1). Cluster means show this group at roughly half the commercial density of the high group across every input category.

The deficit cluster is spatially contiguous, occupying a west-to-north belt through the district's interior, which raises the possibility of a shared causal substrate — poorer accessibility from the Kanpur–Sagar and Jhansi highway corridors, or lower assured irrigation on the upland margin. Crucially, Gohand's position at the bottom of the index coexists with its second-highest FPO count, illustrating precisely the orthogonality identified by the PCA: the block is commercially underserved yet institutionally active. An index-based targeting exercise that ignored this would misdiagnose Gohand's requirement as “more of everything” when the evidence points specifically to a deficit in input retailing and market access, not in collective organisation.

Table 8. Composite Agricultural Infrastructure Index and typology of blocks, 2024–25

	Mean z-score	CAII (0–100)	PC1 score	Cluster	Rank	Level
Rath	0.861	100.000	3.870	3	1	High
Maudaha	0.602	81.669	1.423	1	2	Medium
Sumerpur	0.168	50.935	-0.390	1	3	Medium
Sarila	-0.129	29.959	-0.637	1	4	Medium
Kurara	-0.466	6.104	-1.604	2	5	Low
Muskara	-0.483	4.925	-0.888	2	6	Low
Gohand	-0.553	0.000	-1.774	2	7	Low

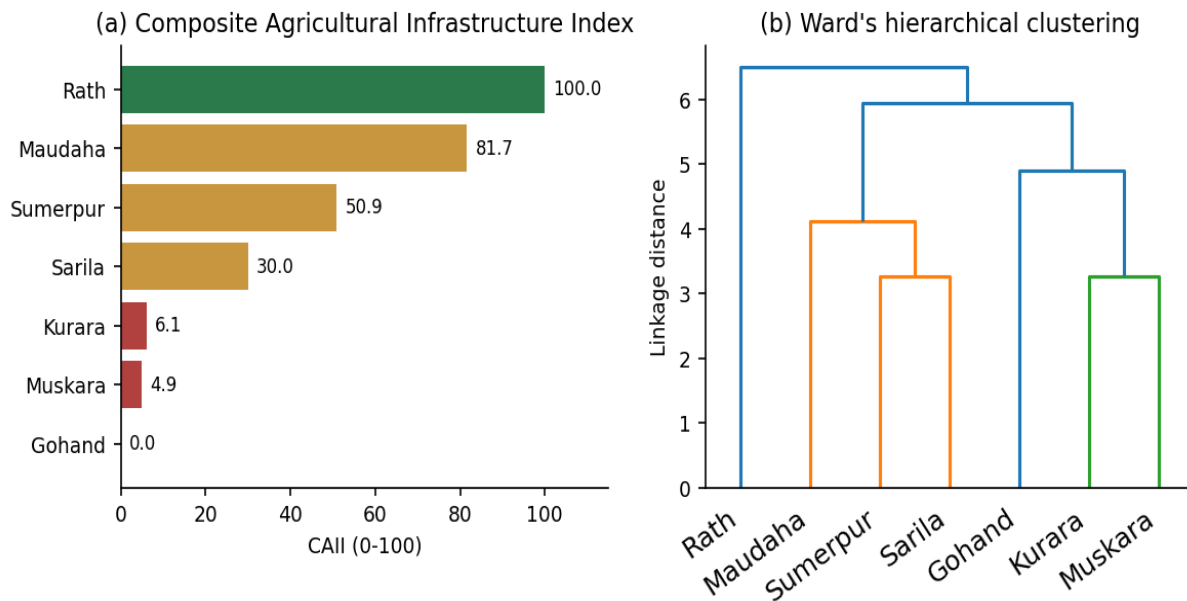


Fig. 7. (a) Composite Agricultural Infrastructure Index by block, coloured by cluster membership; (b) Ward's hierarchical clustering dendrogram of the standardised facility matrix.

