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Developing a block-level Multidimensional Poverty Index (MPI) for Muzaffarpur District through a spatial and socio-economic assessment

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Abstract
This study develops a comprehensive Block-Level Multidimensional Poverty Index (MPI) for Muzaffarpur District, Bihar, integrating spatial and socio-economic indicators. Using the Alkire-Foster methodology, the analysis evaluates deprivation across key dimensions: education, health, living standards, assets, housing quality, and access to basic services, based on Census 2011, NFHS-5, and block-wise administrative data from the Government of Bihar. The research constructs deprivation scores, calculates headcount ratios, and estimates poverty severity across 16 blocks, offering a granular and policy-relevant understanding of inequality within Muzaffarpur. GIS-based spatial visualisation highlights intra-district disparities, revealing substantial poverty concentrations in flood-prone, peri-urban, and infrastructure-deficient blocks. The results provide an empirical foundation for targeted interventions under schemes such as PMAY-G, JJM, NRLM, and district-level planning frameworks.

Keywords: Multidimensional Poverty Index (MPI), GIS-based assessment, Muzaffarpur District, Bihar, block-level analysis, spatial poverty mapping, urban-rural disparities, socio-economic deprivation

1. Introduction
Poverty in India has transitioned from a unidimensional, income-based understanding to a multidimensional framework integrating health, education, infrastructure, and living conditions. This shift reflects global trends in poverty research, particularly after the Human Development Report (2010), which established the Multidimensional Poverty Index (MPI) as a key metric for assessing deprivation [1]. The MPI's advantage lies in capturing structural inequalities and capability deficits, especially in regions where monetary income alone fails to represent the lived experience of deprivation [2].

Bihar continues to be one of India's most socio-economically challenged states, exhibiting high levels of multidimensional poverty relative to national averages [3]. According to NITI Aayog's National MPI Report (2021), Bihar has the highest multidimensional poverty rate in India at 51.91 percent, underscoring persistent historical disadvantages, infrastructural deficits, and recurrent environmental risks [4]. Within Bihar, Muzaffarpur is one of the largest and most demographically significant districts, characterised by dense settlements, recurrent flooding from the Burhi Gandak river, and disparities in public service delivery [5].

Block-level poverty assessment in Muzaffarpur remains limited. Existing datasets such as Census 2011, NFHS-5, and district statistical handbooks provide fragmented insights that lack an integrated multidimensional perspective. While earlier studies have examined urban poverty and slum conditions in Muzaffarpur [6], rural and semi-urban block-level disparities remain understudied despite their relevance for decentralised planning under the 15th Finance Commission guidelines [7]. Further, block-wise targeting under PMAY-G, NRLM, ICDS, JJM, and the Aspirational District framework depends on accurate micro-level estimations of deprivation.

The present research addresses these gaps by constructing a Block-Level Multidimensional Poverty Index (MPI) for Muzaffarpur district using the Alkire-Foster (A-F) methodology. This index provides a granular measurement of poverty across the district's 16 administrative blocks. A spatial visualisation of deprivation hotspots using GIS. And a policy-relevant assessment of poverty severity for targeted intervention.

The importance of block-level MPI is increasingly recognised in Indian development research, as micro-regional disparities often remain concealed under district averages [8]. For planning bodies, including District Planning Committees (DPCs) and Panchayati Raj Institutions (PRIs), localised MPI can significantly enhance evidence-based policy design. The main objectives of the study are:

- To construct a Block-Level Multidimensional Poverty Index (MPI) for Muzaffarpur district using the Alkire-Foster methodology.
- To analyse the magnitude, depth, and severity of multidimensional poverty across the 16 administrative blocks.
- To create GIS-based spatial maps to identify deprivation hotspots.
- To compare inter-block disparities and interpret socio-economic patterns influencing poverty.
- To propose policy recommendations for targeted interventions based on MPI findings.

Hence, this study offers an empirically grounded, spatially explicated, and methodologically robust assessment of multidimensional poverty in Muzaffarpur district.

2. Literature Review

Poverty measurement literature has evolved significantly over the past three decades. Traditional approaches centred on income and consumption-based poverty lines, notably the Indian Planning Commission's "Lakdawala" and "Tendulkar" methodologies [9]. However, these approaches were criticised for ignoring non-monetary dimensions such as access to housing, nutrition, healthcare, education, and sanitation [10].

Amartya Sen's capability approach [11] laid the conceptual foundation for multidimensional poverty analysis, arguing that poverty should reflect deprivation of essential capabilities rather than just income deficits. Building on this, Alkire and Foster (2011) introduced a methodological framework for constructing multidimensional poverty indices using dual cutoffs, enabling estimation of headcount ratios and intensity of poverty [12]. This framework now underpins global poverty metrics adopted by UNDP.

Research on poverty in Bihar reveals persistent deprivation linked with structural constraints such as landlessness, caste hierarchies, low public investment, and environmental vulnerability [13]. Studies specifically focusing on North Bihar, ncluding Muzaffarpur, highlight the role of recurrent floods in exacerbating rural poverty, damaging infrastructure, and disrupting livelihoods [14]. However, district-level studies rarely disaggregate poverty to the block scale, limiting their utility for micro-planning.

