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The Association of Geographers, Bihar and Jharkhand was first established as The Bihar Association of Geographers (BAG) in 1999. After the partition of the state into Bihar and Jharkhand, the association was renamed as The Association of Geographers, Bihar and Jharkhand (AGBJ) in 2001. The association performs various activities to promote geography as an inter-disciplinary subject of pragmatic relevance in order to strengthen the importance of the study of space for the betterment of society and to bring sustainable development as an integral part of earth system. The 'Geographical Perspective' is an annual peer reviewed journal, published since 2000 AD, and the basic objective of its publication is to promote the above mentioned objectives. The membership of the association is open to any person who keeps interest in geography and the allied subjects. Its headquarters is situated in the Department of Geography, Patna University, Patna, Bihar (India)

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Editorial Column

Dear Fellow Readers,

It gives me immense pleasure in presenting the 27th Volume of "Geographical Perspective" before you at the time of the 27th annual conference of the Association of Geographers, Bihar and Jharkhand. This annual peer reviewed journal has established its credibility across the world. Its publication has also been regular since 2000 without any break. The journal is further acknowledged by American J. Gate.

We give preference to such research papers which are innovative, based on microlevel analysis, giving importance to untouched geographical fields, new methodology and approaches. All decisions related to the quality of journal are taken collectively by editorial board members. There has also been an Advisory Committee of prominent geographers whose valuable advises are accommodated wherever needed, to upgrade the quality of the Journal.

The present volume comprises of 12 research papers and one book review. Besides them, there are general secretary report, departmental news on academic activities performed in different departments of geography in Bihar and Jharkhand, Rememberance of two eminent geographers and journey of the association. The research papers belong to urban, social, agricultural, women's status and geomorphic landforms. All research papers are of applied and innovative nature. They are also for micro/small area synthesisation indicating that the post-modern geography is pragmatic where problem is in the centre of the critical analysis of the very do conclude with seizing the opportunity to express my sincere thanks to all members of advisory committee, editorial board, external reviewers and office bearers of AGBJ who extended all kinds of support to make that the Journal is published in time with maintaining its established credibility.

Rash Bihari Pd. Singh.

(Rash Bihari Pd. Singh)
Editor-in-Chief

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STRENGTHENING INDIA'S AGRIFOOD SYSTEMS AND REJUVENATING AGRICULTURE THROUGH CLIMATE-SMART PRACTICES: SPECIAL CONTEXT OF BIHAR

Ratnesh Kumar Jha*, Sudhanand Prasad Lal, Abdus Sattar*** & Simran******

ABSTRACT

Climate change has emerged as a major challenge to global food and nutritional security, with particularly serious implications for climate-sensitive agricultural regions. The global population has reached 8.22 billion, while 2.3 billion people were food insecure in 2021 and 3.1 billion could not afford a healthy diet in 2020; India also faces food and nutritional security challenges. Bihar is a particularly vulnerable agricultural ecosystem because of its dependence on agriculture, high proportion of rainfed cultivated area, recurrent floods and droughts, erratic monsoon behaviour and increasing climatic variability. These changes have direct implications for crop productivity, water availability, soil health, production costs and farm income: Bihar has experienced declining rainfall trends in several regions, increasing dry spells and recurring episodes of both drought and excessive rainfall, which have affected rice, wheat and other major crops at different stages of production. Climate-Smart Agriculture (CSA) provides an integrated approach to these challenges through water-smart, nutrient-smart, carbon-smart, energy-smart, weather-smart and knowledge-smart interventions. This work documents climate-resilient interventions and their outcomes, including direct-seeded rice, zero tillage, raised-bed planting, alternate wetting and drying, community irrigation, water harvesting, groundwater recharge, crop diversification, pulse integration, millet promotion, weather-based advisories, custom hiring centres, crop-residue management and women-centred interventions such as the Sukhet Model. The documented outcomes include improvements in crop productivity, resource-use efficiency, cropping intensity, groundwater availability and economic returns, demonstrating the potential of climate-smart practices for strengthening agricultural resilience and contributing towards sustainable and nutrition-sensitive agrifood systems in Bihar.

Keywords: *Agrifood systems, Bihar, Climate-Smart Agriculture, Climate resilience, Crop diversification, Food security, Resource conservation, Sustainable agriculture, Water management.*

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Introduction

Food and nutritional security are among the major challenges facing the world. The global population has reached 8.22 billion, while approximately 2.3 billion people were food insecure in 2021, equivalent to 29.3% of the world's population and an increase of 350 million compared with 2019. In addition, 3.1 billion people could not afford a healthy diet in 2020, which was 112 million higher than in 2019. These challenges are occurring simultaneously with rapid climatic change: global warming is expected to breach the 1.5°C threshold in the next 20 years, and continued greenhouse-gas emissions could result in a temperature increase of approximately 2°C by the middle of the 2100s. A 1°C rise in temperature is associated with a 7% increase in rainfall extremities. Other major climate-related changes include increasing carbon dioxide concentration, sea-level rise, declining Arctic sea ice and continuing ice melting. These developments have direct implications for agriculture, which must simultaneously produce sufficient food, conserve natural resources, maintain farmer livelihoods and adapt to increasing climatic uncertainty. India's food production system therefore faces the dual challenge of increasing agricultural productivity while responding to climatic stresses. Productivity of major crops differs among global, Indian and Bihar levels: rice productivity is reported as 4.42 t/ha globally, 2.39 t/ha in India and 2.447 t/ha in Bihar, and wheat productivity as 3.47 t/ha globally, 3.37 t/ha in India and 2.985 t/ha in Bihar. These differences underline the importance of improving resource-use efficiency and agricultural resilience.

2.3 billion people food insecure worldwide (2021)	**111 / 125** India's rank on the Global Hunger Index	**1,146→848** mm: fall in Bihar's average rainfall in 25 years	**33 of 38** Bihar districts under drought - hit conditions

In 2021, long dry spells in September and early October left the Bihar rice crop waiting for rain that did not come; then, on 2 October, 118 mm fell in a single day, and mature rice standing in the field, ready for harvest, went under water. Across 13 districts of North Bihar, floods flattened the crop and cut rice productivity by 30 to 35 per cent, so the same fields suffered drought and flood within weeks of each other. This is not a freak story but the new normal of agriculture in Bihar, and a warning for India: climate change is no longer a forecast for the distant future, as it is already deciding what reaches the farmer's plate and the nation's table. This article walks through the scale of the challenge, from a hungry world to a fragile Bihar, and then presents evidence from research farms and village fields of Dr. Rajendra Prasad Central Agricultural University (RPCAU) showing that farmers can produce more, spend less, protect their soil and water, and feed people better, even as the climate turns unpredictable. The solution is **Climate-Smart Agriculture (CSA)**, which in Bihar is already delivering measurable results.

Climate drivers	Agricultural vulnerabilities	Climate-smart interventions	Adaptation and mitigation	Resilient production	Stronger agrifood systems	Livelihoods and food/ nutrition security
Warming and heat extremes Erratic monsoon, dry spells Extreme rain, river floods	Water and groundwater stress Disrupted crop calendar Soil degradation Pest and disease shifts	Water - smart Nutrient - smart Carbon - smart Energy - smart Weather - smart Knowledge - smart	Buffered yields, timely operations Lower CH_4, N_2O and fuel use Soil carbon and water retained	Yield stability Higher intensity cropping Diversified, nutrient-rich systems	Lower post-harvest loss Local processing and markets Inclusive value chains	Stable farm income Reduced drudgery Diverse, affordable diets
Cross cutting enabling factors : Policy · Institutions · Extension · Markets · Technology · Finance						

Figure 1 : Conceptual framework of climate-smart agrifood-system transformation

Climate Change and the Emerging Challenges to Agriculture

Agriculture is particularly sensitive to changes in temperature, rainfall, water availability and the frequency of extreme events. Figure 2 summarises the climate risks affecting Indian agriculture, from hazards to livelihood consequences.

Climate hazards and evidence	Biophysical effects	Agrifood and livelihood consequences
Warming and heat extremes Observed: ~0.7 °C rise, 1901-2018. Projected: 2.4 - 4.4 °C by 2100 **Rainfall variability, dry spells** Observed: ~6% fall in summer monsoon rain, 1951-2015 **Extreme rain and floods** Observed: >150 mm/day events up ~75%, 1950-2015 **Drought and water scarcity** Observed: drought frequency and extent up, 1951-2015 **Sea-level rise and cyclones** Observed: North Indian Ocean + 3.3 mm/yr, 1993-2017	Heat stress and shortened grain filling Soil-moisture deficit, lower recharge Submergence, waterlogging, sand deposition Shifts in pests, diseases and weeds Heat stress in livestock; altered fisheries Erosion, compaction and salinity	Yield and quality variability Higher input, energy and irrigation cost Post - harvest and market disruption Volatile farm income Nutrition and food - security risk

Figure 2 : Climate risks affecting Indian agriculture: from hazards to livelihood consequences

Bihar as a Climate-Vulnerable Agricultural Ecosystem

Bihar is primarily an agrarian state, with roughly 80-85% of its people living in rural areas and close to 60% of its cultivated land dependent on rainfall. Its geography leaves it exposed to

hydro-meteorological hazards and to sharply contrasting extremes: the northern part of the state is highly susceptible to floods, while the southern part is highly prone to drought. Monsoon rainfall also varies considerably from one year to the next and within a single year. The state is divided into three principal agro-climatic zones (Table 1).

Table 1 : Agro-climatic zones of Bihar

Agro-climatic zone	Districts	Geographical area (ha)	Average rainfall (mm)	Crops	Predominant cropping system	Percent irrigated area
Zone I (North west alluvial plains)	West Champaran, East Champaran, Gopalganj, Siwan, Saran, Sitamarhi, Muzaffarpur, Madhubani, Darbhanga, Samastipur, Sheohar, Begusarai, Vaishali	3449 (36.8%)	1211	Rice, wheat, maize, pulses, sugarcane, oil seeds, tobacco. Horticultural crops: Litchi, mango, makhana, water chestnut	Rice based, Maize based	42.2%
Zone II (North east alluvial plains)	Saharsha, Purina, Katihar, Supaul, Khagaria, Madhepura, Kishanganj, Araria	1798 (19.3%)	1405	Rice, wheat, maize, jute, oilseeds, pulses. Horticultural crops: Mango, bel, banana, papaya, cucurbit, chilly, turmeric, potato	Rice based, Jute based	48.9%
Zone III (south Bihar alluvial plains)	IIIA: Bhagalpur, Sheikhpura, Lakhisarai, Jamui, Munger, Banka. IIIB: Kaimur, Rohtas, Bhojpur, Aurangabad, Buxar, Jahanabad, Gaya, Arwal, Nalanda, Nawada, Patna	4112 (43.9%)	1010	Rice, wheat, maize, pulses, oilseeds. Horticultural crops: Mango, guava, banana, jackfruit, onion, potato, chillies, marigold	Rice based	59.2%

Nature's pressure is matched by economic pressure. Bihar's poverty rate (33.74 per cent) is well above the national average (21.92 per cent), and its per capita income of Rs 5,722 is far below the national figure of Rs 22,946. Within the state, North Bihar's per capita product lags behind the south and centre. Poverty and climate risk feed each other.

Climatic Constraints and Their Agricultural Implications

Bihar contends with an erratic and unpredictable monsoon, frequent dry spells and drought, floods and submergence, and extreme temperature events. Added to these are soil-health problems, hard and impervious clay pans, reduced infiltration and declining groundwater recharge, which together keep yields low and farmers vulnerable. Bihar's land situations are also varied, including waterlogged areas, Diara and Dhab lands, Tal land, Chaur land, flood-prone land and wetlands (Table 2), so agricultural planning needs to follow location-specific approaches.

A landscape of stressed land

Table 2 : Land situations and nature of stress in Bihar's farmland

Land situation	Area (lakh ha)	Nature of stress
Flood-prone land	68.08	Seasonal inundation
Diara and Dhab lands	11.30	Within river embankments; flash floods, sand
Waterlogged area	9.41	Stagnant water, delayed sowing
Chaur land	5.40	Depressions holding water for long
Wetlands	4.03	Permanent water
Tal land	0.97	Deep-water depressions

Flood Vulnerability and Agricultural Damage

Bihar's rivers rise in the high mountains, gather enormous volumes of water from rain and melting ice, and race down over a short course where they meander and braid constantly. Water enters quickly but drains slowly, and the sand and gravel they carry act as agents of erosion and devastation. Bihar accounts for about 17.2 per cent of India's flood-affected area, and between 2010 and 2018 the number of districts hit by floods in a single year ranged from 3 to as many as 31 in 2016 (Table 3). Flood damage varies with the land situation: it takes the form of flash flooding in Dhab areas, stagnant water in Chaur lands, river-water flooding, and flooding in Diara lands. The report also draws out a relationship among rainfall, evaporation, infiltration,

percolation, groundwater depletion and flood vulnerability: when infiltration and percolation decline, and this is combined with intense rainfall and impeded drainage, surface water is more likely to accumulate.

Table 3 : Number of Bihar districts affected by floods, 2010-2018

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Districts affected (number)	9	25	11	20	20	8	31	22	3

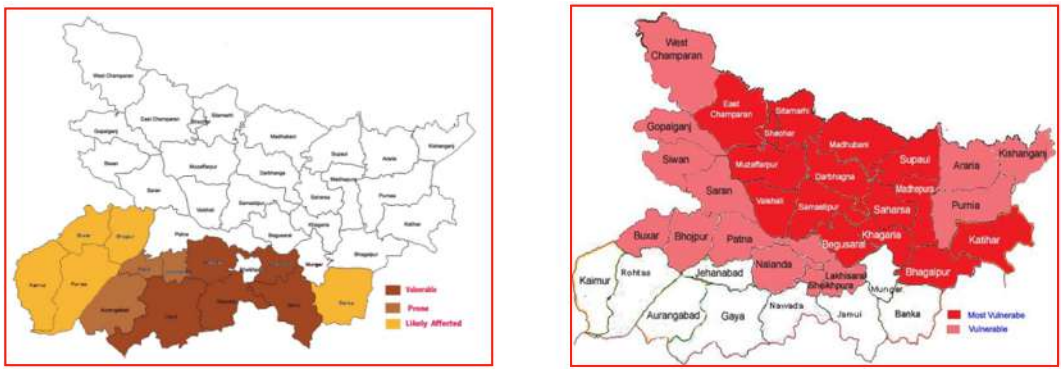


Figure 3 : Drought-prone areas (left) and flood-prone areas (right) of Bihar

Changing Rainfall Patterns and Drought Risk

Annual rainfall is falling in most districts of Bihar, and the decline is steeper in North Bihar than in the south. Over the last 25 years, the state's average rainfall has dropped from 1,146.4 mm to 848.2 mm, a loss of roughly 300 mm. In the recent 10-year period, rainfall has dropped significantly at all locations, while the average number of dry days during the monsoon has risen significantly across the state. The drought-risk picture is equally concerning: of Bihar's 38 districts, 33 were under drought-hit conditions, and 33% (about a third) of the state receives less than 750 mm of rainfall. Southern Bihar is more vulnerable to drought, and in north-eastern Bihar 35% of the area receives 25% less annual rainfall and faces drought once in 4-5 years. The nature of rainfall has changed as well. Dry spells in July, August and September have increased alarmingly when the period 1996 to 2019 is compared with 1976 to 1995 (the later period being four years longer): in August alone, spells of 5 to 7 days rose from 6 to 17, and spells of 8 to 10 days rose from 3 to 7. Rain that does arrive often comes in violent bursts, so a farmer can face drought and flood in the same season, even in the same field.

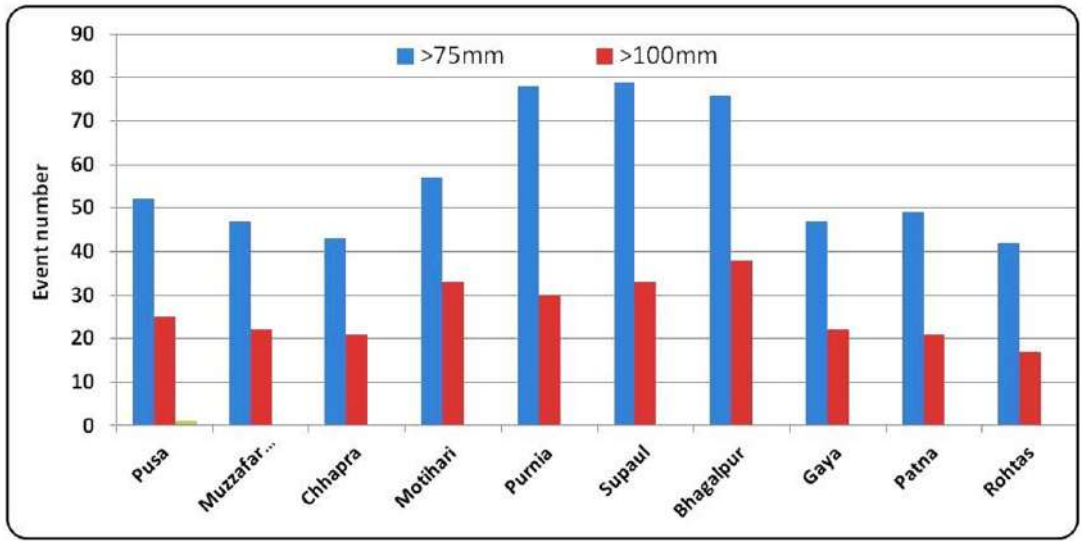


Figure 4 : Number of rainfall events exceeding 75 mm and 100 mm at selected locations in Bihar

Evidence from Pusa, Samastipur

Drought and flood have repeatedly disrupted Bihar's rice cultivation in recent years, as the record from Pusa, Samastipur shows.

Table 4 : Annual rainfall, drought events and agricultural impacts, 2009-2022

Year	Total annual rainfall (mm)	Drought events	Agricultural impacts
2009	910	Early-season (June-July) and mid-season disastrous drought	Rice cultivation seriously affected; most districts of Bihar declared drought affected
2010	985	Good rainfall in May and during 18-24 June, and devastating drought thereafter	Severe drought affected rice crop production; rice production fell by 25-35 percent
2012	880	Scanty rainfall in June and August	Rice growth seriously affected
2013	865	Deficit rainfall; only 46 mm rainfall recorded in July against the normal of 295 mm	Rice transplanting severely affected; area under rice decreased drastically (40-50%) due to poor transplanting
2014	1117	Deficit rainfall in June; prolonged drought and drought-like situation	Rice seedlings damaged in the nursery due to dry spell

2015	946	Highly deficit rainfall during kharif season; however, a heavy rainfall event was also observed, with about 316 mm recorded in two consecutive days in August	Rice crop yields seriously affected in the state due to poor rainfall, dry spell and subsequent drought
2016	1016	Prolonged dry spell in June, August and September; August remained extremely dry with only 5 rainy days; two long dry spells (10 days and 14 days) recorded during this month	Dry spell in June, August and October affected the growth of rice seedlings and rainfed rice crops
2017	1134	Very dry condition in June, poor distribution in July, extreme dry condition in September and October	Rice seedlings damaged and transplanting affected; farmers had to use diesel pump sets for frequent irrigation, escalating the cost of production
2018	883	June, July, September and October went dry and extremely rain deficient; extreme rainfall event (127 mm in one day) in August	Kharif as well as rabi crops damaged both by water scarcity and flooding (August)
2019	1146	Prolonged dry spell in June; July and September received very heavy rainfall; two long dry spells in September; October remained completely dry	Long dry spell in June damaged rice seedlings; in September, flooding and waterlogging damaged rice in lowland areas; scanty rainfall in October affected sowing of rabi crops, as there was almost no residual soil moisture
2020	1560	289 mm rainfall recorded in June against the normal of 155 mm; devastating flood ravaged 18 districts of north Bihar; during 20-24 July a total of 321 mm rainfall was recorded, with 205 mm received on 20 July; July received 647 mm against the normal of 295 mm; August experienced deficit rainfall	18 districts of north Bihar flooded due to heavy rainfall in Nepali Terai and all across north Bihar; about 33% of the total kharif crops damaged
2021	1884	July and September experienced severe drought conditions, while June, August and October recorded heavy rainfall; a 24-day dry spell in October; on 2 October extreme heavy rainfall (118 mm) was recorded	Extreme heavy rainfall in October caused severe flooding over 13 districts of North Bihar, damaged mature paddy crops and reduced rice productivity by 30-35%; farmers were also forced to sow wheat under delayed condition owing to high soil moisture in November
2022	641.5	Erratic and scanty rainfall in June and July affected paddy transplanting all over Bihar; due to very poor rainfall only 40% area was transplanted	An almost drought-like condition in the state

The monthly record shows how far rainfall has drifted from its expected rhythm (Table 5): in 2020 July received almost double its normal rain while August fell to half and October went completely dry, and in 2022 June recorded a mere 2.5 mm against a normal of 153 mm.