4.8 Rural–urban asymmetry

Comparing the rural and urban components of the district total exposes the study's most consequential imbalance (Table 9). Urban areas of Hamirpur hold 34.6% of seed outlets, 38.3% of fertiliser outlets, 39.8% of pesticide outlets, 39.0% of godown capacity and 42.3% of FPO membership while containing, as established in Section 2, just 0.8% of the district's food-grain area. Expressed as a disparity ratio (urban share of facilities divided by urban share of cropped area), the mismatch ranges from about 11 to 53.

Some urban concentration is expected and economically rational: wholesalers, licensed distributors and registered offices cluster in towns, and a dealer located in Hamirpur town or Rath serves a rural hinterland well beyond the municipal boundary. The figures therefore overstate true inaccessibility. But two components cannot be explained away. First, 4,045 MT 39% of the district's godown capacity sits in urban locations, which imposes a transport cost on precisely the post-harvest decision (whether to store or sell immediately) where smallholder bargaining power is weakest. Second, 6,380 FPO members, or 42% of the district total, are registered to urban-based organisations, raising a question about whether the FPO movement in Hamirpur is reaching cultivators in the villages where production actually occurs.

Two facilities are exclusively rural all five regulated mandis and all 2,180 biogas plants and both warehousing measures are strongly rural in count terms (8.9% urban). The overall picture is thus not of a uniformly urban-biased system but of a bifurcated one, in which the *commercial* layer is town-centred while the *public* layer remains village-centred.

Table 9. Rural–urban distribution of agricultural facilities, 2024–25

Indicators	Rural	Urban	District	Urban share (%)	Disparity ratio†
Seed sales centres	157	83	240	34.6	43.2
Fertiliser sales centres	305	189	494	38.3	47.9
Pesticide sales centres	204	135	339	39.8	49.7
Warehouses	41	4	45	8.9	11.1
Godown capacity (MT)	6325	4045	10370	39.0	48.8
Agricultural service centres	37	16	53	30.2	37.8
FPOs	38	22	60	36.7	45.9
FPO membership	8700	6380	15080	42.3	52.9
Regulated mandis	5	0	5	0.0	0.0
Biogas plants	2180	0	2180	0.0	0.0

† Disparity ratio = urban share of facilities ÷ urban share of food-grain area (0.8%). A ratio of 1 denotes proportionality.

5. Discussion

Three themes emerge from the results, each with implications beyond Hamirpur.

Aggregate growth conceals structural stagnation. A district-level reading of these data would record a tripling of input outlets in two years and conclude that agricultural service provision had improved dramatically. The disaggregated reading is less reassuring. The growth is confined to one functional layer privately owned retailing of purchased inputs and is at least partly an artefact of registration rather than new establishment. The layers that buffer risk and secure price, namely storage capacity, regulated marketing and producer organisation, were entirely static: godown capacity unchanged at 10,370 MT, FPO numbers frozen at 60, mandis at five, cold storage at zero for all three years. In a district where 308,082 ha are under food grains, the total rural godown capacity of 6,325 MT amounts to roughly 21 kg per hectare of food-grain area, a figure so small relative to plausible marketable surplus that organised storage cannot be a meaningful option for most cultivators. The complete absence of cold storage forecloses diversification into horticulture, which is otherwise a standard prescription for semi-arid districts seeking to escape the low-value cereal–pulse trap.

The state has withdrawn from supply without being replaced in function. Cooperative seed centres halved and departmental fertiliser retailing ended, while private outlets multiplied. Density improved; functional equivalence did not. A cooperative outlet performs quality assurance, price moderation and, frequently, input credit on deferred terms functions a private dealer performs only incidentally. With the cooperative share of input outlets now in single digits to low teens in every block, no institutional mechanism remains to discipline spurious seed, adulterated agrochemicals or informal credit at interest rates far above institutional norms. The surviving eight departmental outlets, one per block, are too thin to serve this

purpose at scale. The policy implication is not that privatisation should be reversed, but that as the state exits *supply* it must correspondingly strengthen *regulation* dealer licensing, routine sampling of seed and agrochemicals, and mandatory price display which is a different administrative capability from the one being wound down.