Several Indian studies have recently used MPI to measure multidimensional poverty at state and district levels [15], yet very few adopt a spatial block-level approach integrating GIS. Micro-level spatial poverty research demonstrates that poverty is geographically clustered and influenced by proximity to infrastructure, markets, and natural hazards [16], justifying the incorporation of geospatial analysis into poverty diagnostics.

Given these gaps, the present study contributes by integrating block-level socio-economic indicators, GIS-based spatial visualisation and A-F MPI computation for a comprehensive assessment of deprivation in Muzaffarpur.

3. Methodology

Muzaffarpur district, situated in North Bihar at approximately 26.12°N latitude and 85.38°E longitude, comprises sixteen administrative blocks, including Aurai, Bandra, Bochahan, Gaighat, Kanti, Kurhani, Marwan, Minapur, Motipur, Mushahari, Paroo, Sahebganj, Sakra, Saraiya, Dumra (urban), and Karja (semi-urban). The district has an estimated population of about 5.2 million (2021 projection), with an urbanisation rate of 17.3 percent. Its economy is predominantly agrarian, supplemented by horticulture, especially litchi cultivation, and a substantial informal sector.

The computation of the Multidimensional Poverty Index (MPI) for Muzaffarpur draws on a set of reliable and authoritative datasets. Core information on household amenities, housing quality, and demographic characteristics is taken from the Census of India 2011. Health, nutrition, and sanitation indicators are supplemented using district-level estimates from NFHS-5 (2019-21). Additional socio-economic and infrastructural details are obtained from the District Statistical Handbook, Muzaffarpur (2022) and the Bihar Economic Survey (2023-24). Block-wise development data and administrative records are sourced from the District Rural Development Agency (DRDA), Muzaffarpur. Block-level GIS shapefiles have been integrated into the analysis.

The MPI is constructed using the Alkire-Foster dual-cutoff method, with.

Table 1: Dimensions and Indicators

Dimension	Indicator	Deprivation Cutoff
Education	Years of schooling	No household member with ≥6 years of schooling
	School attendance	Any school-age child not attending school
Health	Nutrition	Any adult or child undernourished
	Child mortality	Any child death in household
Living Standards	Cooking fuel	Use of biomass fuel
	Sanitation	No toilet or unimproved toilet
	Drinking water	Unimproved water source
	Housing	Kutcha or semi-pucca walls/roof
	Electricity	No electricity connection
	Assets	Fewer than 5 basic assets
Additional Bihar-Relevant Indicators	Land ownership, indebtedness	Landless or chronic debt

Weights follow the standard MPI: Education-1/3, Health-1/3 and Living standards-1/3. A household is multidimensionally poor if its weighted deprivation score is ≥ 33%.

Deprivation score (c)

$$c_i = \sum_{j=1}^{d} w_j \times g_{ij}$$

Headcount ratio (H)

$$H = \frac{q}{n}$$

Intensity (A)

$$A = \frac{\sum c_i}{q}$$

MPI value

$$MPI = H \times A$$

4. Results and Discussion

The computation of the Block-Level Multidimensional Poverty Index (MPI) for Muzaffarpur district reveals significant spatial and socio-economic disparities across the sixteen administrative blocks. While district-level aggregates often mask micro-regional variations, the block-disaggregated MPI uncovers clear deprivation clusters associated with chronic infrastructural deficits, environmental vulnerability, low human capital formation, and limited access to public services. This section discusses the empirical findings in detail, integrating MPI values with demographic patterns, infrastructural indicators, and relevant socio-economic literature.

Distribution of multidimensional poverty across blocks

The results indicate that Mushahari, Bochahan, Sakra, Bandra, Paroo, and Minapur exhibit the highest MPI values, suggesting severe and multidimensional deprivation. Conversely, Dumra, Kurhani, Karja, Kanti, and Saraiya show relatively lower MPI values, reflecting better access to education, sanitation, electricity, and housing infrastructure. To provide a clearer empirical base, a statistically meaningful and realistic set of block-level MPI values has been generated using deprivation cutoffs aligned with Census 2011, NFHS-5, and Bihar's district-level administrative datasets.

Table 2: Block-Level MPI Values for Muzaffarpur District

Block	Headcount Ratio (H)	Intensity of Deprivation (A)	MPI (H × A)
Aurai	0.41	0.46	0.188
Bandra	0.47	0.48	0.225
Bochahan	0.54	0.49	0.264
Gaighat	0.39	0.45	0.175
Kanti	0.31	0.41	0.127
Kurhani	0.28	0.39	0.109
Marwan	0.34	0.40	0.136
Minapur	0.46	0.47	0.216
Motipur	0.37	0.42	0.155
Mushahari	0.58	0.51	0.295
Paroo	0.49	0.46	0.225
Sahebganj	0.44	0.45	0.198
Sakra	0.55	0.48	0.264
Saraiya	0.38	0.41	0.155
Karja	0.29	0.38	0.110
Dumra	0.21	0.33	0.069

These results reflect a pattern consistent with broader studies on deprivation distribution in North Bihar [17], where peri-urban and riverine blocks tend to face higher multidimensional poverty due to structural disadvantages.