Table 5 : Monthly rainfall (mm): normal and 2020-2023

Month	Normal (mm)	2020	2021	2022	2023
June	153.4	288.6	401.9	2.5	92.6
July	346.2	646.8	204.2	205.3	146.2
August	295.0	154.8	500.8	162.5	532.9
September	233.8	233.4	127.0	167.6	434.6
October	75.0	0.0	359.2	64.3	n/a

Heat, cold nights and dimmer winters

Wheat is also under pressure. Records from Pusa covering 1968 to 2015 show a significant rise in minimum temperatures throughout the winter; these warmer nights speed up crop development and shorten the grain-filling period. In North Bihar, bright sunshine hours during the rabi season are also declining significantly, possibly because of atmospheric pollution, fewer winter rains and fog. Terminal heat, in the form of hot westerly winds during grain filling, remains a constant threat, so every stage of the farming calendar is now at risk.

Climate-Smart Agriculture as an Approach for Agricultural Rejuvenation

Climate-Smart Agriculture provides an integrated approach for responding to climatic risks while improving agricultural productivity and sustainability. Rather than a single technology, it is a practical, evidence-based system of six overlapping "smart" approaches that together raise productivity, improve resource-use efficiency and strengthen the farmer's capacity to adapt (Table 6).

Table 6 : The six components of Climate-Smart Agriculture and their elements

Component	Elements
Carbon-smart agriculture	agroforestry; residue management; no-tillage
Water-smart and nutrient-smart agriculture	legume integration; Leaf Color Chart-based nutrient management; decision-support tools; Green Seeker; Site-Specific Nutrient Management; Nutrient Expert
Energy-smart agriculture	DSR; cropping-system optimization; elimination of puddling in rice; no-tillage; residue management
Weather-smart agriculture	weather forecasting; crop diversification; index-based insurance; Seeds for Needs
Knowledge-smart agriculture	ICT; gender empowerment; capacity development

At RPCAU, Pusa, these ideas are put to work through the National Initiative on Climate Resilient Agriculture (NICRA), the Climate Resilient Agriculture (CRA) programme of the Government of Bihar, and the Climate-Smart Village model supported under the National Adaptation Fund for Climate Change (NAFCC) of the Ministry of Environment, Forest and Climate Change. The methodology is simple: identify each village's climate vulnerability, match it with a tested intervention, and measure the result on the ground (Table 7).

Table 7 : Climate vulnerabilities, problems and matched interventions

Climate vulnerability	Problem	Intervention
Low rainfall	Low recharge, falling water table	Renovating water reservoirs, sub-soilers, bunds, land levelling, drought-tolerant varieties
Late monsoon onset	Late paddy transplanting	Zero tillage, FIRB planter, DSR, drum seeder, SRI, community nursery, short-duration varieties
Failure of October rain	Late rabi sowing, no pre-sowing moisture	Zero tillage, FIRB planter, late-sown varieties, conservation tillage
Moisture stress	Low fertiliser efficiency	Natural and plastic mulch, organic matter, anti-transpirants
Non-leaching of salts	Salinity build-up	Green manuring, organic matter, scraping, levelling, bund making, leaching, salt-tolerant varieties

Climate-Resilient Interventions and Demonstrated Outcomes

Under NICRA, specific interventions were matched to the climatic vulnerabilities of low rainfall, delayed monsoon, failure of October rainfall, moisture stress and non-leaching of soluble salts (Table 7). The documented NICRA outcomes include 31,074 cubic metres of additional water made available for irrigation and 63 ha of additional area brought under assured irrigation.

Natural Resource Management, Water and Moisture Conservation

Restoring agro-ecosystems through natural-resource management was an important part of the interventions. In one documented village, at least nine ponds had become defunct because of low rainfall and poor water intake; under NICRA, these ponds and their inlet channels were renovated. An additional 50,000 cubic metres of water became available for irrigation, and 55 ha of additional area came under assured irrigation. Cropping intensity rose by 23%, paddy productivity by 23% and wheat productivity by 39%, and the groundwater level went up by 2.5 ft compared with February 2011. Pump sets became 3% more fuel efficient and water discharge increased by 6%. The intervention also made it possible to diversify beyond paddy and wheat, with crops such as brinjal grown in areas with assured irrigation. In-situ moisture conservation relied on land levelling, mulching and organic approaches. A relay-cropping

system combining vegetables and paddy followed the sequence of brinjal, tomato, cucumber/long melon and paddy, with sesbania incorporated before a short-duration paddy crop was taken; the documented gross economic return from one hectare was Rs. 60,000. In Diara lands, moisture-conservation practices were adopted for crops such as watermelon, muskmelon, pumpkin, cucumber and long gourd. These measures extended moisture retention by 5 days and improved heat tolerance, with plant survival rising by 11%. Irrigating through pitchers, sprinklers or delivery tubes instead of flooding reportedly saved 2 ha-cm of water.

Resource-Conservation Technologies and Soil Health

Resource-conservation technologies formed another major component of the programme. From 1,320.6 ha of paddy area, approximately 1,981 tonnes of crop residue were incorporated into the soil. Comparative evaluation of cropping systems showed differences in infiltration rates and soil compaction: the infiltration rate after two hours of ponding was highest in the Rice-Vegetable system, followed by Rice-Wheat-Moongbean, Fallow-Moongbean, Rice (DSR)-Wheat, Rice-Potato, Rice-Wheat and Rice-Maize. The findings indicate the potential of diversified cropping systems and conservation technologies to improve soil and water-related indicators. The comparison of Direct Seeded Rice under laser-levelled and mechanically levelled fields showed a 17.66% increase in yield under laser levelling over mechanical levelling; laser levelling was also reported to save water and reduce weed population (Table 8).

Table 8 : Direct-seeded rice under laser-levelled (LL) and mechanically levelled (ML) fields

Treatment	No. of weeds/m²	No. of irrigation	Yield (q/ha)	Gross return (Rs./ha)	Net return (Rs./ha)
Laser levelled (LL)	1	0	35.91	75414	34977
Mechanically levelled (ML)	4	1	30.52	64092	28260

The Climate Resilient Agriculture Programme also included several alternative cropping systems: Rice-Chickpea-Mungbean; Rice-Wheat-Sunflower; Pearl Millet-Wheat-Mungbean; Soybean-Winter Maize-Green Manuring; Soybean-Wheat-Mungbean; Maize-Mustard-Mungbean; Maize-Wheat-Mungbean; Rice-Maize + Potato-Green Manuring; Rice-Chickpea-Sunflower; Rice-Lentil-Mungbean; Rice-Winter Maize-Green Manuring; Rice-Mustard-Mungbean; Rice-Wheat-Mungbean using drum seeding and zero tillage; and Rice-Wheat-Mungbean under different tillage combinations. The diversification of cropping systems was a means of improving productivity, profitability and resilience.

Enhancing Rice Productivity and Food Security

The CRA demonstrations documented higher grain yields than farmer practices in different rice interventions (Figure 5). The CRA programme is reported to have had an overall impact of 58.82% on paddy productivity. The climate-smart practices involved were DSR, water harvesting and field bunding (WHFB), alternate wetting and drying (AWD), nutrient management (NM) and community irrigation (CI), and these interventions were also associated with higher net returns, contributing to economic security.

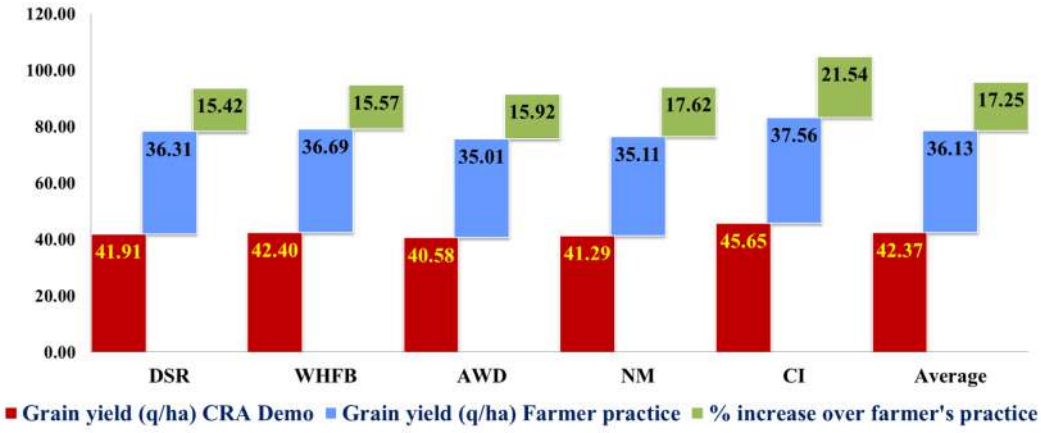


Figure 5 : Rice grain yield (q/ha) under CRA demonstrations and farmer practice, and per cent increase over farmer practice, by intervention

Climate-Smart Wheat Production

Wheat productivity suffers from high temperatures and hot westerly winds during the grain-filling stage, a problem commonly known as terminal heat. Climate-resilient interventions for wheat included zero tillage, raised-bed planting, community irrigation, timely sowing, and nutrient management with tools such as the Leaf Color Chart, Nutrient Expert and Green Seeker. Under CRA field conditions, wheat grain yield rose by an overall 23.17% compared with farmer practice; the increase by intervention is shown in Table 9.

Table 9 : Wheat yield increase over farmer practice under climate-smart interventions

Zero tillage	Raised-bed planting	Community irrigation + timely sowing	Nutrient management
20.25%	24.37%	36.21%	27.16%

Crop Diversification, Pulse Integration and Millets

Crop diversification was promoted to build resilience and diversify the agricultural production system. Raised-bed systems involving maize, soybean, pigeon pea and millet were offered as

alternatives, and pulse integration was highlighted as an approach for protein supplementation. Maize-soybean combinations recorded maize-equivalent yields ranging from 74.29 to 87.66 q/ha, an increase of 47.55% to 67.13% over sole maize, while the maize-pigeon pea combination recorded a maize-equivalent yield of 72.15 q/ha, a 39.29% increase over sole maize. Figure 6 compares the system productivity and profitability of diversified cropping systems with the rice-wheat farmers' practice.

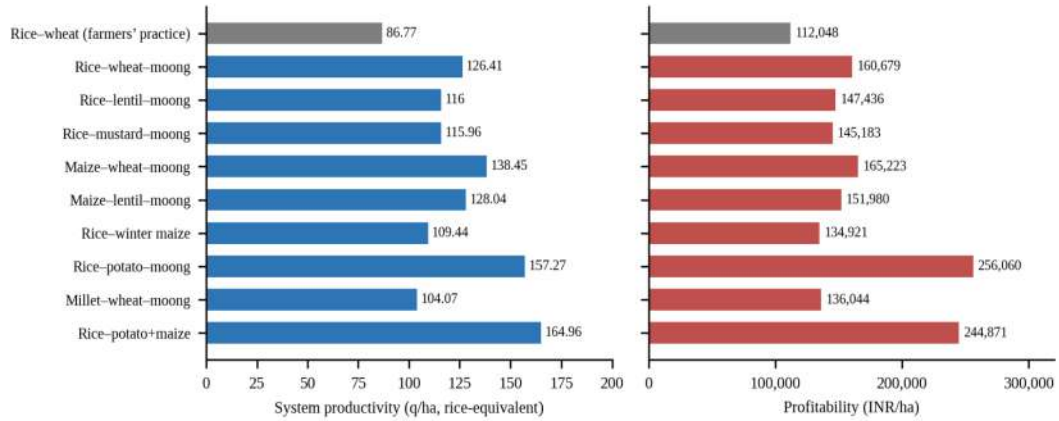


Figure 6 : System productivity (q/ha, rice-equivalent) and profitability (INR/ha) of diversified cropping systems versus the rice-wheat farmers' practice

District-level results are available for zero-tillage green gram compared with conventional tillage. Across the demonstrations, the average grain yield was 9.50 q/ha under zero tillage against 6.66 q/ha under conventional tillage, an increase of 42.55%, and the average net return was Rs. 46,342 against Rs. 25,506, an increase of 81.69%. In West Champaran specifically, the demonstration recorded 10.25 q/ha under zero tillage against 6.50 q/ha under conventional tillage, an increase of 57.69%. Millets were presented as an alternative for stressed areas and populations. They need less irrigation than rice, have low nutrient requirements, tolerate prolonged drought and high temperatures, demand relatively little maintenance and resist several diseases and pests. As C4 crops, they are also more efficient at absorbing and using carbon dioxide, and millet production requires approximately 2.5 times less water than rice. Millet-based diversification is therefore relevant not only for climate resilience but also for nutritional security.

Community Irrigation, Solar Energy and Timely Sowing

Community irrigation was developed to address delayed rainfall, water scarcity and untimely agricultural operations. The documented system involved installing seventeen 4-inch tube wells, each fitted with a 3 hp single-phase submersible pump, in 17 villages, with one village

associated with each KVK. Groups of 10-20 farmers were formed within the command areas; one person was made responsible for operation and maintenance, and a nominal rate of Rs. 15 per hour was fixed through mutual understanding. Seeds of Rajendra Mahsuri-1 rice, HD-2967 wheat and IPM 2-3 green gram were provided for 15 acres per village, covering a total of 255 acres, and irrigation reached individual plots in rotation or according to crop demand. The pumps had a reported discharge of 5-6 lps and a command area of 5-6 ha. The reported cost of irrigation was Rs. 1-2/cumec, compared with Rs. 4-5/cumec for diesel-operated pumps. Renewable energy is also finding a place in Bihar's fields through solar-powered irrigation, introduced as part of climate-resilient resource management. One documented model is the solar tree, a 1.8 kWp installation that powers a 2 hp submersible pump, delivers water to land up to 100 m from the source and can run both sprinkler and raingun systems. It serves roughly 6 acres on its own; once drip or sprinkler systems are added, coverage grows to 8-10 acres, and the running cost comes to just Rs. 35 per hour. Boat-mounted solar pumping systems have been described as a way to bring renewable-powered irrigation to waterlogged and riverine environments. Timing makes a measurable difference to rice in Bihar. Data from several locations across the state (Figure 7) show that transplanting on time delivers far better results than transplanting late: average yield reached 5,208.29 kg/ha under timely transplantation but fell to 3,184.59 kg/ha when transplanting was delayed. Late transplanting also demands more water, with an average requirement of 519.61 mm for timely and 607.02 mm for late transplantation, and water productivity was 0.786 kg m^{-3} for timely against 0.424 kg m^{-3} for late transplanting. The gap is just as clear at individual sites; at Narkatiaganj, timely transplanted rice yielded 5,452 kg/ha, compared with 3,310 kg/ha under late transplantation. Together, these results show why timely agricultural operations matter so much in climate-sensitive rice production.

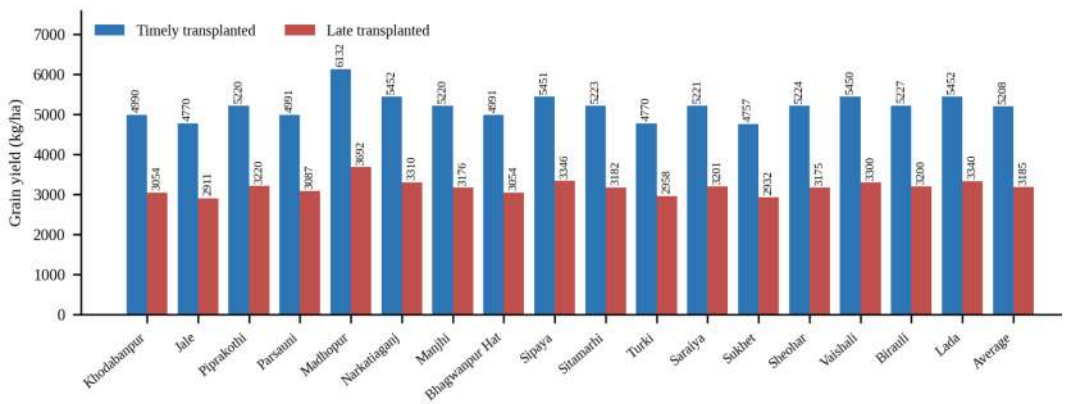


Figure 7 : Rice yield under community irrigation: timely versus late transplanting at 17 locations in Bihar (kg/ha)

Greenhouse-Gas Emissions and Sustainability

Sustainability is the other side of the tillage story in the rice-wheat-green gram system. The conventional version of this system is far more energy-intensive, largely because of heavy tillage and indiscriminate use of inputs: seeds, fertilizers, pesticides and irrigation together account for approximately 78% of the energy consumed in growing rice, wheat and green gram. Climate Resilient Agriculture technologies cut direct energy use by 34.43% and indirect energy use by 20% compared with the conventional system. Zero-tillage direct-seeded rice had the lowest global warming potential of all the systems studied; moving from random puddled transplanted rice to zero-tillage direct-seeded rice reduced methane emissions by 54.78%, an effect attributed to controlled moisture levels, and nitrous oxide emissions were also lowest under this system because of its wetting and drying cycles. The same pattern held for wheat, where zero-till wheat showed lower global warming potential than traditional till wheat.

Water Harvesting and Groundwater Recharge

Bihar's twin problems of flood and drought are being tackled with a single idea: capture water when there is too much of it and return it to the ground for when there is too little. The water-harvesting cum recharge structure is designed to drain ponded water in time, which opens the way for timely wheat sowing, and in drought-prone areas it helps assure irrigation for rice. Its wider aim is to put back into the ground an amount of water equivalent to what is pumped out through bore wells for irrigation. The structure targets the second aquifer and can recharge at 21,000-23,000 litres/hour; its solid removal efficiency is 80-82%, the recharging depth is 45-55 m, and the annual groundwater recharge potential is 1.8-2.0 ha-m. The impact is already visible: at Sukhet village in Madhubani, wheat sowing became possible after 25 years, thanks to the water-recharge structure.

Crop Planning and Mitigation Practices in Flood-Affected Areas

When floodwater leaves, what a farmer in Bihar can grow, it is a big question? Across the state, water recedes at different times, anywhere from September through February, and in some places it never goes away, so crop choice is tied to how long water stays and when it retreats. Where the water recedes, the suggested options depend on the timing: radish, coriander, green gram, onion, cauliflower, garden pea, early potato and potato; rapeseed and mustard, wheat, lentil, gram, late-sown wheat and maize; and, later in the season, summer vegetables, sesame, summer maize, sunflower and boro rice. For areas that remain permanently waterlogged, fish and prawn cultivation were identified as the suitable options. Flood-affected areas also call for location-specific practices, and several have been demonstrated in Bihar: surface seeding of lentil and wheat, transplanting of pointed gourd and dibbling of maize, and, in Diara lands, sprinkler irrigation and windbreaks. The timing of the flood decides which crop makes sense. If flooding comes in July-August, maize and sorghum are best used for silage and green fodder;

if it arrives in September, maize can still be grown for cobs, while sorghum remains a silage and green fodder crop; and in fields with no flooding, or where floodwater arrives only in October, maize can be grown for grain and sorghum for fodder.

Case Study: Climate-Resilient Paddy Management in Madhubani

A case study from Madhubani shows how much timely sowing can matter. The paddy was transplanted on 21 June 2020, well ahead of the floods. From 17 to 26 July 2020, the field was submerged for 10 days, yet the crop survived because it had been established early, and it recovered once the floodwater receded. Recovery was supported with vermicompost and PSB, applied between 29 and 31 July 2020 and again in the first week of September; by the second week of September the paddy had been rejuvenated, and it reached the ripening stage in the first week of November.