Equity of allocation is not equity of access. The chi-square and Gini results show that administratively allocated facilities are distributed almost perfectly evenly: one agricultural defence unit per block, one departmental outlet per block, warehouses with a Gini of just 0.08. This is procedurally fair but substantively blunt, because blocks differ in cropped area, farm-household numbers and crop mix. A uniform allocation rule guarantees that the largest and most agriculturally intensive blocks are relatively underserved, while ensuring that no block is wholly neglected. A norm-based allocation keyed to cropped area or number of operational holdings would preserve the political defensibility of the present rule while improving its efficiency, and the data required to implement it are already collected.

The orthogonality of the commercial and institutional dimensions has a further methodological implication. Composite infrastructure indices are widely used in Indian regional planning and are almost always computed as equal- or PCA-weighted sums of heterogeneous indicators. Where the underlying dimensions are genuinely independent as PC1 and PC2 are here, with 34.4% and 29.5% of variance respectively such a sum averages away the very contrast that should drive intervention design. Reporting the component scores alongside the composite, as done in Table 8, is a minimal safeguard.

6. Conclusions and Policy Implications

Block-level analysis of ten agricultural facility indicators for Hamirpur district establishes that: (i) input retailing expanded by 311–456% between 2022–23 and 2024–25 while storage, marketing and institutional infrastructure remained static or contracted; (ii) this expansion was overwhelmingly private, with private outlets now constituting 88–98% of the retail network and cooperative seed provision halving; (iii) inter-block distribution departs significantly from uniformity for six of eight count indicators, with concentration highest for institutional facilities (Gini 0.26–0.36) and lowest for administratively allocated ones (0.07–0.09); (iv) provision is organised along two independent axes, commercial and institutional; and (v) the composite index identifies Rath as a singular high-provision node and a contiguous Gohand–Muskara–Kurara deficit belt.

Four priorities follow, ordered by the strength of the evidence supporting them.

1. **Expand decentralised storage before expanding anything else.** With rural godown capacity static at 6,325 MT and no cold storage anywhere in the district, storage is the binding constraint on realising better prices. Village- or panchayat-level scientific storage in the three deficit blocks would address the most acute and best-evidenced gap.
2. **Close the mandi gap in Sarila and Gohand.** Two of seven blocks lack any regulated market, and only three of five existing mandis are e-NAM integrated. Establishing sub-market yards in the two unserved blocks and completing e-NAM integration would extend regulated price discovery to the whole district at modest cost.

3. **Replace uniform allocation with norm-based allocation.** Facility norms keyed to cropped area or operational holdings, rather than to the administrative unit, would direct incremental public facilities to where the production base is largest.
4. **Rebuild regulatory capacity as supply capacity is withdrawn.** Systematic dealer inspection, input quality sampling and price transparency requirements are the functional substitute for the cooperative presence that has been lost.

7. Limitations and Directions for Further Research

Four limitations qualify these findings. First, $n = 7$ is a small sample for inferential statistics; correlation coefficients require $|r| > 0.754$ for significance at $\alpha = 0.05$, so several substantively interesting associations (notably warehouse–FPO, $r = -0.717$) remain formally unconfirmed, and the PCA, while descriptively valid, should be read as data reduction rather than as a tested model. Second, the analysis uses absolute facility counts because block-level denominators — cropped area, operational holdings, rural population — were not available in the source; normalised densities (outlets per 1,000 ha, storage capacity per tonne of marketable surplus) would be a more accurate measure of accessibility and could alter the ranking of larger blocks. Third, the abrupt discontinuities between 2022–23 and 2023–24 in several series strongly suggest a change in the reporting or registration basis; the recorded “growth” therefore mixes genuine establishment with improved enumeration, and the three-year series is too short to separate trend from definitional break. Fourth, facility counts measure availability, not utilisation, quality or effective accessibility; two outlets of very different scale count identically, and no road-network or travel-time information is incorporated.

Three extensions would materially strengthen the analysis: computation of area- and population-normalised facility densities once block denominators are obtained; GIS-based accessibility modelling using road networks to convert facility locations into realistic service catchments and travel-time surfaces; and a farm-household survey in the contrasting cases of Rath and Gohand to test whether the infrastructure gradient documented here translates into measurable differences in input use, storage behaviour, price realisation and net farm income.

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