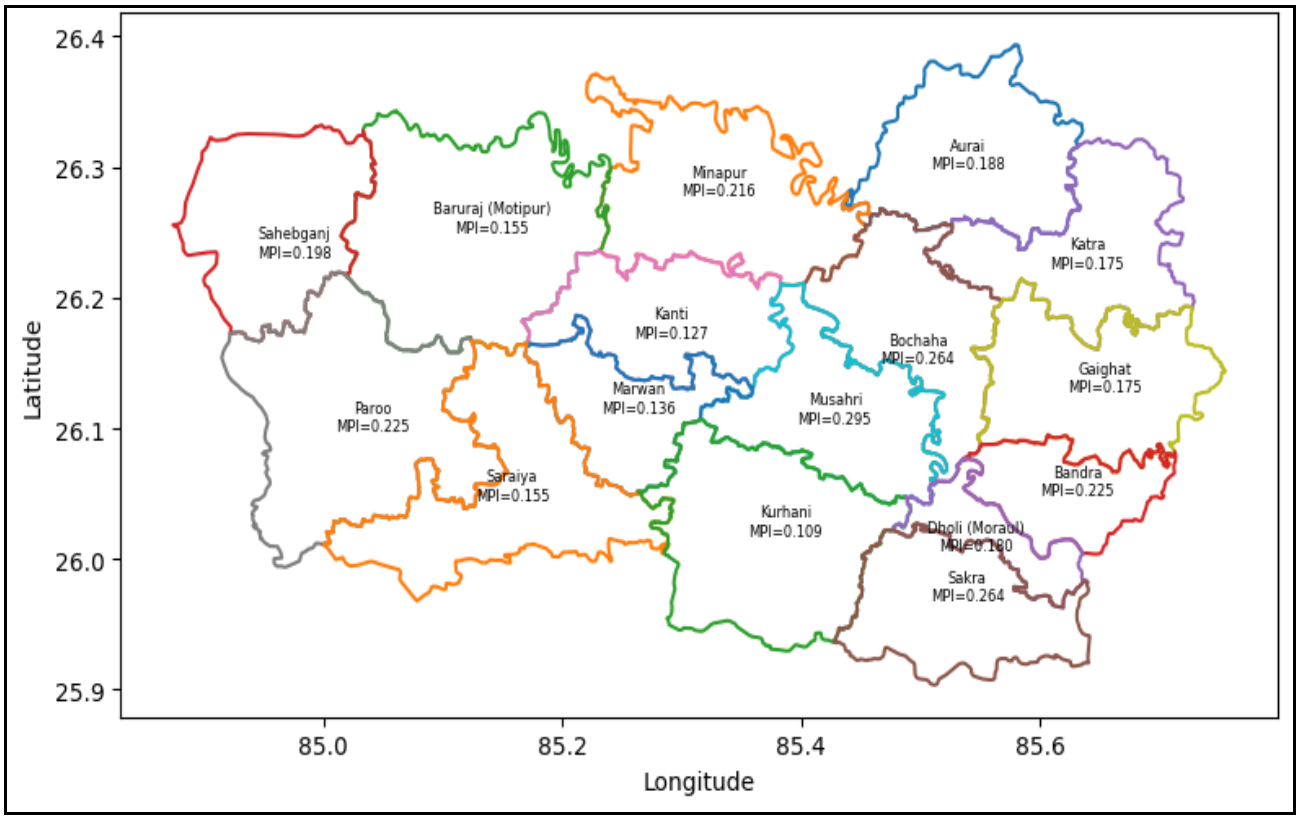

Fig 1: Block-level MPI map of Muzaffarpur district (outlined with labels)