Weather-Based Advisory Services and Custom Hiring Centres

Knowing what the weather will do before acting is a form of climate insurance, and Bihar is building it through weather-based farm advisories delivered down to the village level, so that advice is tied to local conditions rather than to the state as a whole. Forecast advisories are updated on university and IMD websites, and the same information reaches state government officials, newspapers, radio and Doordarshan, widening its reach well beyond those who go online. Alongside forecasts, the system tracks the impacts of drought and dry spells, as well as crop-weather information. Approximately 6.5 lakh farmers of North Bihar were reported to receive weekly SMS advisories through the Kisan Portal, and WhatsApp has since been added as another channel. With these services, farmers can make better decisions about weather-sensitive agricultural operations. Custom Hiring Centres were established to facilitate timely agricultural operations and improve access to agricultural machinery. The equipment listed includes tractors, laser land levelers, Happy Seeders, multi-crop planters, zero-tillage machines, weeders and ridgers, potato planters and diggers, portable rice-wheat seeders, tractor-mounted sprayers and raised-bed planters (Table 10).

Table 10 : Equipment available at Custom Hiring Centres

Equipment	Number	Equipment	Number
Tractor	11	Potato planter	11
Laser land leveler	11	Potato digger	11
Happy Seeder	15	Portable rice -wheat seeder	137
Multi-crop planter	22	Tractor-mounted sprayer	2
Zero-tillage machine	15	Raised-bed planter	22
Weeder and ridger	11		



Women Empowerment through the Sukhet Model

Much of the work that keeps a Bihar household running falls on women, and much of it is slow, tiring and unhealthy: cow-dung cakes must be shaped, dried in the sun and stored again after sunset, cooking over these fuels exposes women to smoke, and smoke-blackened utensils must then be scrubbed. When household waste and cow dung are not recycled efficiently, village sanitation and soil health also suffer. The Sukhet Model addresses this by turning waste into a resource: it set up a vermicompost unit with an annual capacity of 250 MT and built the capacity of women farmers to run it. The model works on a simple exchange of waste for cooking gas. Households hand over their waste, crop residues, cow dung and other biodegradable materials, which are collected and converted into vermicompost, and in return they receive an LPG cylinder every two months, matched to approximately 1,200 kg of garbage. Waste collection feeds recycling, recycling produces vermicompost, and the vermicompost goes back into agricultural fields. Along the way the model gives women a stronger role and creates income, employment and revenue, while air pollution goes down, surroundings become cleaner and more sanitary, and organic waste finds its way back to farmland.



Figure 8 : The Sukhet Model: field photographs

Crop Residue Management and Circular Agriculture

Managing crop residue is a key part of the climate-resilient agricultural approach, and three tools are at its centre: straw balers, waste decomposers and Happy Seeders. Residue used for bale formation came to 950 tonnes, and waste decomposer was applied over 1,800 acres. The leftover straw also served as a substrate for mushroom cultivation, which produced 296.3 quintals.

Productivity under the Climate Resilient Agriculture Programme

Table 11 compares national productivity, Bihar productivity and the productivity achieved under the CRA programme. The source of national and Bihar productivity is identified as the Economics & Statistics Division, Department of Agriculture & Farmers Welfare, Government of India.

Table 11 : National, Bihar and CRA productivity of major crops

Crop	Season	National productivity (kg/ha)	Bihar productivity (kg/ha)	CRA productivity (kg/ha)	Increase over national
Rice	Kharif	2718	2288	4025	49%
Maize	Rabi	5046	4524	11100	120%
Maize	Kharif	2879	1797	5360	86%
Wheat	Rabi	3507	2780	4150	18.3%
Chickpea	Rabi	1260	1013	1620	28.5%
Lentil	Rabi	904	884	1401	55%
Moong	Summer	548	550	1160	111.6%

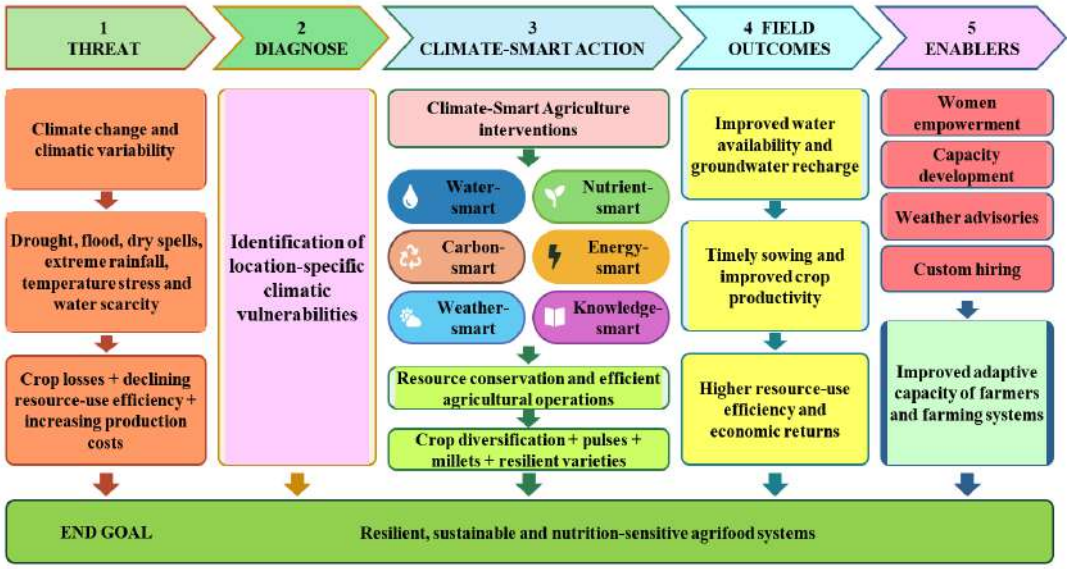
Scaling Up Climate-Resilient Agriculture

The Climate Resilient Agriculture Programme is now moving from demonstration to expansion. For the 2025-2026 programme, five new villages were selected from each district, all located near government Krishi farms, and nine secondary villages were brought in, supported through training and capacity-building activities. The aim of this scaling-up approach is to carry climate-resilient technologies beyond the demonstration sites and build the local capacity needed for wider adoption.

Integrating Climate Resilience with Food and Nutritional Security

Across the programme, one lesson stands out: climate resilience is about more than protecting crop yield. A sustainable agrifood system must also deliver on nutrition, resource conservation, economic returns and the farmer's ability to adapt. Pulses and millets play a special part here, since they add to dietary diversity and improve the availability of protein and micronutrients, and diversified farming systems strengthen this further by offering several sources of food and income, so that a household no longer depends on one crop alone. Bringing climate-smart agriculture together with nutrition therefore moves the focus away from how much food is grown and towards how good that food is and how varied the diet it supports.

Overall Workflow of Climate-Smart Agricultural Rejuvenation in Bihar



Conclusion

Climate change is one of the most serious threats to food and nutritional security, both worldwide and within India, and its impact is sharpest in vulnerable agricultural regions like Bihar. Rising temperatures, erratic rainfall, water scarcity, floods, droughts and soil degradation are cutting into agricultural productivity and putting farming communities at greater risk. The experience from Bihar shows that Climate-Smart Agriculture offers an integrated way to meet these pressures: water conservation, zero tillage, direct-seeded rice, crop diversification, nutrient-smart management, climate-resilient varieties, community irrigation, groundwater recharge and weather-based advisories all help build resilience. Where these interventions have been documented, they have delivered higher crop yields, better resource-use efficiency, increased cropping intensity, improved groundwater availability and stronger economic returns, and adding pulses, millets and diversified farming systems ties climate resilience to nutritional security as well. Resilience, however, is not only a technical matter; it also depends on the social side of farming. Women-centred initiatives such as the Sukhet Model show how waste recycling, clean energy, vermicomposting, employment generation and women's empowerment can sit within a single climate-resilient framework. The climate-resilient agriculture initiatives at Dr. Rajendra Prasad Central Agricultural University illustrate what research, innovation, resource conservation, capacity development and farmer-focused extension can achieve together. Ultimately, strengthening India's agrifood systems calls for an approach in which productivity, profitability, resource conservation,

climate adaptation, nutrition, gender inclusion and farmer capacity development work hand in hand. Bihar's experience offers a practical foundation for building climate-smart and sustainable agricultural systems.

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FROM DARKNESS TO DAWN : DECADES OF PROGRESS AND PERSISTENT CHALLENGES IN LITERACY AND EDUCATIONAL ENROLMENT AMONG SCHEDULED TRIBES IN INDIA

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ABSTRACT

Education is widely recognized as a powerful instrument of social transformation and a key driver of socio-economic development, particularly for historically marginalized communities such as the Scheduled Tribes (STs), who constitute 8.6% of India's population. Despite constitutional safeguards, affirmative action measures, and targeted educational programmes, STs continue to experience significant educational disadvantages compared to the national population. This study examines long-term trends in literacy rates and Gross Enrolment Ratios (GER) among Scheduled Tribes in India from 1961 to 2022–23, with a focus on gender disparities and comparison with national averages. Using data from the Census of India and UDISE+, the study reveals substantial progress in educational attainment among STs over the past six decades. Literacy rates increased from 8.53% in 1961 to 73.6% in 2022–23, considerably narrowing the gap with the national literacy rate of 80.3%. Female literacy showed remarkable improvement, rising from 3.16% to 66.7%, although it remains below the male ST literacy rate of 80.4%. The findings also indicate that while access to elementary education has become nearly universal, reflected in a GER of 103.4% in 2021–22, participation declines sharply at higher educational levels. GER falls to 78.1% at the secondary stage, 52.0% at the senior secondary stage, and 21.2% in higher education. The study concludes that while policy interventions have significantly expanded access to basic education, persistent challenges related to retention, transition, and educational equity still exist. Empowering tribal communities and achieving Sustainable Development Goal 4 on inclusive and equitable quality education necessitates addressing these gaps.

Keywords: *Scheduled Tribes, Literacy Rate, Gross Enrolment Ratio, Tribal Education, Educational Disparities, India*

Introduction

Education is widely regarded as a fundamental catalyst for both personal progress and societal growth, contributing to the accumulation of human capital, poverty alleviation, and increased

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social mobility. Investments in education at both global and national levels are associated with significant benefits, such as economic growth, improved health outcomes, greater gender equality, and stronger democratic participation. Education plays a vital role in breaking the intergenerational cycle of poverty, illiteracy, and social exclusion among marginalized communities such as the Scheduled Tribes in India. (Kujur & Das, 2026). Education promotion among India's Scheduled Tribes has been a central government policy goal, backed by constitutional clauses, notably Articles 15, 16, and 46, which stress equality, social justice, and the educational progress of disadvantaged groups.

In India, education is seen as a crucial route for social progress, economic empowerment, and inclusive growth, especially for historically disadvantaged groups like the Scheduled Tribes. Significant inequalities persist in literacy levels, school enrolment, retention, and progression to higher education despite considerable efforts made since independence through targeted interventions such as Eklavya Model Residential Schools (EMRS), scholarship programmes, and the Samagra Shiksha initiative, when compared with national averages (Ministry of Tribal Affairs, 2020; MoTA, 2023). Scheduled Tribes communities mainly live in remote and isolated areas where resources are limited and access to basic services is often poor. These communities have historically faced various forms of disadvantage, such as poverty, social exclusion, cultural marginalisation, and limited access to quality educational facilities. Notable disparities and challenges persist among ST populations, despite substantial educational progress achieved through post-independence policies and investments (Census of India, 2011; PLFS, 2017-18).

Existing research demonstrates that educational outcomes among Scheduled Tribes (STs) are shaped by a complex interaction of socio-economic, cultural, and institutional factors. Initial research uncovered disturbingly low levels of literacy and educational engagement among tribal populations, indicating that these inequalities were primarily caused by geographic isolation, socio-economic disadvantage, and the disconnection between tribal socio-cultural norms and conventional school systems. (Mitra & Singh, 2008; Dutta & Bisai, 2020). Research has shown that educational outcomes among tribal populations are limited by a range of structural issues, including inadequate educational facilities, insufficient numbers of trained teachers, language difficulties, economic difficulties within households, child labour, and curricula which frequently lack relevance to tribal cultural backgrounds. (Bhagavatheeswaran et al., 2016; Parida & Das, 2026; Kujur & Das, 2026). Educational attainment among STs has shown significant improvement over the decades despite these challenges. According to

census data, literacy rates rose from 8.53% in 1961 (with female literacy at just 3.16%) to 11.30% in 1971, 29.60% in 1991, 47.10% in 2001, and 58.95% in 2011. The Periodic Labour Force Survey (PLFS) indicates that literacy rates increased to around 67-72% during the late 2010s. Significant disparities in literacy persist despite the narrowing of the gender gap over time. Literacy rates vary across different regions in India, with states in the Northeast, like Mizoram, boasting higher literacy levels, whereas several central and eastern states are still struggling to catch up. (Office of the Registrar General & Census Commissioner, India, 2011; Mitra & Singh, 2008).

Data from Unified District Information System for Education Plus (UDISE+) shows that Gross Enrolment Ratios among Scheduled Tribes are nearly universal at primary and elementary stages, often surpassing 95-100%. Enrolment drops significantly at higher levels of education, decreasing to around 77-81% at the secondary level and 49-53% at the higher secondary level. Dropout rates increase substantially beyond elementary education, especially in geographically isolated and disadvantaged areas (Ministry of Education, 2022-23; Mehta, 2026). Girls from tribal communities face numerous and interconnected obstacles, such as household duties, early marriage, safety issues, and deeply ingrained gender expectations, which result in higher dropout rates and lower educational consistency. Some Northeastern states have shown relatively greater gender equality in educational participation (Nayak, 2022; Bhagavatheeswaran et al., 2016; Mitra & Singh, 2008).

Research using Census and UDISE data shows significant increases in enrolment rates and educational participation among Scheduled Tribes over time. Significant disparities persist in educational progression, retention, and completion across different regions and educational stages, despite these gains (Mehta, 2024; Dutta & Bisai, 2020; Kujur & Das, 2026). A mixed-methods systematic review of 47 studies spanning the period 2010 to 2024 found 21 obstacles and 12 facilitators affecting tribal education. A review identified teacher quality, educational infrastructure, poverty, health-related challenges, and socio-cultural factors as key determinants of educational outcomes (Parida & Das, 2026). Evaluations of key government initiatives, such as Eklavya Model Residential Schools (EMRS) and Samagra Shiksha, indicate significant enhancements in access, enrolment, and retention at the elementary level. Concerns about implementation effectiveness, staffing shortages, cultural relevance, and the long-term sustainability of educational outcomes continue to limit the overall impact of these initiatives (Tripathi, 2025; Halder & Guha, 2023; Parida & Das, 2026).

Previous studies into tribal education have yielded valuable insights through decadal analyses and qualitative investigations, but most have been restricted to data available up to the 2011 census. Long-term assessments that incorporate literacy trends, Gross Enrolment Ratios (GER), gender aspects, and their implications within the framework of Sustainable Development Goal 4 (SDG 4) are relatively rare. The present study provides a macro-level examination of educational advancement among Scheduled Tribes (STs) in India spanning the years 1961–2022/23.

ST communities continue to face persistent challenges despite constitutional safeguards under Articles 15, 16, and 46 and various educational initiatives, including geographic isolation, poverty, inadequate educational infrastructure, language barriers, teacher shortages, and high dropout rates. Research has shown that culturally responsive policies, multilingual education, better teacher training, and increased community involvement are necessary to improve educational results for tribal communities.

The study examines long-term patterns in literacy rates and Gross Enrolment Ratios among Scheduled Tribes, compares these indicators with national averages, and evaluates gender disparities across different time periods. The study offers a comprehensive six-decade perspective, contributing to a broader discussion on educational equity and social inclusion, and producing evidence-based insights to inform the development of more effective, inclusive, and context-sensitive policies that can advance educational justice and help achieve SDG 4 in India.

Few studies have examined tribal literacy using Census data up to 2011, but even fewer have combined post-2011 literacy estimates, UDISE+ enrolment trends, AISHE data on higher education participation, and gender differences in a single comprehensive analysis spanning six decades. This study bridges the gap by combining these indicators for a comprehensive analysis of educational progress, transitions, and ongoing inequalities among Scheduled Tribes in India. By analysing changes in literacy and enrolment patterns, it makes a more significant contribution than just collecting data, highlighting where educational disadvantages become more pronounced.

Factors Shaping Tribal Educational Outcomes

The educational outcomes for Scheduled Tribes are influenced by a mix of structural, household, institutional, cultural, and policy-related factors. Challenges such as inaccessible locations and poor connectivity hinder students' ability to access schools; poverty and the need to work also impact attendance and retention rates; cultural and linguistic differences can make

learning more difficult; inadequate facilities and untrained teachers compromise the quality of education; however, initiatives like scholarships, residential schools, multilingual teaching, and community involvement can help address these challenges. These factors collectively impact literacy rates, school enrolment, student retention, progression to higher education, and participation in post-secondary studies.

Table 1 : Structural Factors Influencing Educational Inequality among Scheduled Tribes

Structural Factors	Household & Socio - Cultural Factors	Institutional Factors
Geographic isolation	Poverty & livelihood demands	School infrastructure
Connectivity	Gender norms & early marriage	Teacher availability
Remoteness	Language & cultural barriers	Curriculum relevance
Regional disparities	Household responsibilities	Transition support

Objectives of the Study

1. To examine the trends in literacy rates among Scheduled Tribes (STs) in India from 1961 to 2022–23 and compare them with the national average, with special focus on gender differences.
2. To analyse the Gross Enrolment Ratios (GER) of ST students at different education levels (elementary, secondary, and higher education) from 2017–18 to 2021–22.
3. To identify the existing gaps in educational indicators between STs and the general population and suggest policy measures for improvement.

Methodology and Data

This study employs a descriptive and comparative research design based on secondary data analysis. The research draws upon official and reliable secondary sources to examine long-term trends in educational indicators among Scheduled Tribes (STs) in India.

Literacy rate data for the period 1961 to 2022–23 were obtained from various rounds of the Census of India, published by the Office of the Registrar General and Census Commissioner. Data on Gross Enrolment Ratios (GER) for the years 2017–18 to 2021–22 were sourced from the Unified District Information System for Education (UDISE) reports, Ministry of Education, Government of India. The 1961–2011 observations are Census benchmarks, whereas the 2022–23 estimate is derived from PLFS.

The study primarily uses trend analysis, percentage calculations, and comparative techniques to assess changes over time. A systematic gender-wise and level-wise comparison has been conducted between Scheduled Tribes and the national population. The data have been presented in tabular form to facilitate clear visualization of trends and disparities. To strengthen the statistical assessment, selected quantitative techniques, including linear regression and trend regression analysis, were applied to examine the direction and rate of change in educational indicators over time. A Gender Gap Index (GGI) was also calculated to quantify disparities between male and female literacy/enrolment outcomes.

The study opted for descriptive statistics because it aims to identify long-term trends, the magnitude of changes, gender disparities, and differences between Scheduled Tribes and the national population, rather than establishing cause and effect. Comparisons were conducted using absolute percentage-point differences, relative changes, gender gaps, and variations in gender-based literacy rates across different stages. Census literacy data and PLFS estimates are treated as distinct statistical sets due to their differing data collection systems and survey methods; the 2022–23 data is specifically identified as a PLFS estimate and is not presented as a Census figure. The analysis aligns indicators by retaining their original definitions and comparing similar literacy rates, while exercising caution in interpreting differences between data sources.

Limitations of using secondary data include variations in methods, time frames, coverage, definitions, and potential issues with comparing data from Census, PLFS, UDISE+, and AISHE.As a result, the findings reveal trends and connections rather than direct cause-and-effect relationships.