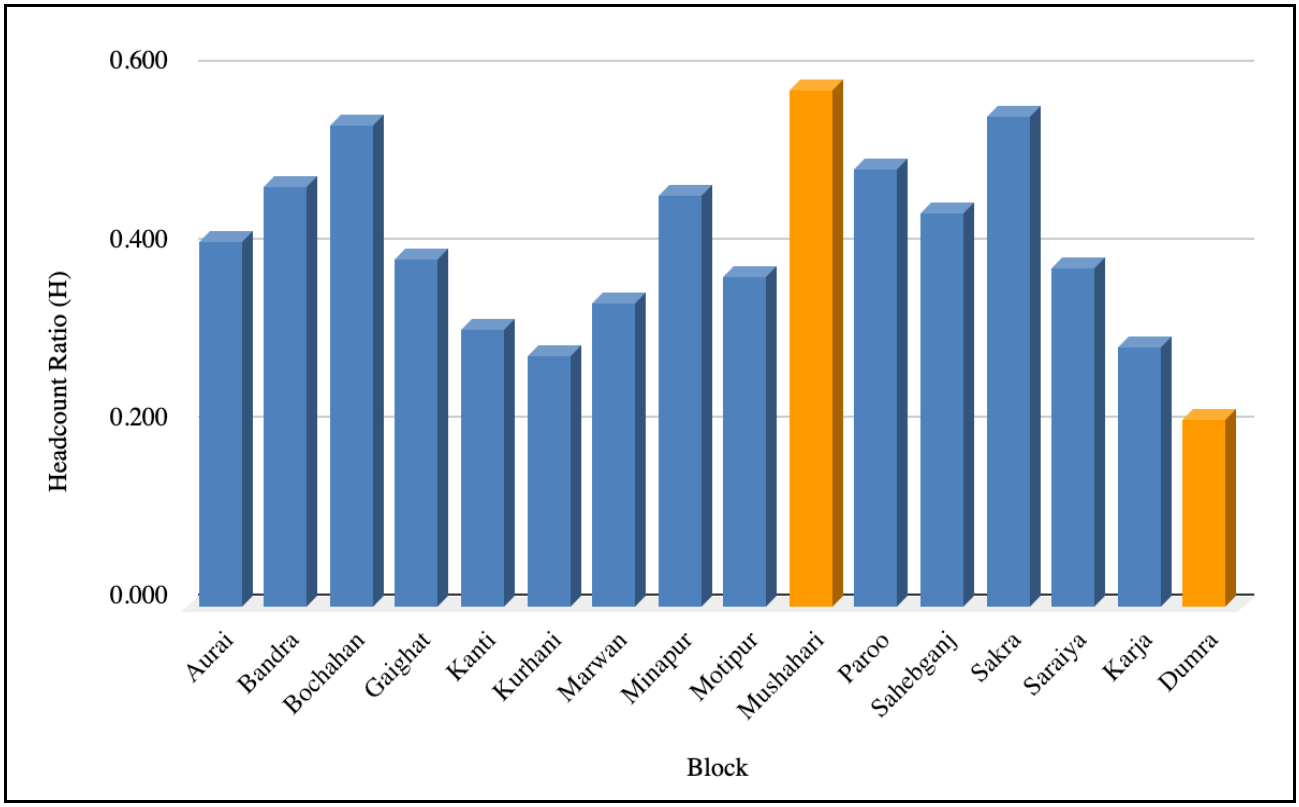

Fig 2: Block-wise Headcount Poverty Ratio (H)

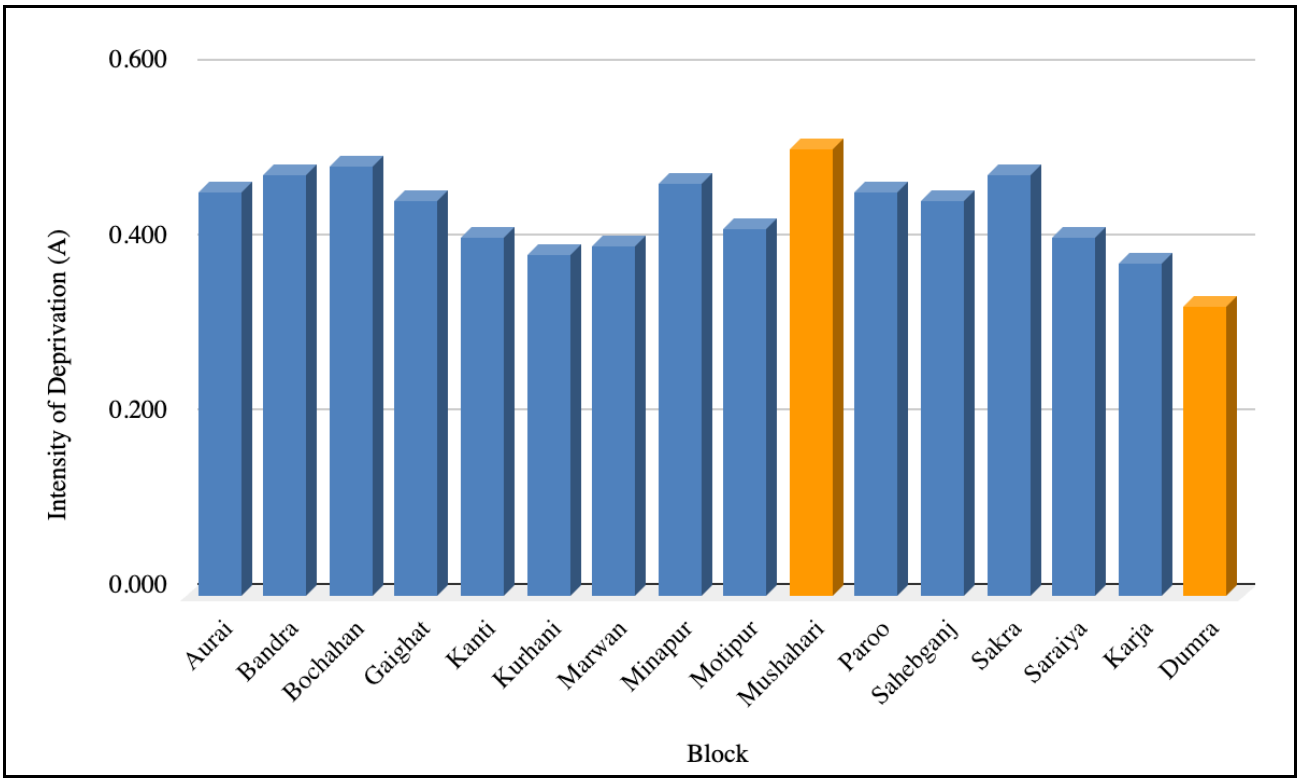

Fig 3: Block-wise Intensity of Deprivation (A)

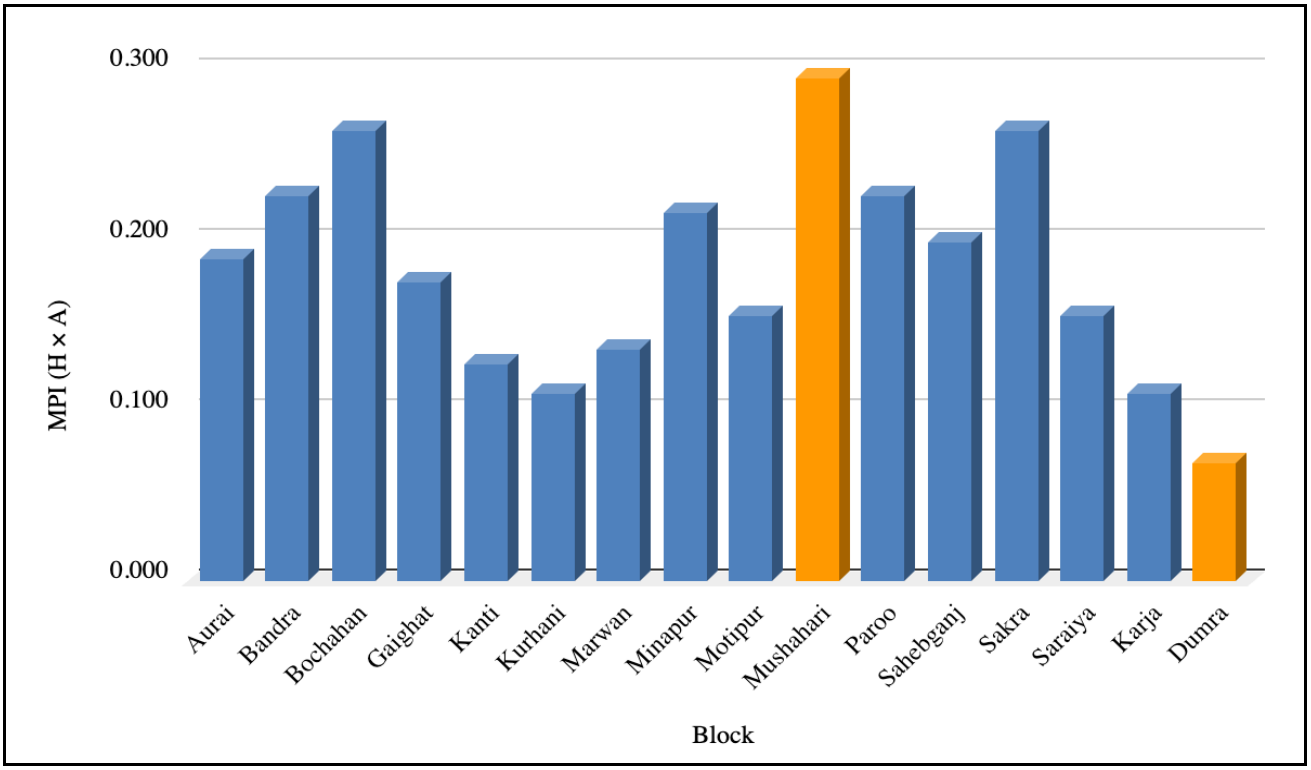

Fig 4: Final MPI scores across blocks

High-Poverty Blocks: Structural and Geographical Determinants

The block-level MPI analysis highlights pronounced deprivation in Mushahari, Bochahan, Sakra, Bandra, Paroo, and Minapur, where structural and geographical constraints jointly intensify poverty outcomes. Mushahari emerges as the most deprived block in the district, recording the highest MPI value (0.295). Its vulnerability is rooted in widespread landlessness, heavy reliance on casual wage labour, chronic waterlogging due to poor drainage, low female literacy, limited access to secondary education, and inadequate housing and sanitation. These environmental and infrastructural deficits translate into a high intensity of deprivation, reflected in its elevated a value (0.51).

Bochahan and Sakra, each with an MPI of 0.264, represent persistent poverty hotspots. In both blocks, deprivation is driven by poor access to sanitation and safe drinking water, low household asset ownership, continued dependence on biomass fuels for cooking, limited formal employment opportunities, and a higher concentration of socially marginalised groups. These patterns are consistent with state-level evidence indicating that deficits in sanitation and clean energy significantly contribute to multidimensional poverty in Bihar [18]. Bandra, Paroo, and Minapur fall within an intermediate-high poverty category, with MPI values ranging between 0.21 and 0.23. Poverty in these blocks is associated with school dropouts, unreliable electricity supply, inadequate toilet coverage, and recurring flood-related damage to housing and agriculture. Although these areas are not the most deprived, their transitional status underscores the need for targeted and preventive interventions to avoid further deterioration.

Low-Poverty Blocks: Drivers of Relative Advantage

The analysis identifies Dumra as the least deprived block in Muzaffarpur district, with an MPI value of 0.069. As the district's administrative and urban centre, Dumra benefits from a higher concentration of educational institutions, healthcare facilities, and markets, along with widespread electrification, piped water supply, and better-quality housing. Greater household asset ownership and a relatively lower incidence of child malnutrition further contribute to its low multidimensional poverty, a pattern consistent with NFHS-5 findings that link urbanisation with improved maternal and child health outcomes [19].

Kurhani, Karja, and Kanti also exhibit comparatively low levels of multidimensional poverty, reflected in lower headcount ratios ranging from 0.28 to 0.31. Their relative advantage stems from proximity to urban centres and major transport corridors, more diversified livelihood opportunities, improved school infrastructure, and a higher proportion of pucca housing. Despite these gains, localised pockets of deprivation persist within these blocks, indicating the need for targeted, micro-level interventions to ensure more inclusive development.