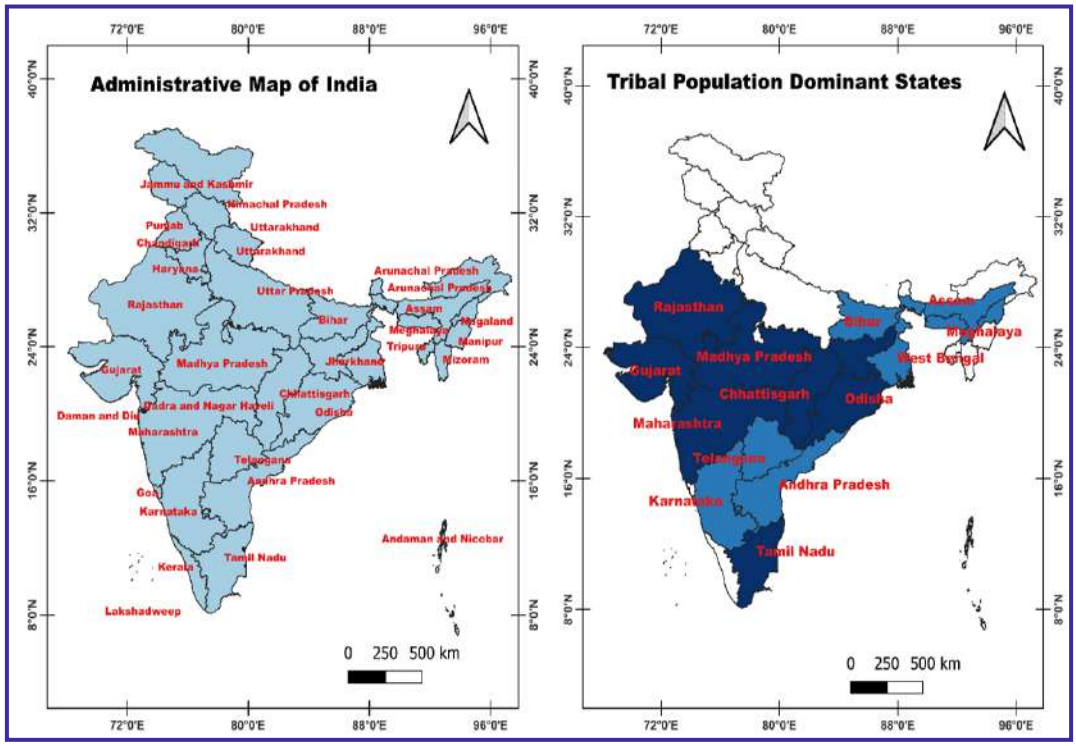
Limitations of the Study

The study is limited by the availability and consistency of secondary data sources. Census data offer benchmarks only every ten years, up to 2011, while the 2022–23 literacy estimate comes from the PLFS and should not be treated as a new Census measurement. UDISE+ and AISHE also employ distinct reporting structures and definitions for age and education stages. The study does not use data at the individual level, so it cannot identify the direct effects of gender norms or policy actions. When analysing the long-term trends, these restrictions must be taken into account.

Study area

The study encompasses all Scheduled Tribes in India, utilising national-level secondary data from the Census of India, PLFS, UDISE+, AISHE, and reports from the Ministry of Tribal

Affairs. The analysis concentrates on a national-level examination, highlighting variations over time, gender, and educational levels rather than providing a conventional description of India's geography.



Source: *Prepared by Author*

Figure 1 : Study Area & Tribal Population Dominant States

Result and Discussion

Long term literacy trends among STs

Analysis of literacy rates and Gross Enrolment Ratios among Scheduled Tribes over the past six decades shows significant educational progress, which can be attributed to policy interventions and increased educational access. Significant disparities persist, particularly across gender and among those with higher levels of education. This section examines these trends, compares special education outcomes with national averages, and highlights the key challenges that continue to impede educational equity and inclusion.

Table 2 : Literacy Rates among Scheduled Tribes and the General Population

Year	All (in %)			ST (in %)		
	Person	Male	Female	Person	Male	Female
1961	28.3	40.4	15.35	8.53	13.83	3.16
1971	34.45	545.96	21.97	11.3	17.63	4.85
1981	43.57	56.38	29.76	16.35	24.52	8.04
1991	52.21	64.13	39.29	29.6	40.65	18.19
2001	64.84	75.26	53.67	47.1	59.17	34.76
2011	73	80.9	64.6	59	68.5	49.4
2022 -23 (PLFS 2022 -23)	80.3	86.2	74.2	73.6	80.4	66.7

Source: *Census of India (1961 to 2011), Office of the Registrar General & Census Commissioner, India, Ministry of Home Affairs, Government of India; Periodic Labour Force Survey (**PLFS) 2022–23**, Ministry of Statistics and Programme Implementation (MoSPI), Government of India; Ministry of Tribal Affairs (MoTA) Annual Report 2023–24, Government of India.*

Current study indicates a pattern of advancement accompanied by enduring disparities. Over the past six decades, the literacy rate among Scheduled Tribes has seen a substantial increase, rising from 8.53% in 1961 to 73.6% in 2022-23(PLFS), in contrast to the overall population's literacy rate, which increased from 28.3% to 80.3%. The remaining gap of 6.7 percentage points suggests that the literacy level of Scheduled Tribes has not yet reached the national average. The significant increase in literacy among Scheduled Tribes noted in this study is also supported by previous research. Pothal and Panda (2017) found that literacy rates among tribal communities in Odisha have improved over time, but differences based on gender, region, and socio-economic background still affect educational outcomes. Similarly, Dutta and Bisai (2019) observed variations in literacy levels among tribal communities in Meghalaya and highlighted the ongoing disparity between male and female literacy. Biswas and Sharma (2022) also noted that, despite improvements in literacy and school enrolment, Scheduled Tribes in West Bengal continue to face educational disadvantages compared to non-ST groups.

Despite significant advancements, continued action is required to guarantee that tribal communities, particularly those encountering issues related to gender, geography, and socio-economic circumstances, can access educational opportunities on a level playing field.

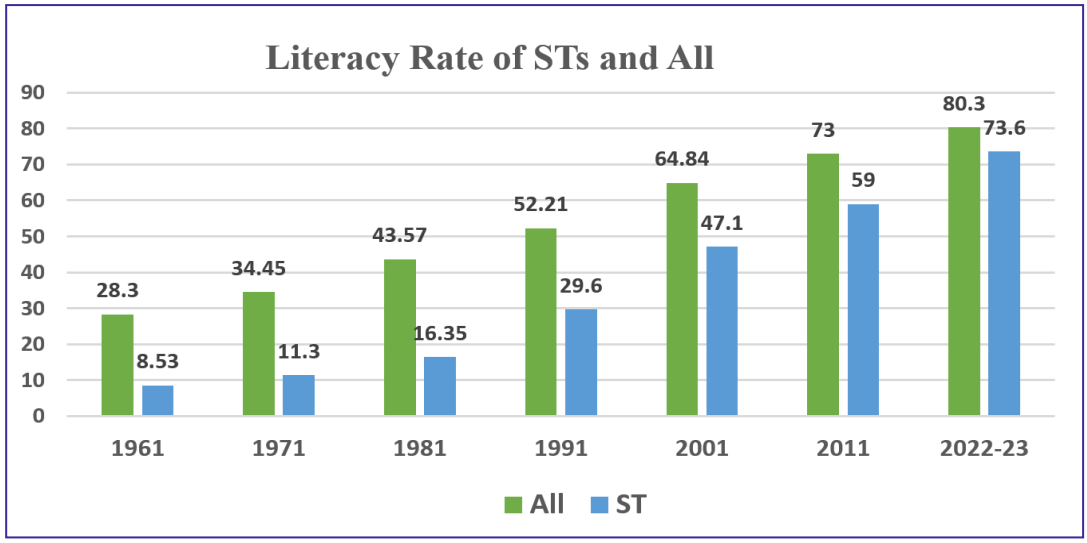


Figure 2: Literacy Rate of Scheduled tribes and All (General Population)

This impressive growth reflects the impact of constitutional provisions, affirmative action policies, and targeted interventions such as scholarships and residential schools. However, the ST literacy rate continues to lag behind the national average, indicating that educational disparities remain significant despite decades of effort.

Statistical Analysis

The linear regression analysis indicates a strong and statistically significant upward trend in Scheduled Tribe (ST) literacy over the study period. Treating 2022–23 as 2022.5 to reflect its survey-period nature, the fitted regression equation is

$\hat{Y} = -2217.43 + 1.131(\text{Year})$

where $\hat{Y}$ represents the estimated ST literacy rate (%). The slope coefficient of **1.131** indicates an average increase of approximately 1.13 percentage points in ST literacy per year over the observed period. The model explains approximately **96% of the variation in literacy rates ($R^2 = 0.96$)**, demonstrating a strong long-term upward trend.

For 2030:

$\hat{Y}_{2030} = -2217.43 + (1.131 \times 2030)$

$\mathbf{\hat{Y}_{2030} \approx 77.0\%}$

Thus, if the historical linear trend continues at approximately the same rate, the ST literacy rate could reach around 77.0% by 2030. However, this estimate should be interpreted as an indicative scenario rather than a precise forecast, as literacy growth may change over time due

to variations in educational access, retention, gender disparities, socio-economic conditions, regional inequalities, policy implementation, and future changes in data sources and methodology. Nevertheless, the regression results demonstrate substantial long-term progress and suggest that sustained, targeted interventions will be essential for further reducing educational disparities and advancing SDG 4: Quality Education among Scheduled Tribes in India.

Gender Disparities in ST Literacy

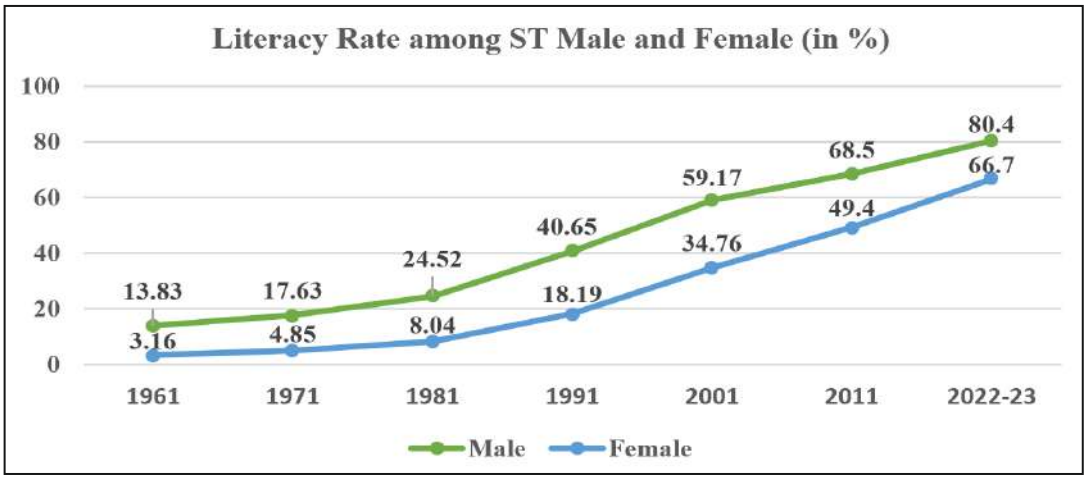


Figure 3 : Literacy Rate among Scheduled tribes Male and Female

The literacy trends by gender, as found in this study, align closely with previous research on tribal education. Ghosh (2007) conducted a comparison of Scheduled Tribes in Jharkhand and West Bengal and noted that while educational conditions had improved, tribal women still faced more disadvantages than men. More recently, Rani and Kumar (2023) reported a 21% literacy gap between male and female Scheduled Tribes in Jharkhand, based on data from the 2011 Census, and pointed out poverty, low levels of parental education, and domestic responsibilities as key factors affecting women's access to education.

The study, however, shows a positive change over time. Literacy among Scheduled Tribes' females has risen substantially, from 3.16% in 1961 to 66.7% in 2022-23, whereas male literacy has increased from 13.83% to 80.4%. Consequently, the disparity in literacy between the genders has narrowed to roughly 13.7 percentage points (Figure 3). Tribal women have made significant advances in education over the years, as evidenced by this considerable progress. The ongoing disparity in literacy rates between men and women indicates that gender-based educational inequalities remain unresolved. Ongoing focus on girls' education, especially in socially and economically disadvantaged tribal regions, remains essential.

Gross Enrolment Ratio and Educational Progression

Table 3 : Gross Enrolment Ratio (GER) among Scheduled Tribe Students

Level/Year	Primary (I-V) 6-10 Years (in %)			Upper Primary (VI-VIII) 11-13 Years (in %)			Elementary (I-VIII) 6-13 Years (in %)		
	Girls	Boys	Overall	Girls	Boys	Overall	Girls	Boys	Overall
2017-18	106.23	109.26	107.77	92.74	94.64	93.71	101.24	103.84	102.57
2018-19	105.64	107.63	106.66	92.18	93.62	92.92	100.66	102.45	101.57
2019-20	106.57	107.63	107.11	93.01	93.93	93.48	101.54	102.58	102.08
2020-21	106.62	106.81	106.72	95.42	96.1	95.77	102.46	102.88	102.68
2021-22	106.7	106.3	106.5	97.6	98.3	98	103.3	103.4	103.4

Level/Year	Secondary (IX-X) 14-15years (in %)			Senior Secondary (XI-XII) 16-17years (in %)			Higher Education 18-23 years (in %)		
	Girls	Boys	Overall	Girls	Boys	Overall	Female	Male	Overall
2017-18	73.11	72.99	73.05	39.37	39.51	39.44	14.9	17	15.9
2018-19	75.85	74.87	75.35	42.7	41.8	42.24	16.5	17.9	17.2
2019-20	77.24	76.22	76.72	43.9	41.92	42.89	17.7	18.2	18
2020-21	79.32	77.91	78.6	46.52	43.83	45.15	19.1	18.8	18.9
2021-22	79.2	77	78.1	53.6	50.5	52	20.9	21.4	21.2

Source: *Unified District Information System for Education Plus (UDISE+), Ministry of Education, Government of India (for School Education); All India Survey on Higher Education (AISHE) Reports, MHRD,(for Higher Education); Ministry of Tribal Affairs (MoTA) Annual Report 2023–24, Government of India.*

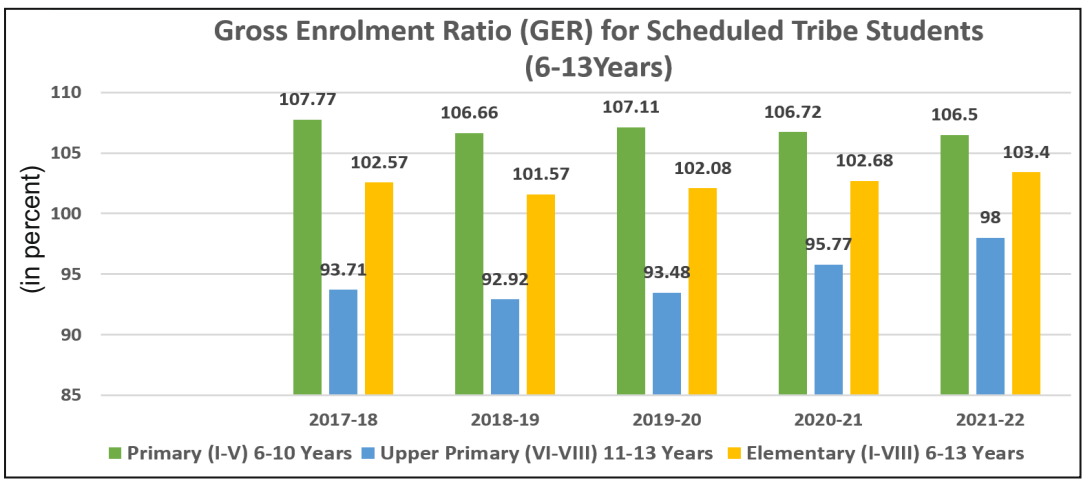


Figure 4: Gross Enrolment Ratio of Scheduled Tribe Students (Aged 6–13 Years), India

The Gross Enrolment Ratio (GER) data presents a contrasting picture across different levels of education (Figure 4). At the elementary level (Classes I-VIII), ST students have shown highly encouraging results. The overall Elementary GER reached 103.4% in 2021–22, indicating not only near-universal access but also some over-enrolment, possibly due to late admissions and grade repetitions. Both girls and boys achieved GER above 100%, reflecting the significant success of government interventions such as Sarva Shiksha Abhiyan and the Right to Education Act in ensuring enrolment at primary and upper primary stages.

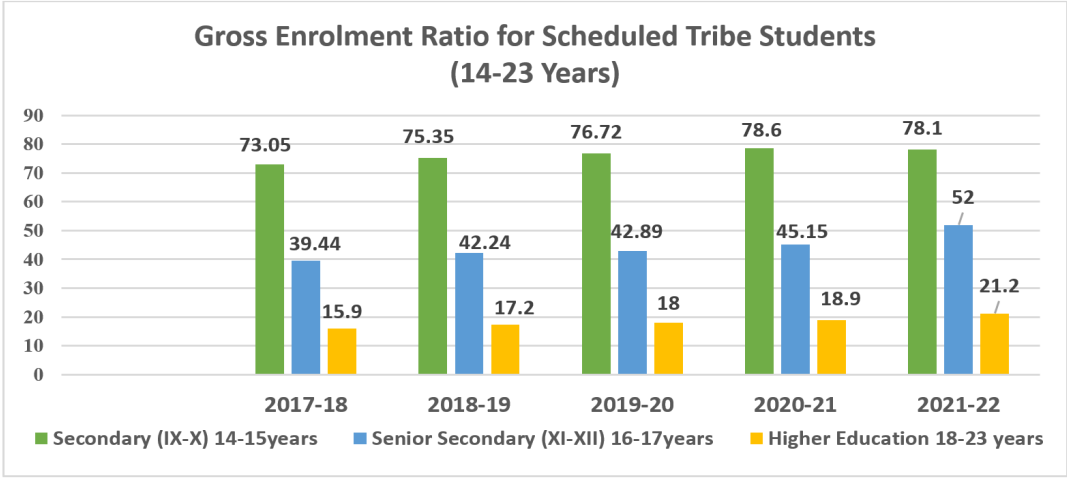


Figure 5 : Gross Enrolment Ratio of Scheduled Tribe Students (Aged 14–23 Years), India

However, a sharp and concerning decline in GER is observed as students' progress to higher levels of schooling (Figure 5). At the secondary level (Classes IX–X), the overall GER drops to 78.1%, which further decreases to 52% at the senior secondary level (Classes XI–XII). The situation is most critical in higher education (18–23 years), where the GER stands at a low 21.2% in 2021–22. Although girls perform slightly better or on par with boys at the secondary level, the gender gap tends to widen again in higher education.

Tribal communities have traditionally struggled with gaining access to education and continuing it beyond the elementary stage, as noted by Xaxa in 2014.The current results indicate a similar trend. The 2021-22 Elementary Gross Enrolment Ratio of 103.4% suggests that more tribal students are now entering elementary education than previously. At higher levels, the numbers drop significantly, reaching 78.1% at the secondary level, 52.0% at the senior secondary level, and only 21.2% in higher education. Getting tribal children into the education system has improved, but retaining them as they advance to higher levels remains a significant challenge. The research supports Xaxa's (2014) assertion that merely increasing access is insufficient; there is also a requirement for greater emphasis on retaining students in

school, facilitating their progression through successive levels, and offering improved opportunities for higher education among tribal students.

Dropout and Retention Challenges

Table 4 : Drop-Out Rates in School Education for Scheduled Tribe Students

Years	Primary			Upper Primary			Secondary		
	Girls	Boys	Overall	Girls	Boys	Overall	Girls	Boys	Overall
2017-18	3.48	3.82	3.66	6.14	5.95	6.04	21.36	22.90	22.14
2018-19	5.23	5.72	5.48	6.46	6.89	6.69	23.38	26.40	24.93
2019-20	3.61	4.06	3.85	5.81	6.30	6.06	22.65	25.64	24.18
2020-21	2.31	2.72	2.52	4.69	5.36	5.02	19.65	22.14	20.91
2021-22	2.60	3.04	2.83	5.70	6.35	6.03	15.33	17.87	16.62

Source: *Unified District Information System for Education Plus (UDISE+), Ministry of Education, Government of India & Ministry of Tribal Affairs (MoTA) Annual Report 2023–24*

Table 3 shows dropout rates of Scheduled Tribe students from 2017-18 to 2021-22. Dropout rates are lowest at the primary level (2.52%–3.85%) and highest at the secondary level (16.62%–24.93%). Although rates have declined over the years, especially at the secondary stage, they remain significantly high, indicating retention challenges. Girls consistently show slightly lower dropout rates than boys across most levels.