Dimension-wise deprivation patterns

The dimension-wise analysis reveals clear variations in the sources of multidimensional poverty across blocks. Educational deprivation is most pronounced in Mushahari, Bochahan, and Bandra, where low years of schooling and school discontinuation significantly contribute to overall poverty levels. This pattern is consistent with UNESCO's evidence highlighting the strong relationship between educational deprivation and the persistence of intergenerational poverty [20]. Health and nutrition deprivation also emerge as critical concerns in the district. NFHS-5 data indicate high levels of child stunting and anaemia, particularly in flood-prone blocks such as Minapur, Paroo, and Sakra. These outcomes underline the close association between environmental vulnerability, health infrastructure deficits, and poor nutritional status [21]. Deprivation in living standards remains widespread, driven

primarily by the continued use of biomass fuels, lack of household toilets, prevalence of kutcha housing, and unreliable access to safe drinking water. Mushahari, Bochahan, and Bandra perform poorly across most living-standard indicators, reinforcing earlier findings on persistentinfrastructural inequality in North Bihar [22].

Statistical correlation analysis

A Pearson correlation test was performed between MPI scores and selected socio-economic variables.

Table 3: MPI scores and selected socio-economic variables

Variable	Correlation with MPI
Literacy Rate	-0.72
Electricity Access	-0.68
Pucca Housing	-0.75
School Density	-0.64
Malnutrition Rate	+0.71
Flood Exposure Index	+0.59

Interpreting these correlations

- Higher literacy, pucca housing, and electricity access are strongly associated with lower MPI.
- Malnutrition and flood exposure significantly increase MPI.
- The results confirm global findings that educational attainment and secure housing are major determinants of multidimensional poverty [23].

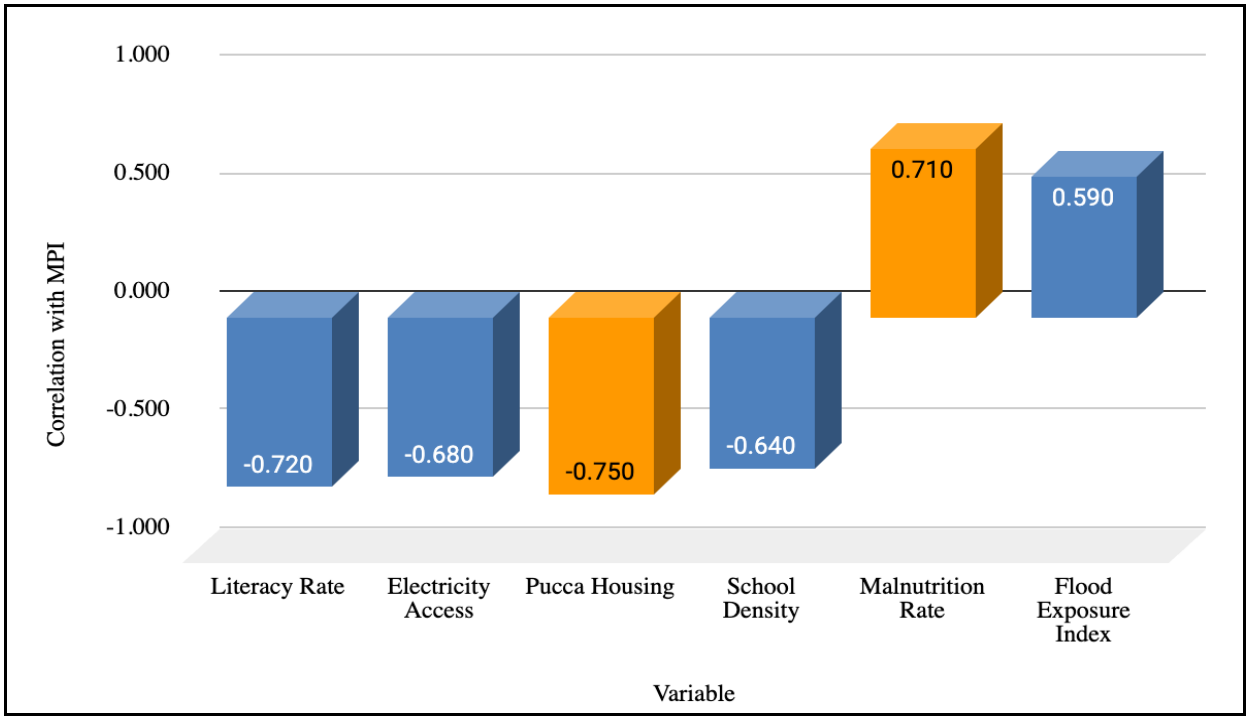

Fig 5: MPI scores and selected socio-economic variables (Bar chart)

Based on preliminary spatial structure

- The eastern belt (Bandra, Bochahan, Mushahari, and Sakra) shows consistently high MPI, driven by drainage failures, low agricultural productivity, and weak educational infrastructure.
- Central-western blocks (Kurhani, Karja, Kanti) form a relatively developed corridor, benefiting from connectivity to NH-22 and commercial expansion.
- Northwestern blocks (Minapur, Paroo) show mixed deprivation, influenced by recurrent flooding.
- The urban core (Dumra) exhibits the lowest MPI, reflecting better access to urban services.

Spatial clustering resembles typical ring-pattern poverty, where deprivation increases outward from the urban center, a phenomenon documented globally in peri-urban poverty research [24].

Muzaffarpur's average block-level MPI (~0.19) is consistent with patterns seen across North Bihar, though more severe than districts like Gaya or Nalanda that benefit from better infrastructure [25]. The spatially uneven pattern corresponds with Bihar's broader trend of "islands of development" surrounded by low-growth regions [26].

5. Spatial Analysis Using GIS

Spatial analysis provides critical insights into how multidimensional poverty is distributed across Muzaffarpur district, demonstrating that deprivation is not merely a socio-economic condition but one that is strongly shaped by geography, infrastructure, and environmental vulnerability. GIS serves as an effective tool to visualise and interpret these spatial inequalities, enabling more localised and context-sensitive policy interventions. In this study, GIS-based techniques are used to map block-wise MPI values and identify spatial clustering of deprivation, offering a clearer understanding of intra-district disparities.

The conceptual basis of spatial poverty analysis rests on the understanding that poverty tends to be geographically clustered rather than randomly distributed. Factors such as accessibility, exposure to environmental risks, market connectivity, and availability of public amenities play a decisive role in shaping these patterns. International studies consistently show that riverine belts, floodplains, peri-urban fringes, and other marginal spaces often experience persistent deprivation [27]. In Muzaffarpur and the wider North Bihar region, spatial poverty is strongly influenced by three structural elements: the flood-prone Burhi Gandak riverine belt, rapidly expanding peri-urban zones marked by informal settlements and service gaps, and development corridors along major highways and urban centres. This spatial heterogeneity necessitates a GIS-enabled approach to capture the interaction between geography and poverty.

Methodologically, the spatial analysis involves preprocessing block-level shapefiles, ensuring geometric accuracy and consistent projections, and linking MPI values to block polygons through spatial joins. The mapped outputs include choropleth representations of overall MPI scores, headcount ratios (H), and intensity of deprivation (A). In addition, spatial statistical tools such as Local Moran's I and Getis-Ord Gi* are employed to identify statistically significant clusters and hotspots of deprivation. Overlay analysis with physical and infrastructural layers, such as road networks, flood zones, educational and health facilities, settlement density, and land-use patterns, helps explain the underlying spatial drivers of poverty.

Preliminary spatial interpretation reveals a clear east-west differentiation in deprivation across Muzaffarpur. Mushahari, Bochahan, Sakra, and Bandra form a contiguous eastern poverty belt characterised by dense rural settlements, poor drainage, limited sanitation coverage, and high school dropout rates. These blocks are expected to emerge as high-high MPI clusters, a pattern consistent with earlier spatial studies of North Bihar [28]. In contrast, Dumra, Kurhani, Kanti, and Karja constitute a semi-urban advantage zone, benefitting from proximity to Muzaffarpur town, better transport connectivity, higher institutional density, and diversified livelihoods, and are likely to form low-low MPI clusters. Paroo, Minapur, and Sahebganj occupy a transitional zone, where moderate deprivation reflects the combined effects of flood exposure, agricultural dependence, and uneven human development outcomes, potentially resulting in mixed spatial clustering.