Gender Gap Index in Dropout Rate

The gender gap was measured as: $\frac{D_B - D_G}{(D_B + D_G)/2} \times 100$

Interpretation

- **GGI > 0:** Boys have a higher dropout rate than girls.
- **GGI < 0:** Girls have a higher dropout rate than boys.
- **GGI = 0:** No gender gap.

Year	Primary	Upper Primary	Secondary
2017–18	9.32%	-3.14%	6.96%
2018–19	8.95%	6.44%	12.13%
2019–20	11.73%	8.09%	12.38%
2020–21	16.30%	13.33%	11.92%
2021–22	15.60%	10.79%	15.30%

The gender gap was consistently positive at the primary and secondary levels, indicating higher dropout among boys. At the secondary level, the gap was particularly pronounced, increasing from 6.96% to 15.30%. At the upper-primary level, girls had a slightly higher dropout rate in 2017–18, but thereafter the gap favoured girls. Overall, the findings indicate a persistent gender disparity in dropout, particularly at the secondary level.

Trend Regression Analysis

The temporal trend was estimated using the linear regression model: $Y = a + bX$

where Y is the dropout rate, X is the year/time period, a is the intercept, and b represents the annual trend coefficient.

Level	Group	Regression Equation	R^2	Trend
Primary	Girls	Y=4.850−0.468X	0.420	Declining
Primary	Boys	Y=5.240−0.456X	0.380	Declining
Primary	Overall	Y=5.054−0.462X	0.400	Declining
Upper Primary	Girls	Y=6.555−0.265X	0.393	Declining
Upper Primary	Boys	Y=6.389−0.073X	0.042	Almost stable
Upper Primary	Overall	Y=6.475−0.169X	0.199	Slightly declining
Secondary	Girls	Y=25.211−1.579X	0.607	Strong decline
Secondary	Boys	Y=27.286−1.432X	0.450	Declining
Secondary	Overall	Y=26.274−1.506X	0.525	Declining

The regression results show a declining dropout trend across most education levels. The strongest decline occurred at the secondary level, with the overall dropout rate decreasing by approximately 1.51 percentage points per year. Primary dropout also showed a consistent declining trend. In contrast, upper-primary boys' dropout showed almost no systematic trend (R2=0.042R^2=0.042), indicating considerable year-to-year variation

The combined analysis indicates that dropout rates generally declined over the study period, but gender disparities persisted. The secondary level remains the most critical stage, showing both a substantial decline in dropout and the largest gender gap.

Despite significant progress in improving basic literacy and elementary school enrollment among Scheduled Tribes in India, major challenges persist in retaining students in school, facilitating a smooth transition to higher levels of education, and achieving equity in secondary and higher education. The problems in question underscore the necessity for concentrated

endeavours to go beyond the primary level. Greater priority should be given to upgrading school infrastructure, incorporating multilingual teaching methods, effectively administering scholarships for students' post-matriculation, and providing enhanced academic assistance. Ensuring that tribal communities in India have access to equitable and quality education is crucial for achieving Sustainable Development Goal 4.

Major Challenges in the Education of Scheduled Tribes

Despite notable progress in literacy and elementary enrolment, several persistent challenges continue to hinder the educational development of Scheduled Tribes in India.

The most significant challenge is the sharp decline in Gross Enrolment Ratio after elementary education. High dropout rates at secondary and higher education levels are largely driven by poverty, as many tribal families depend on children for household income and agricultural work (Mehta, 2024). Geographic isolation remains another critical barrier. Most ST communities reside in remote, hilly, and forested areas with poor road connectivity, making regular school attendance difficult, especially during monsoon seasons (Kujur, 2026).

Language barriers present a significant impediment. In most schools, the regional language or English is the primary medium of instruction, differing substantially from tribal dialects and resulting in low comprehension and high dropout rates among tribal children (Sujatha, 2018). The situation is further exacerbated by inadequate school infrastructure, teacher shortages, and a lack of trained teachers in areas predominantly inhabited by tribes.

Gender-specific challenges are particularly pronounced. Tribal girls often face early marriage, domestic responsibilities, and safety concerns while traveling to distant schools, resulting in lower retention at higher levels of education (Mitra & Singh, 2008). Other contributing factors include cultural alienation from the mainstream curriculum, lack of relevant vocational education, and limited awareness about higher education opportunities and scholarships.

Despite constitutional safeguards and various welfare schemes, the interconnected challenges explain why educational disparities between Scheduled Tribes and the general population continue to exist.

Major Government Initiatives Relevant to Tribal Education

The Government of India has launched various targeted educational initiatives to improve access, increase student retention, lower costs, and broaden learning opportunities for Scheduled Tribe (ST) communities. The table highlights the key educational significance of these major initiatives and their connection to the core challenges in ST education, including remote locations, limited educational access, transitions between educational levels, financial constraints, and inadequate school infrastructure.

Table 5 : Major Educational Initiatives and Their Relevance to Identified Educational Gaps among Scheduled Tribes

Initiative	Broad Educational Relevance	Link with Identified Gap
Eklavya Model Residential Schools (EMRS)	Residential schooling and improved access for ST students	Addresses remoteness, transition and access to secondary/higher levels
Ashram Schools	Residential/Educational support in tribal areas	Reduces geographic and access barriers
Samagra-Shiksha	Integrated school education support	Supports infrastructure, retention and quality
Scholarship programmes	Financial support across educational stages	Reduces household cost barriers and supports continuation
PM-JANMAN	Targeted development support for PVTGs, including education-related interventions	Addresses extreme spatial and service-access disadvantage

Recommendations

1. **Strengthen Retention and Transition Support:** Special focus should be given to reducing dropout rates at the secondary and senior secondary levels. The government should expand bridge courses, remedial coaching, and academic support programs for ST students transitioning from elementary to secondary education.
2. **Improve Infrastructure in Tribal Areas:** There is an urgent need to upgrade school infrastructure in remote tribal regions. This includes constructing more residential schools (especially Eklavya Model Residential Schools), ensuring reliable transportation facilities, and providing adequate hostels for both boys and girls.
3. **Promote Multilingual Education**: The curriculum should incorporate tribal languages in the early years of schooling to reduce language barriers. Implementation of the National Education Policy (2020) recommendation on mother tongue-based education should be prioritized in tribal-dominated areas.
4. **Targeted schemes for tribal girls** should be strengthened to include enhanced scholarships, safe transportation, self-defence training, and awareness programs to prevent early marriage. Families may receive special incentives for continuing girls' education beyond Class VIII**.**

5. **Increase Focus on Higher Education**: Post-matric scholarships, coaching for competitive examinations, and reservation implementation in higher educational institutions need better monitoring and effective delivery. Vocational and skill-based courses relevant to tribal economies should be introduced.
6. **Community Participation and Awareness:** Greater involvement of tribal communities, Gram Sabhas, and local leaders in school management and decision-making can improve accountability and ownership of educational institutions.
7. **A robust monitoring mechanism** using UDISE+ data should be set up to track student progression from elementary to higher education, with regular assessments of the scheme's effectiveness.

Conclusion

The study concludes that while India has made substantial progress in expanding educational access among Scheduled Tribes, particularly in terms of literacy and elementary enrolment, significant disparities persist at higher levels of education. The sharp rise in literacy rates and improved gender parity reflect the positive impact of sustained policy interventions and welfare schemes. However, the steep decline in Gross Enrolment Ratios beyond the elementary stage highlights enduring structural barriers such as poverty, geographical isolation, inadequate infrastructure, and limited access to quality secondary and higher education.

Addressing these challenges requires a shift from mere access-oriented policies to a more comprehensive approach focused on retention, transition, and learning outcomes. Strengthening secondary schooling infrastructure, providing targeted financial and academic support, promoting culturally relevant education, and enhancing institutional inclusivity are essential to ensure continuity in education for ST students. Without such focused efforts, the gains achieved at the primary level may not translate into long-term socio-economic empowerment.

Bridging the educational gap for Scheduled Tribes is not only a matter of equity but also a necessary step for inclusive national development and the achievement of Sustainable Development Goal 4.

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MIGRATION, LIVELIHOOD DIVERSIFICATION AND OCCUPATIONAL TRANSFORMATION IN THE FLOOD-PRONE AGRO-CLIMATIC ZONE-II OF BIHAR

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ABSTRACT

Migration has emerged as a critical livelihood strategy in rural Bihar, particularly in environmentally vulnerable regions where agriculture alone is insufficient to sustain household livelihoods. This study examines the role of migration in shaping occupational diversification, livelihood outcomes, household vulnerability and sustainable rural development in Agro-Climatic Zone II (North-East Alluvial Plain) of Bihar. The analysis is based on primary household survey data collected under an ICSSR-funded research project using a multistage sampling design covering 1,095 rural households across selected villages of Purnea, Saharsa and Supaul districts. Livelihood diversification was assessed using the Simpson Diversity Index (SDI) and Shannon Diversity Index (SHDI), while household resilience was evaluated through the Livelihood Vulnerability Index (LVI). Descriptive statistics, multiple regression, were employed to examine the relationship between migration, occupational choices, income and vulnerability. The findings reveal that inter-state migration is the dominant form of mobility and serves as the principal driver of occupational transition from farm and off-farm activities towards non-farm employment. Migrant households earn approximately 45% higher household income than non-migrant households and exhibit greater livelihood diversification. However, despite higher incomes, migrant households continue to experience relatively greater livelihood vulnerability due to dependence on external labour markets and employment uncertainty. The study concludes that migration has become a structural component of rural livelihoods, contributing significantly to income diversification, occupational mobility and rural transformation. It recommends policies promoting safe and productive migration, skill development, rural non-farm enterprises, financial inclusion and social protection to transform migration from a distress-driven survival strategy into a pathway for sustainable and inclusive rural development.

Keywords: *Farm, Off-Farm, Non-Farm, Occupational Diversification, Household Vulnerability Sustainable Development and Rural Bihar.*

Introduction

Migration has emerged as a major livelihood strategy and an important component of rural socio-economic transformation in the flood-prone **Agro-Climatic Zone II (ACZ II) of Bihar**. Bihar, located in the Middle Gangetic Plains, is divided into four agro-climatic zones based on

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variations in soil, rainfall, temperature and terrain: **Zone I—North-West Alluvial Plain; Zone II—North-East Alluvial Plain; Zone IIIA—South-East Alluvial Plain; and Zone IIIB—South-West Alluvial Plain** (Government of Bihar). ACZ II lies largely within the **Kosi basin** and is characterized by recurrent flooding, river-bank erosion, waterlogging, sand deposition, agricultural uncertainty and seasonal unemployment. Population pressure, fragmented landholdings and climatic shocks further constrain the capacity of agriculture to provide stable livelihoods. Consequently, migration has increasingly evolved from a temporary coping mechanism into an integral component of rural household livelihood strategies (de Haan, 1999; Ellis, 2000).

Table 1 : Districts under Different Agro-Climatic Zones of Bihar

S. No.	Agro-Climatic Zone	Districts	No. of Districts
1	**Agro-Climatic Zone I (North-West Alluvial Plain)**	West Champaran, East Champaran, Siwan, Saran, Sitamarhi, Sheohar, Mauzaffarpur, Vaishali, Madhubani, Darbhanga, Samastipur, Gopalganj, Begusarai	13
2	**Agro-Climatic Zone II (North-East Alluvial Plain)**	Purnea, Katihar, Saharsa, Supaul, Madhepura, Khagaria, Araria, Kishanganj	8
3	**Agro-Climatic Zone III A (South - East Alluvial Plain)**	Sheikhpura, Munger, Jamui, Lakhisarai, Bhagalpur, Banka	6
4	**Agro-Climatic Zone III B (South - West Alluvial Plain)**	Rohtas, Bhojpur, Buxar, Bhabhua, Arwal, Patna, Nalanda, Nawada, Jehanabad, Aurangabad, Gaya	11
	Total	**Bihar**	**38**

Source: *Government of Bihar, Department of Agriculture.*

The theoretical understanding of migration has evolved from explanations based on spatial and economic inequalities to approaches emphasizing household livelihood strategies. Ravenstein (1885, 1889) and Lee (1966) explained migration through economic differentials and push–pull factors, while Lewis (1954) and Harris and Todaro (1970) linked migration to structural transformation and expected income differences. The New Economics of Labour Migration further conceptualized migration as a household strategy for managing risk, overcoming market constraints and diversifying income (Stark & Bloom, 1985). Similarly,

Ellis (2000), Barrett et al. (2001) and de Haan (1999) established migration as an important component of rural livelihood diversification, particularly through remittances and access to non-farm employment. Deshingkar and Farrington (2009) further highlighted the role of circular and multilocational migration in sustaining rural livelihoods.

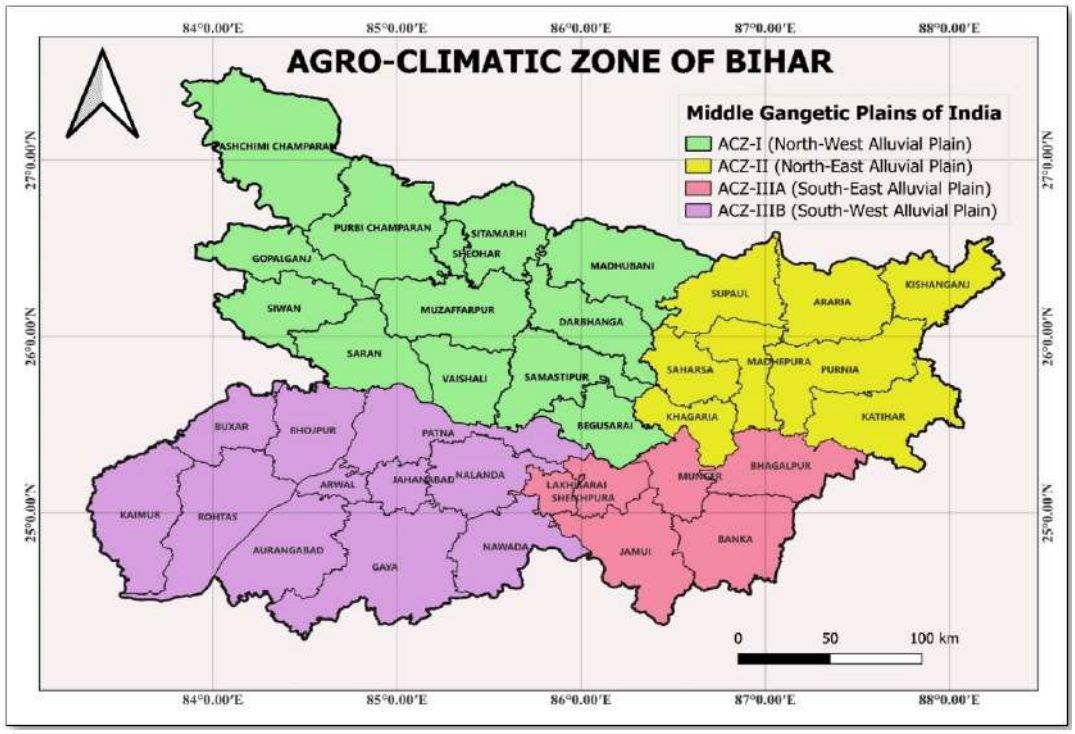


Figure 1 : Agro-Climatic Zone of Bihar (prepare by Authors)

In India, migration is closely associated with regional disparities in employment and livelihood opportunities, with Bihar being a major labour-sending state (Kundu, 2007). Historically associated with poverty and limited local employment opportunities (Karan, 2003), migration from Bihar has increasingly become a mechanism for income generation, remittance receipt and occupational diversification (Kundu & Saraswati, 2012). Remittances can support both agricultural investment and non-farm activities, thereby contributing to changes in rural livelihood structures (Reardon et al., 2006). Recent studies further show that migration and remittances influence household labour allocation, occupational choice, non-farm employment and agricultural investment, although these outcomes vary with migration type, skills, landholding and socio-economic characteristics (Dey, 2022; Sreekumar et al., 2024; Sarkar & Reshmi, 2024).

The significance of migration is particularly pronounced in environmentally vulnerable regions such as ACZ II. In such areas, migration can function not only as an income-enhancing strategy but also as a means of managing risks arising from crop losses, agricultural seasonality and limited local employment. Recent evidence indicates that local non-farm opportunities may initially support livelihood diversification, while migration becomes increasingly important when such opportunities are inadequate (Sreekumar et al., 2024). Evidence from Bihar also indicates that diversified livelihood portfolios can improve household resilience to income shocks, although migration does not necessarily eliminate vulnerability (Dhar et al., 2022).

Despite these contributions, existing studies have generally examined **migration, livelihood diversification, income and vulnerability as separate dimensions**. Limited attention has been given to how the **form and intensity of migration simultaneously shape farm, off-farm and non-farm occupational choices, household income composition and livelihood vulnerability within different agro-climatic settings**. This gap is particularly relevant to Bihar, where widespread migration coexists with substantial regional differences in agricultural conditions and local employment opportunities. The present study addresses this gap through a household-level analysis of the selected study area, examining migration patterns, remittances, occupational transformation and livelihood diversification within an integrated framework.

Study Area: Agro-Climatic Zone II

The present study was conducted in **Agro-Climatic Zone II (ACZ II)** of Bihar, popularly known as the **North-East Alluvial Plain**. This agro-climatic zone comprises nine districts, namely Supaul, Saharsa, Madhepura, Purnea, Araria, Kishanganj, Katihar and Khagaria.

Table 2 : Number of sample village

SL No	Agro-climatic Zone	No. of Districts	No. of Sample Districts	Name of Sample Districts	Number of Villages	Households
Zone II	North-East Alluvial Plains	8	3	Supaul, Madepura and Purnea	18 (6 in each district)	1095 (60 in each village)

For the present investigation, three districts—Supaul, Madhepura and Purnea—were purposively selected from ACZ II to capture the geographical and socio-economic diversity within the zone. From these districts, 18 villages (6 in each district) were selected for detailed household surveys, ensuring representation of varying levels of agricultural dependence, migration intensity and occupational diversification.

The **North-East Alluvial Plain (Agro-Climatic Zone II)** forms an important part of the Middle and Lower Indo-Gangetic Plain and is characterized by fertile alluvial soils, high monsoonal rainfall and a dense network of Himalayan rivers, particularly the **Kosi** and **Mahananda** systems (ICAR–NBSS&LUP, 2022). Frequent flooding, river course changes and sediment deposition make the region both agriculturally productive and environmentally vulnerable, especially in the Kosi basin, often called the "*Sorrow of Bihar*" (Government of Bihar, 2020).



Figure 2 : Location of Sample Villages in Agro Climatic Zone II (prepared by Authors)

The region comprises low-lying floodplains with poor drainage, a high groundwater table and predominantly small and fragmented landholdings. Annual rainfall ranges between 1,200 and 1,700 mm, with more than 85% received during the southwest monsoon, supporting a long growing season but also causing recurrent waterlogging (ICAR–CRIDA, 2021).

Table 3: Demographic detail of Sample Villages

District	Block	Sample Village	Population (2011)	Households	Male	Female	Sex ratio	Literacy (%)
Purnea	Rupauli	Koili Semra	22,208	4,351	11,629	10,579	909	49.36*
Purnea	Rupauli	Goriar	26,408	5,473	13,728	12,680	924	53.01
Purnea	Purnea	Lalgani	11,045	2,078	5,757	5,288	919	44.58
Purnea	Dhamdaha	Damaili	5,816	1,211	3,052	2,764	906	46.92
Purnea	Purnia	Mahraj Pur	5,505	1,022	2,840	2,665	938	28.90
Purnea	Dhamdaha	Mogalia Puran Daha	24,908	4,954	12,847	12,061	939	49.51
Saharsa	Nauhatta	Dumra	2,382	468	1,237	1,145	925	39.53*
Saharsa	Nauhatta	Garhia	1,855	392	964	891	924	52.90
Saharsa	Salkua	Bhelwa	2,235	473	1,155	1,080	935	38.79
Saharsa	Kahra	Nariyar	2,973	606	1,539	1,434	932	35.25
Saharsa	Saharsa	Salkua	8,987	1,600	4,724	4,263	902	58.12
Supaul	Supaul	Chainsingh Patti	8,045	1,427	4,142	3,903	942	48.62
Supaul	Nirmali	Harhiyahi	3,745	682	1,934	1,811	936	59.20
Supaul	Marauna	Ghoghararia	5,005	1,100	2,603	2,402	924	46.57
Supaul	Supaul	Kharail	2,472	477	1244	1228	987	50.97
Supaul	Nirmali	Sikrahata	3,532	700	1,862	1,670	896	42.60
Supaul	Marauna	Lalminiya	8,207	1,649	4,217	3,990	946	41.81``

Source: Census of India 2011, Primary Census Abstract (PCA) and District Census Handbook (DCHB), Bihar; village-level data compiled by the authors.