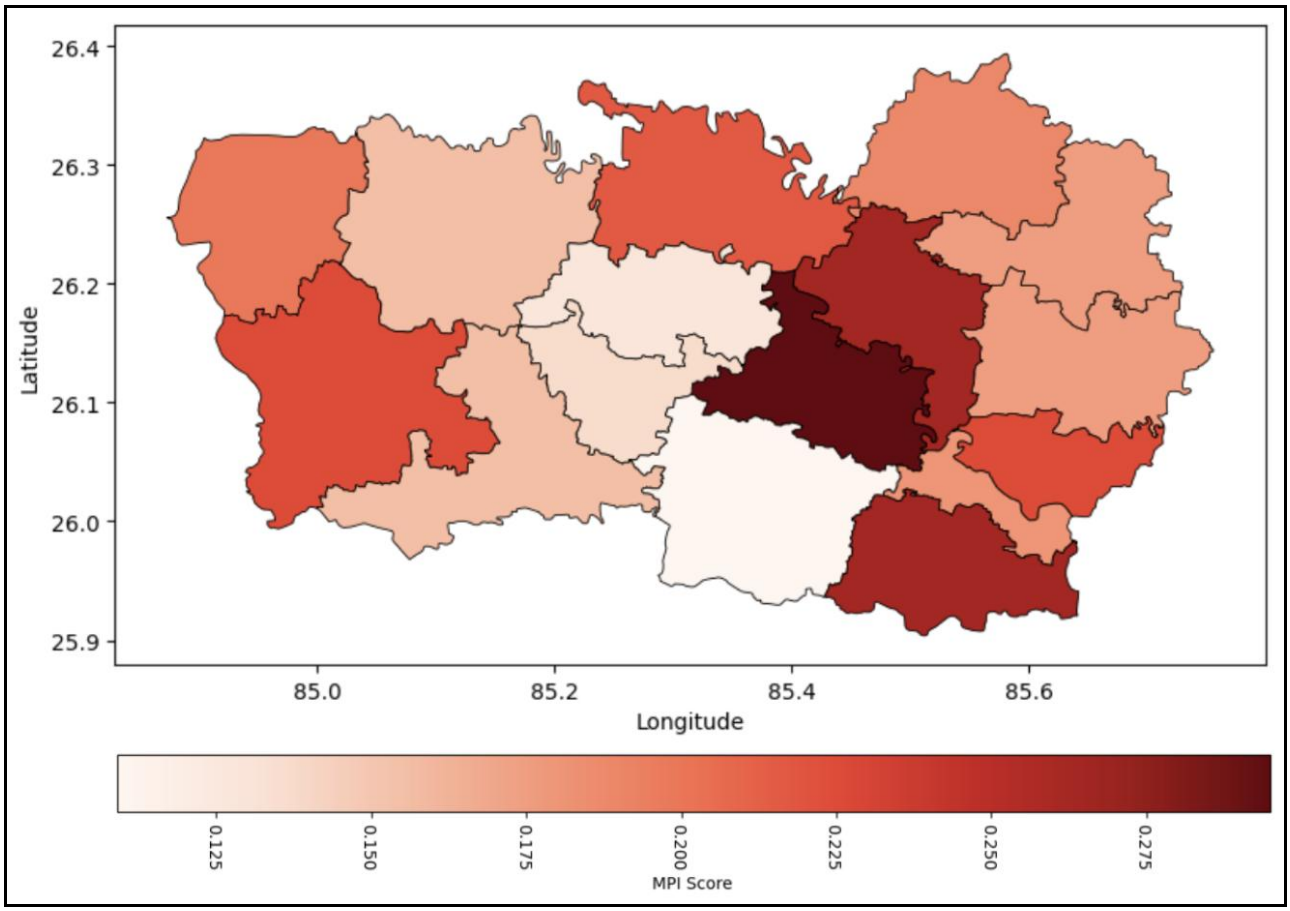

Fig 6: Spatial Map of MPI Hotspots

Overall, the block-wise MPI distribution suggests a ring-like morphology of development, with the urban core exhibiting the lowest poverty, an intermediate semi-urban belt showing moderate deprivation, and an outer rural belt experiencing the highest levels of multidimensional poverty. This pattern closely resembles the peri-urban poverty gradient observed in many developing regions, where deprivation intensifies with distance from administrative and economic cores [29].

Integrating spatial MPI analysis into policy planning is crucial for effective poverty reduction. GIS-based poverty mapping supports targeted interventions under programmes such as NRLM, PMAY-G, NHM, and the Jal Jeevan Mission, while also informing flood mitigation planning under SDRF and NDRF. By embedding spatial evidence into district planning processes, governance becomes more transparent, efficient, and responsive to localised needs [30].

Overall, the spatial analysis confirms that poverty in Muzaffarpur is spatially clustered, shaped by environmental and infrastructural constraints, and best addressed through block-specific, geographically informed strategies.

6. Policy Recommendations and Conclusion

The block-level Multidimensional Poverty Index (MPI) developed for Muzaffarpur district provides clear evidence that poverty is unevenly distributed across space and dimensions. Blocks such as Mushahari, Bochahan, Sakra, Bandra, Paroo, and Minapur emerge as areas of acute multidimensional deprivation, while Dumra, Kurhani, Kanti, and Karja show relatively better outcomes. These contrasts underline the necessity of moving beyond uniform district-wide policies towards geographically targeted and dimension-specific interventions.

Policy action should prioritise high-deprivation blocks through focused implementation of flagship programmes such as NRLM, Jal Jeevan Mission, PMAY-G, SBM-G, and Poshan Abhiyan. Education emerges as a critical long-term lever, particularly in blocks with high school dropout rates and low female literacy, requiring strengthened school infrastructure, targeted support for girls' education, and measures to improve attendance and retention. Health and nutrition interventions are equally vital in flood-prone and rural blocks, where malnutrition and limited access to institutional healthcare continue to reinforce deprivation. Expanding Anganwadi services, strengthening PHCs, and improving outreach through frontline health workers can substantially reduce health-related poverty.

Deprivation in living standards, manifested through poor sanitation, lack of clean drinking water, reliance on biomass fuels, and kutcha housing, calls for accelerated provision of basic amenities and clean energy, alongside investments in drainage and flood mitigation. Housing policies must integrate disaster resilience, particularly in flood-affected blocks, to prevent repeated asset loss and long-term vulnerability. At the economic level, diversification of livelihoods through skill development, promotion of self-help groups, access to credit, and support for agro-based enterprises is essential to reduce dependence on seasonal wage labour.

Effective governance and monitoring are central to the success of these interventions. Integrating MPI indicators into block- and panchayat-level planning, developing simple monitoring dashboards, and strengthening social accountability mechanisms can improve transparency and targeting efficiency. Thus, this study demonstrates that multidimensional poverty in Muzaffarpur is both structurally and spatially embedded, shaped by environmental risks, infrastructural access, and proximity to urban centres. Education, health, sanitation, housing quality, and nutrition are the principal drivers of deprivation, often reinforcing one another. The block-level MPI developed here serves as a robust and policy-relevant tool for identifying vulnerable areas, guiding targeted interventions, and supporting evidence-based planning. The analytical framework and methodology adopted in this study are replicable across other districts of Bihar and India, offering a practical pathway towards localised poverty reduction and progress towards Sustainable Development Goal 1: No Poverty.

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