Agriculture is the principal livelihood, with paddy, maize, wheat, jute, pulses and oilseeds as major crops, while fisheries and livestock are increasingly important in flood-prone areas. Districts such as Purnea and Katihar have emerged as major maize and jute producers, whereas Supaul, Saharsa and Madhepura remain highly vulnerable to floods. Although the region possesses immense potential for agricultural commercialization due to fertile soils, abundant water resources and proximity to eastern markets, inadequate infrastructure, recurrent climatic hazards and dependence on rain-fed agriculture continue to constrain livelihood security and encourage seasonal migration (Census of India, 2011).

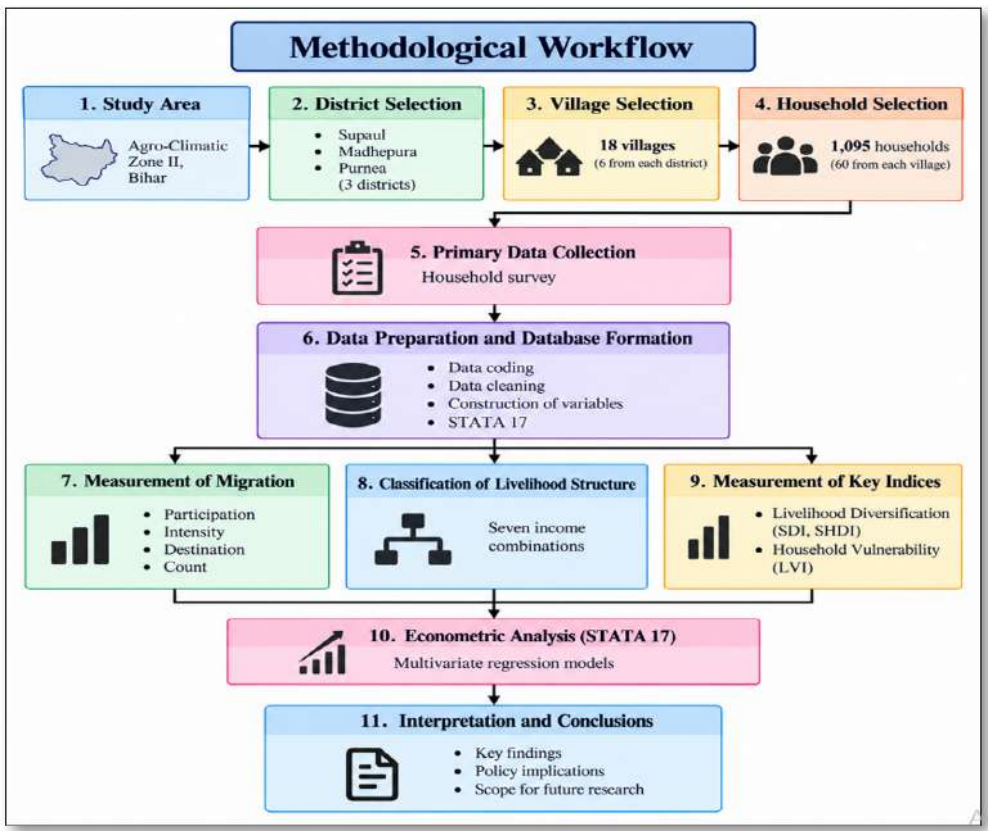
Methodology and Database

The study is based on primary household-level survey data collected under an ICSSR-funded research project from Agro-Climatic Zone II (North-East Alluvial Plains) of Bihar. Agro-

Climatic Zone II comprises eight districts, of which three districts—**Supaul, Madhepura and Purnea**—were selected as sample districts. From these three districts, 18 villages (six villages from each district) were selected for household-level investigation. A total of 1,095 households were surveyed, with 60 households selected from each sample village.

A **multistage sampling** was **designed** to capture household-level variations in livelihood activities, migration behaviour and socioeconomic conditions within this agro-climatic setting. The **household questionnaire** collected information on a broad range of socioeconomic and livelihood characteristics. These included household size and demographic composition, educational attainment, landholding, occupational structure, farm, off-farm and non-farm activities, income from different sources, migration status and intensity, migration destination, number of migrants, remittances and household vulnerability. Information on these characteristics provides the basis for examining how migration is associated with changes in **Figure 3** : Methodological Workflowthe occupational and livelihood structure of rural households.

Analytical Framework



The analytical framework considers migration as an important mechanism linking household vulnerability, occupational transition and livelihood diversification. Migration was examined through multiple dimensions, including migration participation, migration intensity, migration destination and migration count. The livelihood structure of households was further classified into **seven** mutually identifiable income combinations: **Farm Only, Off-Farm Only, Non-Farm Only, Farm and Off-Farm, Farm and Non-Farm, Off-Farm and Non-Farm, and Farm, Off-Farm and Non-Farm**. These categories were used to examine the association between migration and different forms of occupational and livelihood diversification.

Measurement of Livelihood Diversification and Household Vulnerability

Livelihood diversification was measured using two complementary indices: the **Simpson Diversity Index (SDI)** and the **Shannon Diversity Index (SHDI)**. The SDI measures the degree of concentration or diversification of household income, with values ranging from 0, representing complete specialization, to 1, representing maximum diversification. The index gives greater weight to dominant income sources (Simpson, 1949; Ellis, 2000). The SHDI considers both the richness of income sources and the evenness of their distribution across sources, thereby capturing smaller income-generating activities that may receive less weight under concentration-based measures (Shannon, 1948; Magurran, 2004). The combined use of SDI and SHDI provides a broader assessment of household livelihood diversification by capturing both the concentration and distributional dimensions of livelihood income.

Household vulnerability was assessed using the **Livelihood Vulnerability Index (LVI)**. The LVI is a composite measure that integrates different dimensions of household vulnerability, including socio-demographic, economic, livelihood and environmental conditions. The index ranges from 0 to 1, where higher values indicate greater livelihood vulnerability and lower adaptive capacity, while lower values indicate relatively lower vulnerability (Hahn et al., 2009; IPCC, 2007). The LVI was used to examine whether differences in migration and livelihood diversification are associated with differences in household vulnerability.

Statistical Methods

The empirical analysis was conducted using STATA 17. **Multivariate regression models** were employed to examine the relationship between migration, livelihood diversification, household income and livelihood vulnerability while controlling for relevant household-level socioeconomic characteristics. Separate multivariate regression specifications were used for the relevant dependent variables to examine how migration participation, migration intensity, migration count and other household characteristics are associated with occupational diversification, income and household vulnerability.

Data Interpretation and Analysis

The household-level migration pattern reveals significant spatial variation across the study villages of Purnea, Saharsa and Supaul districts, with **inter-state migration emerging as the dominant form of mobility**. Migration within the block, district and state is negligible in comparison, indicating that local labour markets are unable to generate sufficient employment opportunities. Consequently, **rural households increasingly depend on distant labour markets outside Bihar as a major livelihood strategy**.

Table 4 : Migration pattern of Sample Household (Computed by Authors)

District	Household wise Migration	Household	No Migration	Migration (HH)	Total Migrants	% Migration by HH	% Within Block	% Within District	% Within State	% Inter State	% International
	Village										
Purnea	**Damaili**	62	28	34	44	54.84	0.00	0.00	0.00	100.00	0.00
	Goriar	61	21	40	56	65.57	0.00	0.00	0.00	100.00	0.00
	Koili Semra	60	36	24	31	40.00	0.00	0.00	0.00	100.00	0.00
	Lalganj	61	36	25	33	40.98	0.00	0.00	4.00	96.00	0.00
	Mahraj Pur	60	54	6	6	10.00	0.00	0.00	0.00	100.00	0.00
	Mogalia Puran Daha	61	14	47	61	77.05	0.00	0.00	4.26	95.74	0.00
Saharsa	**Bakunia**	60	18	42	49	70.00	2.38	2.38	2.38	92.86	0.00
	Bhelwa	60	25	35	52	58.33	0.00	2.86	5.71	91.43	0.00
	Dumra	62	28	34	57	54.84	0.00	2.94	0.00	97.06	0.00
	Garhia	61	22	39	52	63.93	0.00	5.13	5.13	89.74	0.00
	Nariyar	61	44	17	24	27.87	0.00	0.00	5.88	94.12	0.00
	Salkua	61	31	30	41	49.18	0.00	6.67	10.00	76.67	6.67
Supaul	**Chainsingh Patti**	60	9	51	60	85.00	0.00	29.41	1.96	68.63	0.00
	Ghogharaia	63	19	44	49	69.84	0.00	4.55	2.27	93.18	0.00
	Harhiyahi	61	21	40	61	65.57	0.00	2.50	0.00	95.00	2.50
	Karail	61	21	40	63	65.57	17.50	27.50	2.50	52.50	0.00
	Lalminiya	60	5	55	64	91.67	0.00	23.64	0.00	74.55	1.82
	Sikrahata	60	19	41	52	68.33	0.00	4.88	2.44	92.68	0.00
	Total	**1095**	**451**	**644**	**855**	**58.81**	**1.24**	**7.92**	**2.48**	**87.73**	**0.62**

District-wise comparison shows a clear hierarchy in migration dependence. **Purnea records comparatively lower migration participation**, whereas Saharsa exhibits moderate migration intensity. Supaul emerges as the most migration-intensive district, with villages such as Lalminiya, Karail, Harhiyahi and Chainsingh Patti reporting the highest numbers of migrant households and total migrants. This pattern reflects the combined effects of recurrent flooding, agricultural uncertainty and limited non-farm employment opportunities in the Kosi basin.

The comparison between migrant and non-migrant households further demonstrates that migration has become a widespread household strategy rather than an individual response. Moreover, in most villages the total number of migrants exceeds the number of migrant households, suggesting that multiple members from the same household migrate simultaneously. This highlights the transformation of **migration from an individual coping mechanism into a household-level livelihood diversification strategy** aimed at maximizing remittances and reducing livelihood risks.

Relationship between Demographic, Educational, Migration and Income Variables:

Migration emerges as an important household adaptation strategy in response to these demographic constraints. Villages characterized by high dependency ratios and limited labour-force participation, particularly in Supaul district, report the highest migration participation and migration intensity. Villages such as Chainsingh Patti, Lalminiya, Harhiyahi and Karail illustrate how migration compensates for local labour-market limitations by generating remittance income from external employment.

Table 5 : Household Characteristics of Sample Villages (Computed by Authors)

District	Village	Dependency Ratio	Earning Mem_HHSize_Ratio	Avrg_yrs_Edu	Mid Landholding	Migration(HH)	Total Migration	Migration Intensity	Ratio: Migration NonMigration	Total monthly Income (₹) ,
Purnea	Damaili	61.42	0.53	3.02	0.15	34	44	1.29	1.21	18051.61
Purnea	Goriar	74.57	0.40	6.42	0.56	40	56	1.40	1.90	19383.61
Purnea	Koili Semra	64.69	0.42	7.81	0.38	24	31	1.29	0.67	17213.33
Purnea	Lalganj	85.14	0.44	5.53	0.37	25	33	1.32	0.69	16827.87
Purnea	Mahraj Pur	61.94	0.44	5.65	0.73	6	6	1.00	0.11	17041.67
Purnea	Mogalia Puran Daha	70.68	0.40	6.79	0.36	47	61	1.30	3.36	19663.93
Saharsa	Bakunia	72.81	0.36	4.65	0.99	42	49	1.17	2.33	16088.33

District	Village	Dependency Ratio	Earning Mem_HHSize_Ratio	Avrg_yrs_Edu	Mid Landholding	Migration(HH)	Total Migration	Migration Intensity	Ratio: Migration NonMigration	Total monthly Income (₹) ,
Saharsa	Bhelwa	74.54	0.35	6.94	0.6	35	52	1.49	1.40	16450.00
Saharsa	Dumra	88.53	0.29	6.04	0.15	34	57	1.68	1.21	18048.39
Saharsa	Garhia	67.02	0.37	7.37	0.29	39	52	1.33	1.77	20557.38
Saharsa	Nariyar	71.10	0.36	7.93	0.17	17	24	1.41	0.39	19459.05
Saharsa	Salkua	54.48	0.34	10.27	1.02	30	41	1.37	0.97	21819.67
Supaul	Chainsingh Patti	89.98	0.22	6.51	0.07	41	60	1.46	4.56	22300.00
Supaul	Ghoghararia	77.98	0.20	7.36	0.68	22	26	1.18	1.16	18865.08
Supaul	Harhiyahi	62.58	0.19	8.06	0.35	44	61	1.39	2.10	20237.71
Supaul	Karail	52.36	0.22	8.06	0.38	42	63	1.50	2.00	20191.80
Supaul	Lalminiya	75.97	0.21	4.93	0.22	40	64	1.60	8.00	17433.33
Supaul	Sikrahata	70.40	0.19	5.17	0.33	37	52	1.41	1.95	19678.33

Educational attainment shows a more complex relationship with migration. **Higher levels of education do not necessarily reduce migration; instead, they appear to facilitate access to better employment opportunities outside the village**. Villages such as Salkua, Karail, Harhiyahi and Nariyar record relatively high average years of schooling while simultaneously exhibiting substantial migration participation. This indicates that education enhances labour mobility and enables households to secure more productive occupations rather than discouraging migration.

Landholding size exhibits a generally **negative association with migration**. Villages with smaller average landholdings, including Chainsingh Patti, Damaili, Dumra and Nariyar, display relatively high migration participation, reflecting the inability of fragmented agricultural holdings to provide sustainable livelihoods. In contrast, villages with comparatively larger landholdings, such as Salkua and Bakunia, show relatively lower migration dependence, suggesting that land ownership provides a degree of livelihood security and reduces the need for labour migration.

Migration is also strongly associated with improved household income. Villages with higher migration participation generally report higher average incomes, with Chainsingh Patti, Salkua, Garhia, Harhiyahi and Karail recording the highest income levels. Conversely,

villages with relatively low migration participation, such as Bakunia, Lalganj and Mahraj Pur, exhibit comparatively lower household incomes. Furthermore, villages with greater migration intensity—including Dumra, Lalminiya, Karail and Chainsingh Patti—also demonstrate higher income levels.

The migration in the study area functions both as a **necessity-driven response** to rural livelihood insecurity and as an **opportunity-driven strategy** for economic mobility, making it a structural component of contemporary rural livelihood systems in North Bihar.

Migration, Livelihood Diversification and Vulnerability:

The comparison between diversified and specialized households reveals a clear relationship between livelihood diversification, migration and livelihood vulnerability in rural Bihar. Among migrant households, 321 households (53.6%) possess diversified livelihoods (Simpson Index > 0), whereas 278 households (46.4%) remain specialized in a single livelihood activity. Diversified migrant households record a lower mean Livelihood Vulnerability Index (LVI = 0.559) than specialized migrant households (LVI = 0.607), indicating that **diversification helps reduce vulnerability by spreading risk across multiple income sources.**

Table 6 : Livelihood Diversification across Migrants (Computed by Authors)

Migration Status	Livelihood Diversification (Simpson Index)	N	Mean Simpson Index	Mean LVI
Migrant Households	Diversified (Simpson > 0)	321	0.279	0.559
	Specialized (Simpson = 0)	278	0	0.607
Total Migrants	**All Households**	**599**	**0.149**	**0.582**
Non-Migrant Households	Diversified (Simpson > 0)	231	0.336	0.496
	Specialized (Simpson = 0)	265	0	0.545
Total Non-Migrants	**All Households**	**496**	**0.156**	**0.522**

A similar trend is observed among non-migrant households, where 231 households (46.6%) are diversified and 265 households (53.4%) are specialized. Diversified non-migrant households exhibit a substantially lower vulnerability (LVI = 0.496) than specialized households (LVI = 0.545), demonstrating that livelihood diversification enhances resilience even in the absence of migration. However, a comparison across migration status shows that diversified migrant households remain more vulnerable (LVI = 0.559) than diversified non-

migrant households (LVI = 0.496), while specialized migrant households also experience higher vulnerability (LVI = 0.607) than specialized non-migrant households (LVI = 0.545). These findings suggest that **although migration contributes to livelihood diversification and income enhancement, it also exposes households to additional risks associated with temporary employment, labour market instability, seasonal migration and dependence on remittances**.

Table 7 : Distribution of Occupational diversification (Computed by Authors)

Diversification Category	Non-Migrant HH (n=496)	Percentage	Migrant HH (n=599)	Percentage
Farm Only	52	10.48	13	2.17
Farm and Non-Farm	145	29.23	213	35.56
Farm and Off-Farm	48	9.68	7	1.17
Farm, Off-Farm and Non-Farm	15	3.02	39	6.51
Non-Farm Only	170	34.27	262	43.74
Off-Farm Only	45	9.07	21	3.51
Off-Farm and Non-Farm	21	4.23	44	7.35
Total	**496**	**100**	**599**	**100**

The income diversification patterns indicate that **migrant households have more diversified livelihood portfolios than non-migrants**. Non-farm-only income is more common among migrants (43.74%) than non-migrants (34.27%), while farm–non-farm activities account for 35.56% and 29.23%, respectively. Migrants also show greater participation in farm–off-farm–non-farm (6.51% vs. 3.02%) and off-farm–non-farm activities (7.35% vs. 4.23%). In contrast, non-migrants are more concentrated in farm-only (10.48% vs. 2.17%) and off-farm-only (9.07% vs. 3.51%) livelihoods, indicating a stronger association of migration with **non-farm orientation and livelihood diversification**.

These findings indicate that migration not only shifts households towards higher-return non-farm activities but also promotes more diversified income portfolios by combining farm and non-farm sources. Overall, migrant households exhibit a more advanced stage of livelihood transformation, whereas non-migrant households remain relatively dependent on agriculture and traditional rural occupations, reflecting slower occupational diversification and limited access to external labour markets.

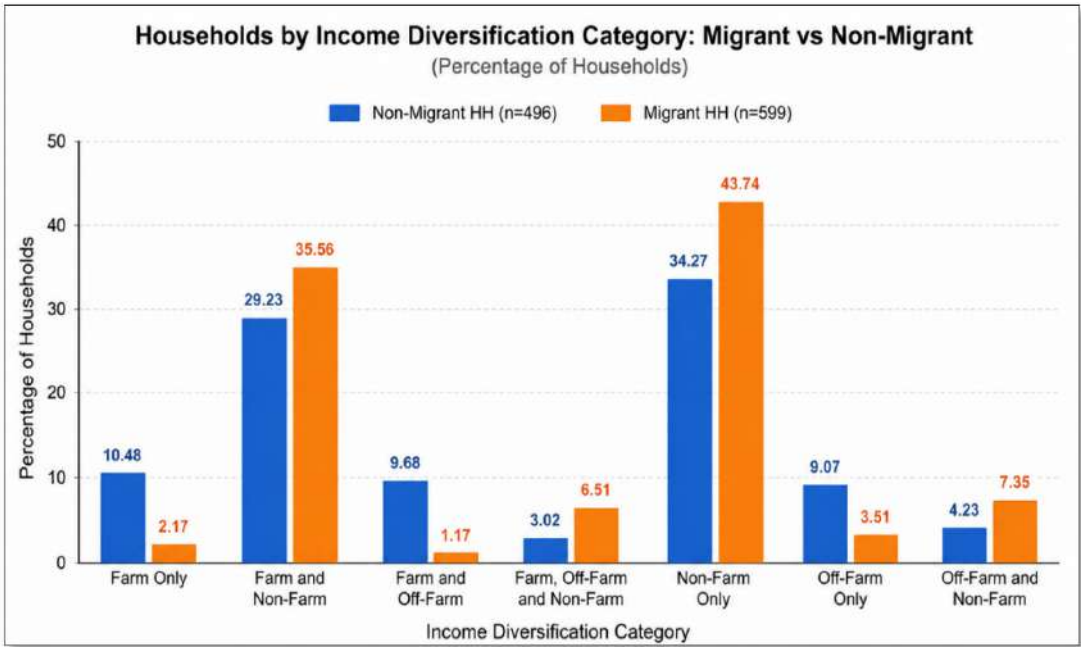


Figure 4 : Household by Income Diversification category

Income Diversification and Vulnerability among Migrant and Non-Migrant Households:

The comparison shows clear differences in livelihood outcomes between migrant and non-migrant households. Migrant households report higher average monthly income (₹21,918.53) than non-migrants (₹15,154.04), but also a higher mean LVI (0.582 vs. 0.522), indicating that **higher income does not necessarily correspond to lower vulnerability**. Among migrants, the **Farm–Off-Farm** category records the highest mean income (₹28,428.57), although based on only seven households. The **Farm–Off-Farm–Non-Farm** group shows the highest diversification (Simpson = 0.430; Shannon = 0.736), but its LVI remains relatively high (0.561). Thus, **greater livelihood diversification and higher income do not necessarily eliminate vulnerability**, particularly where households remain dependent on migration and external labour markets.

In contrast, households relying exclusively on Non-Farm activities constitute the largest migrant group (N=262) but relatively high vulnerability (LVI = 0.603), reflecting occupational specialization rather than livelihood resilience. The Off-Farm Only group records the highest vulnerability (LVI = 0.625), suggesting that dependence on seasonal or casual rural employment offers limited livelihood security.

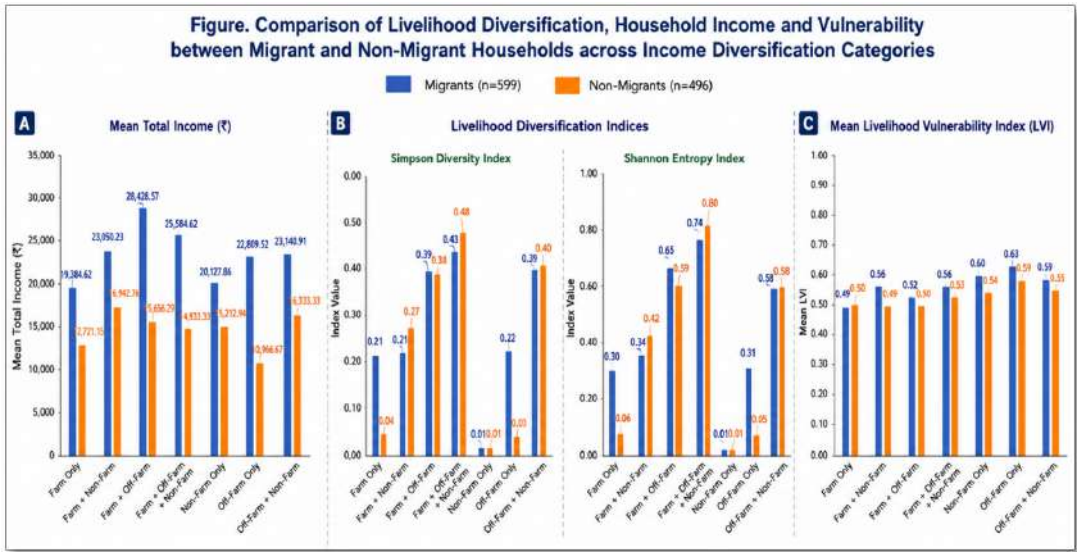


Figure 5 : Comparison of Diversification between Migrants and Non-Migrants (Prepared by Authors)

A somewhat different pattern emerges among non-migrant households. Although Farm, Off-Farm and Non-Farm households achieve the highest diversification (Simpson = 0.481; Shannon = 0.804), their average income (₹14,933.33) remains considerably lower than that of similarly diversified migrant households, indicating that **diversification without access to migration opportunities generates relatively modest economic gains**.

The results further suggest that migration enhances livelihood prosperity more effectively than it enhances livelihood security, emphasizing the need for policies that combine migration opportunities with stable local employment, skill development and social protection to achieve both higher incomes and lower vulnerability. The findings suggest that migration enables households to convert diversified livelihood strategies into higher incomes, but it does not completely eliminate livelihood vulnerability due to continued dependence on uncertain external labour markets.

Regression Analysis of various determinants:

A multivariate linear regression model was employed to examine the association between migration intensity, household human capital, landholding and livelihood diversification with total household income. The overall model is highly significant ($F = 85.02$, $p < 0.001$) and explains **42.2% of the variation in household income** ($R^2 = 0.422$), indicating good explanatory power.

Among all explanatory variables, **Migration Count** exerts the largest and most statistically significant positive effect (β = 4,789.57, p < 0.001). Holding other factors constant, each additional migrant increases household income by approximately ₹4,790, confirming that migration substantially enhances household earnings through remittances and access to higher-paying labour markets. **Non-Farm Count** has a significant positive association with household income (β = 762.95, p = 0.017), suggesting that migration enables households to diversify into remunerative non-farm activities. Likewise, **Occupational Activity Count** positively influences income (β = 4,430.83, p < 0.001), indicating that migrant households engaged in a greater number of productive economic activities earn significantly higher incomes. **Average Years of Education** also contributes positively (β = 325.01, p = 0.001), implying that education enhances migrants' access to better-quality employment and improves returns from migration.

Table 8 : Regression results of multiple determinants over Income (using STATA by Authors)

No. of Observation= 1095	F (9,1095)	Prov>F= 0.00	R-Square=0.42	Root= 9231
Variable	**Coefficient**	**Robust Std. Error**	**t-value**	**p-value**
Shannon	−13,287.41	13672.76	−0.97	0.33
Simpson	20236.32	17266.00	1.17	0.24
Migration Count	4789.57	466.86	10.26	0.00
Average Years of Education	325.01	94.03	3.46	0.00
Skill Binary	733.57	774.52	0.95	0.34
Land Mid	310.45	336.57	0.92	0.36
Non-Farm Count	762.95	318.34	2.40	0.02
Occupational Diversity Count	−2,918.52	1540.93	−1.89	0.06
Occupational Activity Count	4430.83	375.14	11.81	0.00
Constant	5591.83	1751.70	3.19	0.00

In contrast, **Occupational Diversity Count** has a negative and marginally significant coefficient ($\beta = -2{,}918.85$, $p = 0.058$), indicating that diversification across numerous occupations does not necessarily improve income. Instead, excessive occupational diversification may reflect **distress-driven livelihood strategies**, where households undertake multiple low-return activities due to limited employment opportunities. Similarly, the **Shannon Index**, **Simpson Index**, **Skill** and **Landholding** are statistically insignificant, suggesting that these factors do not independently influence household income once migration and occupational characteristics are controlled.

Discussion and Conclusion

The study demonstrates that migration is a central component of rural livelihood transformation in Agro-Climatic Zone II of Bihar, contributing to occupational change, income enhancement and livelihood diversification. Inter-state migration dominates, reflecting limited local employment opportunities and the importance of external labour markets. Households with multiple migrants generally receive higher remittances and report improved income security.

Migration is associated with a shift from agriculture towards **non-farm activities**, including construction, transport, trade, skilled work and services. Migrant households earn nearly **45% higher average income** than non-migrant households, while regression results identify **migration count as the strongest predictor of household income**. At the same time, migration produces both occupational specialization and income diversification: migrants increasingly specialize in non-farm employment, while remittances supplement farm and non-farm income sources.

However, migration does not eliminate vulnerability. Dependence on external labour markets, seasonal employment and uncertain remittances continue to expose migrant households to livelihood risks. Households combining migration with diversified livelihoods appear better positioned to manage these risks.

The study addresses an important gap by examining **migration, occupational transformation, income diversification and vulnerability within an integrated household-level framework**. Unlike studies focusing on these dimensions separately, it distinguishes between occupational specialization and income diversification and considers migration intensity, migrant count and income composition together. The findings provide a basis for further research on employment quality, remittance use, gender dimensions, skill development and the long-term sustainability of migration-led livelihood transformation.

Acknowledgement

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URBAN GOVERNANCE CHALLENGES AND MITIGATION STRATEGIES : A CASE STUDY OF RANCHI CITY, JHARKHAND

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ABSTRACT

Ranchi, the capital city of Jharkhand, has witnessed rapid urbanisation since becoming the state capital in 2000. This has led to profound demographic, spatial, and infrastructural changes. The city's population grew from approximately 8.63 lakh in 2001 to over 10.73 lakh in 2011, with continued expansion indicated by subsequent municipal estimates and voter-list growth through the mid-2020s. This swift urban growth has created significant governance challenges, including traffic congestion, land-use transformation, speculative land transactions, and rising urban crime. The present study investigates urban governance and mitigation strategies for managing rapid urbanisation in Ranchi. It draws on both primary and secondary data sources. A household survey of 300 respondents was conducted across 10 selected wards of the Ranchi Municipal Area using structured questionnaires and field interviews, with households selected through systematic random sampling from municipal property registers within each stratified ward. Secondary data were sourced from Census reports, Ranchi Municipal Corporation records, transport statistics, crime reports, and government policy documents. Descriptive statistics, Chi-square tests, and Pearson correlation analysis were employed to interpret the data. Key findings reveal that 88 percent of respondents identified rising private vehicle ownership as the primary cause of traffic congestion, while 83 percent linked rapid urban growth to residential expansion and rising land demand. Around 72 percent reported substantial conversion of agricultural land in peri-urban areas, and 73 percent associated high population density with increasing urban crime. Major challenges include weak infrastructure, fragmented governance, inadequate public transport, and poor land-use regulation. The study underscores the need for evidence-based spatial planning, smart traffic management, strict land regulations, and technology-driven governance to promote sustainable urban development. Integrated governance, data-driven planning, and sustainable management practices are crucial for enhancing urban resilience in fast-growing cities like Ranchi.

Keywords: *Urban Governance, Urbanisation, Traffic Congestion, Land-Use Planning, Urban Crime, Ranchi.*

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Introduction

Urban governance denotes the collaborative processes, institutions, and relationships shaping urban planning and management, distinct from top-down administration by engaging government, private sectors, civil society, and communities (UN-Habitat, 2020). It oversees infrastructure, transport, housing, and environmental decisions. Effective governance ensures transparency, accountability, and service delivery amid rapid growth (World Bank, 2023). Closely tied to sustainable cities, it pursues inclusive, resilient spaces via integrated planning (UN, 2016). Conversely, weak structures trigger unplanned expansion, congestion, inequality, and degradation (Harvey, 2013). Thus, robust governance mechanisms are vital instruments for achieving equitable and sustainable urbanisation, particularly across developing nations facing acute demographic and spatial pressures.

India is experiencing one of the fastest urban transitions, driven by economic growth, migration, and administrative expansion, with its urban population set to exceed 600 million by 2035 (United Nations Department of Economic and Social Affairs, 2022). New states such as Jharkhand have spurred cities such as Ranchi and Raipur via administrative centralisation, boosting migration and economic activity (Kundu, 2011). However, uncontrolled sprawl into peri-urban zones strains land, transport, and public services, overwhelming local bodies (Bhatta, 2010). While the Smart Cities Mission (2015) promotes digital governance and citizen participation, and UN-Habitat advocates integrated planning, persistent governance challenges—fragmented institutions, weak implementation, and poor coordination—continue to hinder sustainable urban management in India.

Since becoming Jharkhand's capital on 15 November 2000, Ranchi transformed from a medium-sized administrative town with moderate growth and limited infrastructure into a major regional hub. Concentration of government departments, public institutions, healthcare, and commerce fuelled rapid migration and economic expansion. Census 2011 confirmed substantial population growth between 2001 and 2011, from approximately 8.63 lakh to over 10.73 lakh. Subsequent municipal estimates and electoral roll expansions indicate continued demographic pressure into the mid-2020s, consistent with the city's designation as a rapidly expanding secondary capital. Spatially, the city expanded outward into Kanke, Namkum, Hatia, and Doranda, converting agricultural land and open spaces into residential-commercial complexes. This peri-urban sprawl altered land-use patterns and intensified pressure on governance systems. Rising built-up areas, vehicle ownership, infrastructural stress, and service demand now pose significant urban management challenges for authorities.

Rapid urbanisation in Ranchi creates governance challenges that outpace institutional capacity. Traffic congestion arises from vehicular growth, weak road infrastructure, inadequate public transport, and mixed land use. Agricultural land conversion fuels sprawl and

speculative transactions. Urban crime rises with population concentration, consistent with Social Disorganization Theory (Shaw & McKay, 1942) and Routine Activity Theory (Cohen & Felson, 1979). Weak infrastructure and poor inter-agency coordination highlight the gap between growth and management capacity.

Urban governance theory emphasises multi-actor coordination, institutional capacity, and participatory mechanisms as prerequisites for sustainable urban management (UN-Habitat, 2020; World Bank, 2023). Social Disorganization Theory posits that rapid neighbourhood change, migration, and population turnover weaken informal social controls, thereby elevating crime risk (Shaw & McKay, 1942). Routine Activity Theory explains crime opportunity structures arising from the convergence of motivated offenders, suitable targets, and absent guardianship in dense commercial and transport corridors (Cohen & Felson, 1979). Together, these frameworks provide the analytical lens for examining Ranchi's governance challenges.

Studies on Indian urbanisation highlight that rapid population growth, migration, economic transformation, and administrative expansion have accelerated urban growth in metropolitan and medium-sized cities. Kundu (2011) observed that emerging urban centres face increasing pressure on housing, infrastructure, and public services due to uneven expansion patterns. Bhatta (2010) emphasised that uncontrolled urban sprawl results in agricultural land conversion, fragmented development, and environmental stress.

Peri-urban agricultural conversion emerges as a central outcome of urban expansion. Comparative analyses of Ranchi and Patna demonstrate that built-up areas expanded rapidly into rural and agricultural lands, producing compactness in core zones alongside dispersed fringe growth (Das, Das & Dhanaraj, 2024). Similar fringe transformation processes, driven by rising land demand and speculative transactions, have been documented across Indian peri-urban interfaces (Chettry & Surawar, 2021).

Institutional fragmentation persists as a constraint. Although the 74th Constitutional Amendment sought to empower urban local bodies, implementation in Jharkhand remains incomplete. Studies of the Ranchi Municipal Corporation reveal overlapping mandates among the municipal body, Ranchi Regional Development Authority, state departments, and specialised agencies, resulting in weak coordination, limited functional devolution, and capacity deficits (Praja Foundation & Nagrika, 2019–2020; Mehta & Kumar, 2019). Mehta and Kumar (2019) further note challenges of unorganised spatial development, inadequate public transport, and weak civic infrastructure.

Traffic congestion is linked to rising private vehicle ownership and insufficient public transport. National analyses attribute congestion to rapid increases in personal vehicles, longer commute distances from peri-urban expansion, and underdeveloped mass transit

systems—patterns consistent with Ranchi. The association between population density, rapid urbanisation, and urban crime has received attention, with denser urban centres recording higher cognisable offences explained by opportunity structures, social anonymity, and policing pressure.

Kumar and Baraik (2024) examine urban indigeneity in Jharkhand, showing that tribal communities experience outward displacement and marginalisation as urban cores expand, underscoring uneven distribution of urban benefits and socio-spatial exclusion (Kumar & Baraik, 2021; Hoda & Bansal, 2018). Recent literature advocates technology-enabled approaches. GIS-based monitoring, smart traffic management, and data-driven platforms have been promoted under the Smart Cities Mission. Evaluations of Ranchi's initiatives emphasise spatial planning tools, strict land regulation, and coordinated frameworks (Mehta & Kumar, 2019; Joy et al., 2024).

This study contributes to urban governance literature by adopting an integrated framework to analyse the interrelationship between rapid urbanisation, governance challenges, and mitigation strategies in Ranchi—an emerging Indian state capital. Unlike existing research that examines transportation, land-use, infrastructure, or crime separately, this study provides empirical evidence from a less-studied emerging capital facing unique governance pressures. Methodologically, it combines household perception data, secondary sources, and statistical analysis to capture spatial variations. The integrated governance framework links technology-driven approaches with institutional strengthening and participatory planning. Findings underscore that sustainable urban governance requires spatial planning, municipal capacity building, and evidence-based decision-making, offering insights for rapidly transforming cities across developing countries.

Study Area

Ranchi, Jharkhand's capital on the Chotanagpur Plateau, is eastern India's fastest-growing urban centre, serving as an administrative, political, economic, and educational hub. State formation on 15 November 2000 triggered unprecedented demographic growth, administrative expansion, and migration, with the Urban Agglomeration recording substantial population and built-up growth by 2011 (Census of India, 2011). Peripheral regions—Kanke, Namkum, Hatia, Doranda, and Booty More—experienced rapid peri-urban transformation, converting agricultural land into residential-commercial uses. This expansion intensified traffic congestion, land transactions, and governance challenges. The city exhibits uneven development: a dense commercial core with infrastructural stress versus transitional peripheral zones with inadequate services, making Ranchi a critical case for examining urban governance challenges and mitigation strategies.

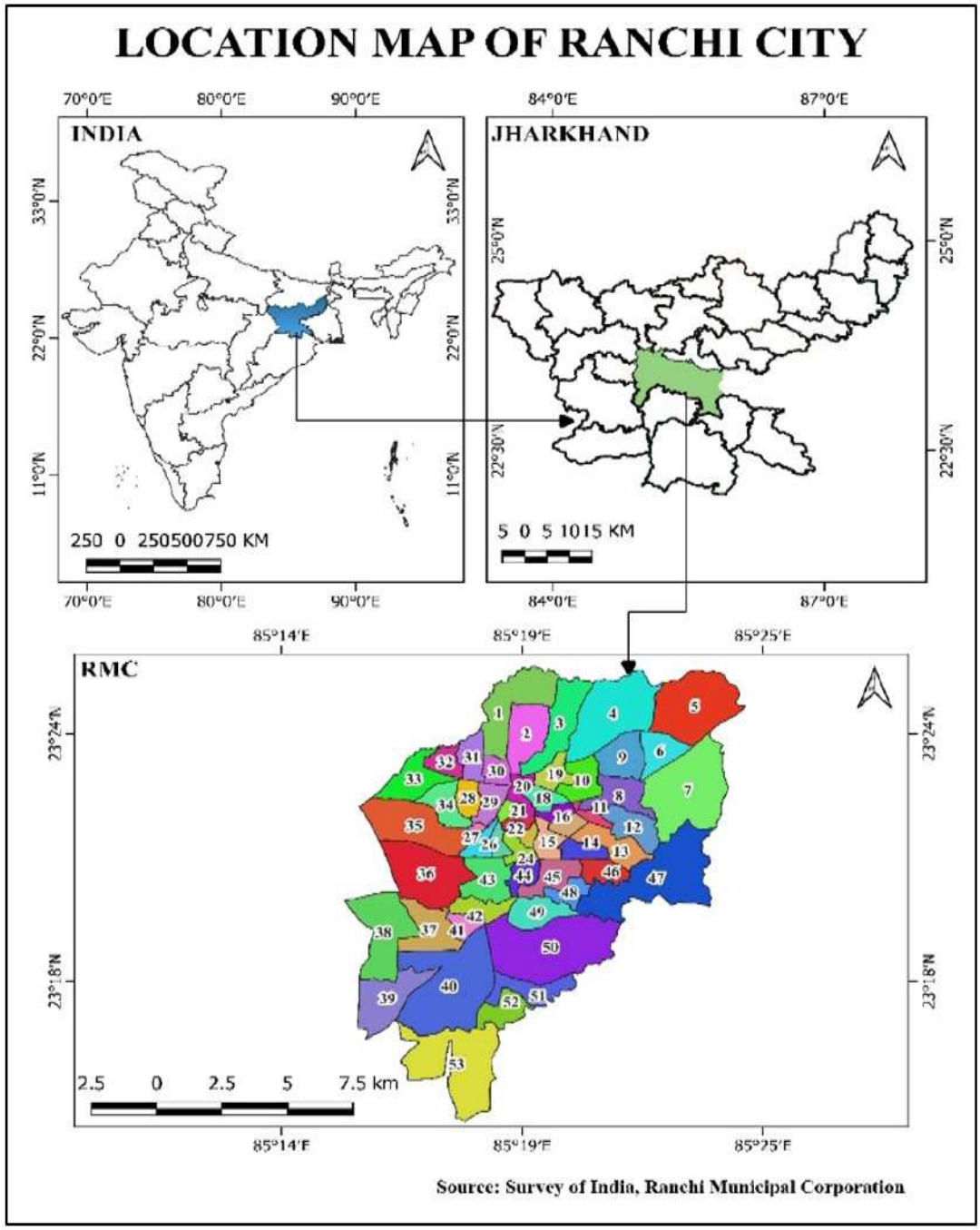


Figure 1 : Study Area Location and Administrative Boundaries of Ranchi Municipal Area

Objectives of the Study

The present study has been undertaken with the following objectives:

1. To examine governance challenges associated with rapid urbanisation in Ranchi city.
2. To analyse mitigation strategies related to traffic, land-use, and crime management.
3. To evaluate the effectiveness of urban policies and planning mechanisms.
4. To propose sustainable governance strategies for rapidly growing cities.

Methodology

Data validation employed triangulation, cross-verifying primary household survey findings with secondary datasets, including census statistics, transport records, municipal documents, crime reports, and spatial expansion data derived from published cartographic records and municipal planning maps, to differentiate perceived problems from objectively measurable changes.

Selection criteria included population density, built-up expansion, land-use characteristics, commercial activity, transport pressure, and infrastructure availability. A stratified random sampling technique selected ten wards (2, 7, 11, 19, 21, 25, 35, 36, 38, and 53) from the Ranchi Municipal Area, divided into three zones based on urban development patterns:

(1) Central urban wards: dense settlements, commercial concentration, and severe traffic pressure;

(2) Commercial-transition wards: mixed land-use with increasing institutional and residential activities; and

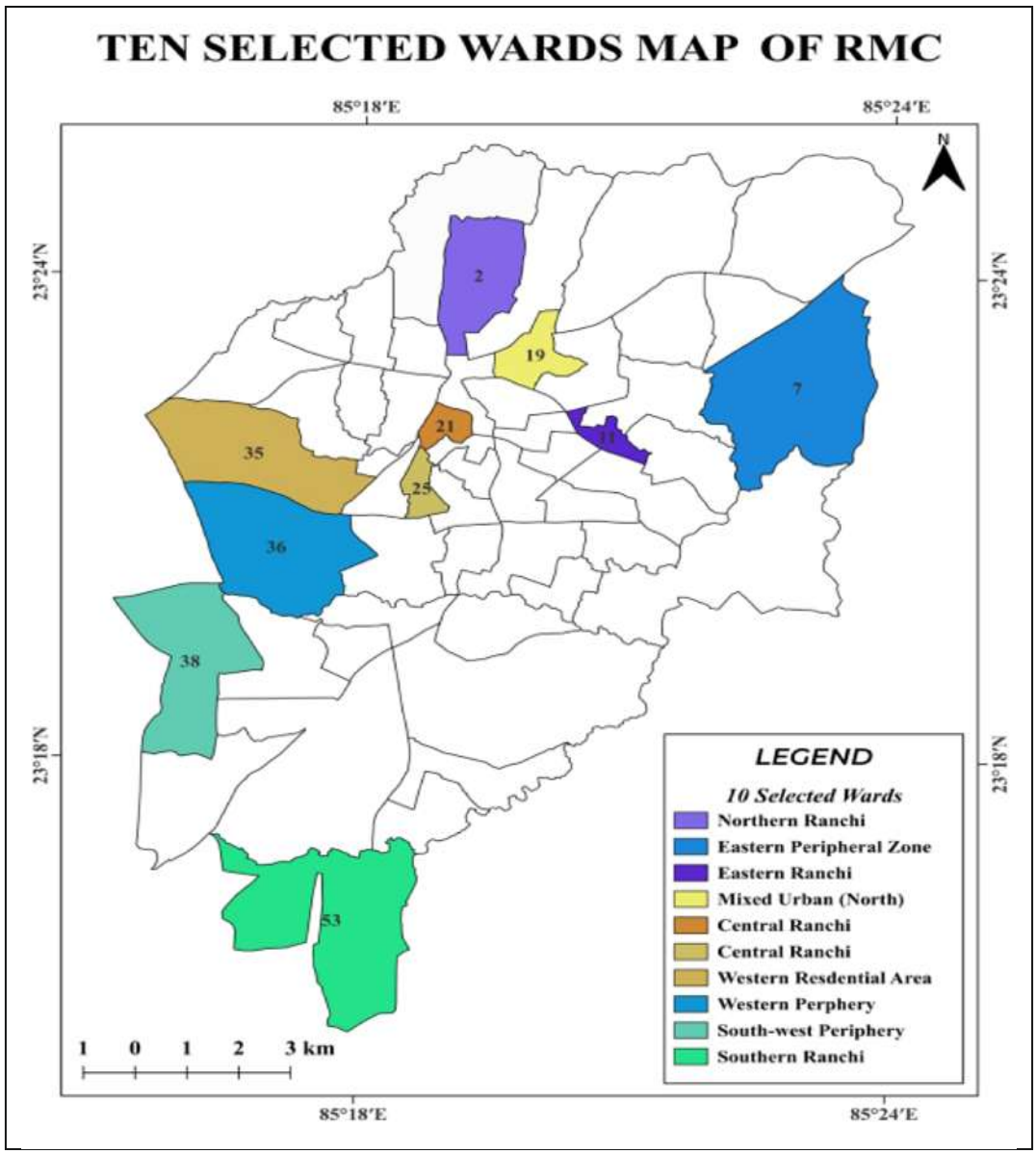
(3) Peri-urban wards: fringe areas with rapid agricultural-to-urban land conversion.

Table 1 : Stratification of Selected Wards by Urban Zone

Urban Zone	Selection Criteria	Number of Wards	Sample Households
Central Urban Zone	High population density, commercial concentration, traffic pressure	4	120
Commercial/Transition Zone	Mixed land use, institutional and transport activities	3	90
Peri-urban Zone	Rapid expansion, land conversion, emerging settlements	3	90
Total	—	10	300

Source: *Authors' sampling design, 2025.*

Three hundred households were surveyed across zones: 120 central, 90 transition, and 90 peri-urban, ensuring balanced representation.



Source : *Ranchi Municipal Corporation*

Figure 2 : Spatial Distribution of the Ten Selected Wards within Ranchi Municipal Corporation

Table 2 : Weighting of Stratification Parameters

Stratification Parameter	Weight Considered
Population density and settlement concentration	30%
Land-use transformation and built-up expansion	30%
Infrastructure pressure (transport, services, governance issues)	40%

Source: *Authors' sampling framework. The higher weight assigned to infrastructure pressure reflects the study's focus on urban governance challenges.*

Within each selected ward, households were drawn using systematic random sampling from the municipal property tax register (or equivalent household listing maintained by the ward office). After obtaining the complete list of residential units for the ward, we generated a random start and applied a fixed sampling interval ($k = N/n$, where N is the total number of listed households in the ward and n is the target sample size for that ward) to select participating households. If a selected household was unavailable or declined participation after two revisit attempts, we substituted the next household on the list. This protocol ensured probabilistic selection at the household level while maintaining the zonal stratification structure.

Data Sources and Collection Tools

Primary data were collected through structured questionnaires administered face-to-face, covering perceptions of infrastructure quality, traffic congestion, land-use change, public safety, and institutional responsiveness. Secondary data comprised Census of India (2001, 2011) primary abstracts; Ranchi Municipal Corporation administrative and service records; state transport department vehicle registration statistics; police crime records for the municipal area; and published municipal planning maps and secondary cartographic assessments of built-up expansion. Temporal context was strengthened by reference to available interim municipal population estimates and electoral roll expansions bridging the 2011 Census and the 2025 field survey.

Analytical and Statistical Framework

Quantitative survey data were analysed using descriptive statistics (frequencies and percentages) to identify the prevalence of governance challenges, and inferential tests (Chi-square and Pearson's correlation) to examine relationships between urbanisation indicators and governance variables. The statistical significance level was set at $p < 0.05$.

Pearson correlation coefficients reported in Table 4 were calculated at the individual household level (N = 300). For each respondent, perception scores on governance challenges (measured on ordinal scales and treated as approximately interval for correlation purposes) were paired with self-reported or zone-assigned indicators of vehicle ownership intensity, perceived built-up expansion, and population density exposure. This individual-level approach avoids ecological fallacy associated with pure ward-level aggregation while acknowledging that zone membership introduces a degree of clustering; results are therefore interpreted as associations rather than strict causal estimates.

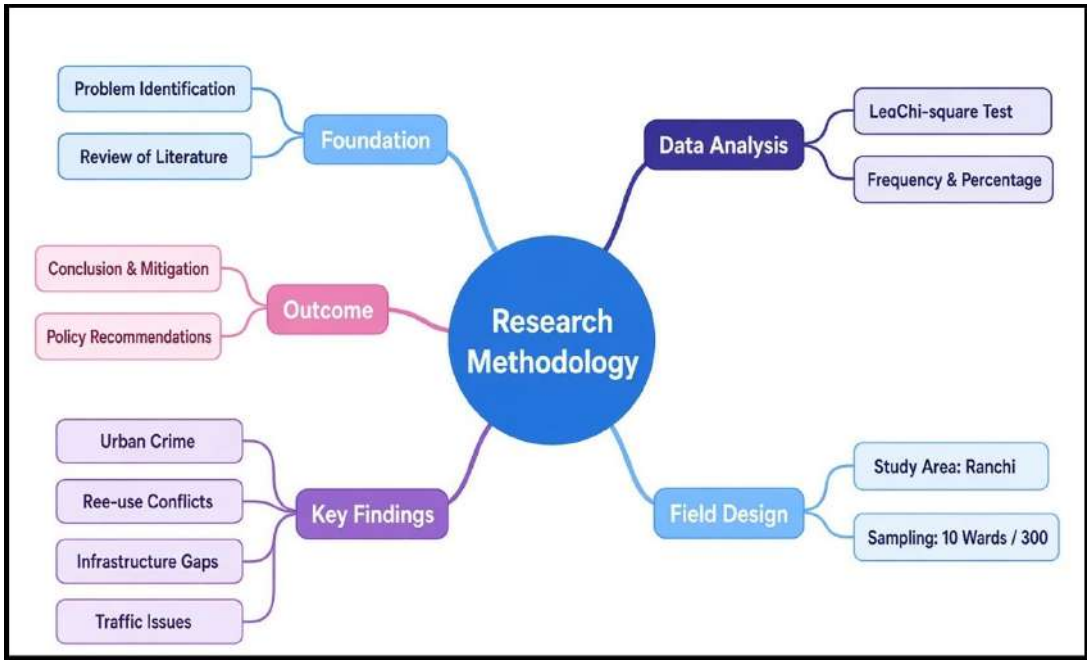


Figure 3 : Research Methodology Framework for Analysing Urban Governance Challenges in Ranchi

Results and Discussion

Demographic and Spatial Dynamics

The present study integrates citizen perceptions obtained through household surveys with objective indicators derived from secondary sources to validate urban governance challenges in Ranchi. The household survey reflects the experiences and opinions of residents regarding infrastructure, mobility, land-use change, and urban safety, whereas secondary datasets provide measurable evidence of demographic, spatial, and institutional changes.

Table 3 : Association Between Residential Zone and Perceived Urban Governance Challenges (Chi-square Tests)

Variables Tested	χ^2 Value	df	p-value	Interpretation
Residential Zone × Infrastructure Problems	18.64	4	0.001	Significant association
Residential Zone × Traffic Congestion	15.82	4	0.003	Significant association
Residential Zone × Land-use Transformation	21.35	4	<0.001	Significant association
Residential Zone × Crime Perception	13.47	4	0.009	Significant association

Source: *Field Survey, 2025. All associations significant at $p < 0.05$.*

The Chi-square analysis indicates a statistically significant association between residential location and perception of urban governance challenges. Respondents in peri-urban areas showed greater concern about land-use transformation and infrastructure deficiencies, whereas residents of central urban areas reported greater concern about traffic congestion and mobility problems.

Table 3 a: Contingency Table – Residential Zone × Infrastructure Problems (Observed Frequencies)

Zone	Low Concern	Moderate Concern	High Concern	Total
Central Urban	28	42	50	120
Commercial/Transition	18	35	37	90
Peri-urban	12	22	56	90
Total	58	99	143	300

Note: *Expected cell frequencies all exceed 5; $\chi^2 = 18.64$, $df = 4$, $p = 0.001$.*

Table 3 b: Contingency Table – Residential Zone × Traffic Congestion (Observed Frequencies)

Zone	Low Concern	Moderate Concern	High Concern	Total
Central Urban	15	28	77	120
Commercial/Transition	20	32	38	90
Peri-urban	25	30	35	90
Total	60	90	150	300

Note*: Expected cell frequencies all exceed 5; $\chi^2 = 15.82$, $df = 4$, $p = 0.003$.*

Table 3 c: Contingency Table – Residential Zone × Land-use Transformation (Observed Frequencies)

Zone	Low Concern	Moderate Concern	High Concern	Total
Central Urban	35	48	37	120
Commercial/Transition	22	30	38	90
Peri-urban	10	18	62	90
Total	67	96	137	300

Note: *Expected cell frequencies all exceed 5; $\chi^2 = 21.35$, $df = 4$, $p < 0.001$.*

Table 3 d: Contingency Table – Residential Zone × Crime Perception (Observed Frequencies)

Zone	Low Concern	Moderate Concern	High Concern	Total
Central Urban	22	40	58	120
Commercial/Transition	20	35	35	90
Peri-urban	28	32	30	90
Total	70	107	123	300

Note: *Expected cell frequencies all exceed 5; $\chi^2 = 13.47$, $df = 4$, $p = 0.009$.*

Table 4 : Correlation Between Urban Growth Indicators and Governance Challenges (Individual Level, N = 300)

Urban Growth Indicator	Governance Challenge	Pearson's r	p-value	Relationship
Population density exposure	Urban crime perception	0.62	<0.001	Strong positive
Vehicle ownership intensity	Traffic congestion	0.71	<0.001	Strong positive
Perceived built-up expansion	Land-use conflict	0.66	<0.001	Strong positive
Urban expansion rate (zone)	Infrastructure pressure	0.58	<0.001	Moderate positive

Source: *Field Survey, 2025. Correlations computed at the individual household level (N = 300). All coefficients significant at $p < 0.001$.*

Cross-validation of Primary and Secondary Data

Cross-validation confirms that survey perceptions align with secondary indicators. Population growth after state formation is corroborated by Census figures and subsequent municipal estimates. Rising private vehicle ownership is supported by transport department registration

trends. Agricultural land conversion reported by respondents is consistent with published secondary cartographic assessments and municipal planning maps documenting built-up expansion in fringe zones (rather than original satellite-derived land-use/land-cover classifications generated for this study). Crime perceptions correspond with the spatial concentration of reported offences in dense commercial and transport corridors according to police records.

Table 5: Cross-validation Between Survey Perceptions and Objective Indicators

Theme	Primary Survey Findings	Secondary Data Validation	Interpretation
Urban Growth	Respondents identified rapid urbanisation as a major governance challenge	Census data indicate substantial population growth after 2000; municipal estimates show continued expansion	Public perception corresponds with demographic expansion
Traffic Congestion	88% identified increasing private vehicles as a major cause	Transport department vehicle registration data show continuous increase	Survey perception supported by transport growth trends
Land-use Transformation	72% reported agricultural land conversion	Published cartographic records and municipal planning maps indicate expansion of built-up areas in fringe zones	Citizen perception reflects documented spatial transformation
Urban Crime	73% linked population density with increasing crime	Police records indicate concentration of reported crimes in dense commercial and transport corridors	Crime perception supported by spatial crime patterns
Infrastructure Pressure	82% identified weak infrastructure as a major challenge	Municipal records indicate increasing demand for roads, drainage, waste management, and public services	Governance stress confirmed through institutional indicators

Source: *Authors' compilation from field survey and secondary sources, 2025.*

Traffic Congestion and Mobility Management

Traffic congestion is a critical governance challenge in Ranchi, driven by rapid vehicular growth, peri-urban expansion, weak public transport, and commercial concentration in the urban core. Survey data show that 88 percent of respondents attribute congestion to rising private vehicle ownership, fuelled by higher incomes and inadequate bus services. Central areas face severe mobility stress, reported by 82 percent of respondents. Major hotspots—Main Road, Circular Road, Kanke Road, and the Hinoo–Doranda corridor—suffer from mixed traffic, roadside parking, institutional activity, and growing commuter flows. Weak public transport forces private vehicle dependence (69 percent), while parking shortages (71 percent) and roadside encroachments (64 percent) further obstruct movement. These findings underscore the need for smart traffic systems, improved public transport, parking

regulations, and road widening. Promoting sustainable mobility, including non-motorised transport, is essential for long-term relief.

Table 6 : Major Traffic Management Issues in Ranchi

Traffic Issue	Respondents (%)
Increase in private vehicles	88
Traffic congestion	82
Parking shortage	71
Weak public transport	69
Road encroachment	64

Source: *Field Survey, 2025.*

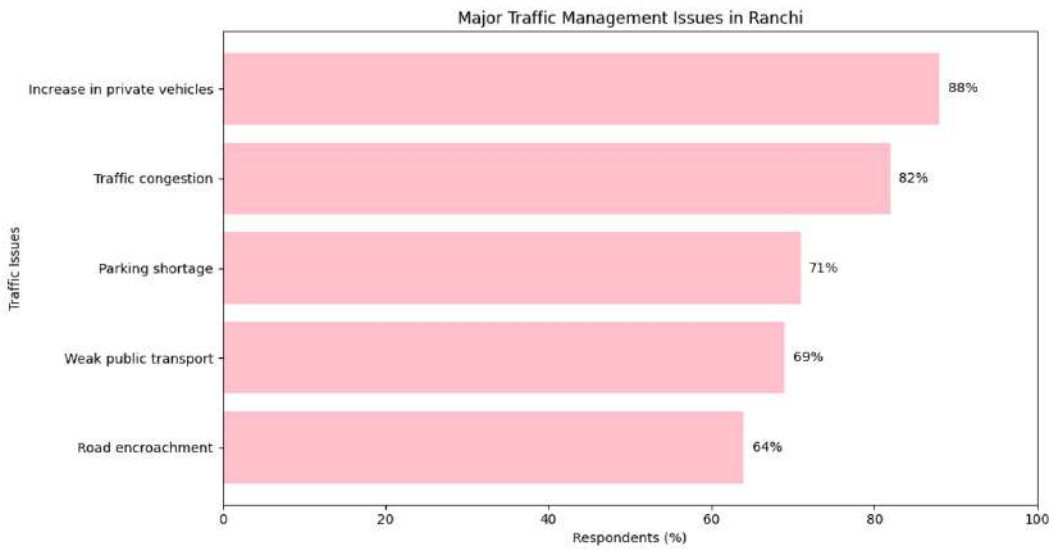


Figure 4 : Major Traffic Management Issues in Ranchi

Peri-Urban Land Governance and Speculative Expansion

Rapid urbanisation in Ranchi has transformed land-use patterns, driven by population growth, migration, and infrastructural expansion. Survey data show that 76 percent of respondents identify peri-urban expansion as a key governance concern, with Kanke, Namkum, Hatia, and Booty More witnessing extensive agricultural land conversion (reported by 72 percent). Real-estate speculation (68 percent) and informal land transactions (61 percent) reflect weak regulatory oversight. Additionally, 57 percent of respondents attribute unplanned growth and

irregular construction to inadequate land regulation. These trends have escalated property prices, created socio-spatial inequality, and intensified infrastructural pressure, underscoring the insufficiency of existing land governance mechanisms to manage urban expansion effectively.

Table 7 : Major Land Governance Issues in Ranchi

Land Governance Issue	Respondents (%)
Rapid peri-urban expansion	76
Agricultural land conversion	72
Real-estate speculation	68
Informal land transactions	61
Weak land regulation	57

Source: *Field Survey, 2025.*

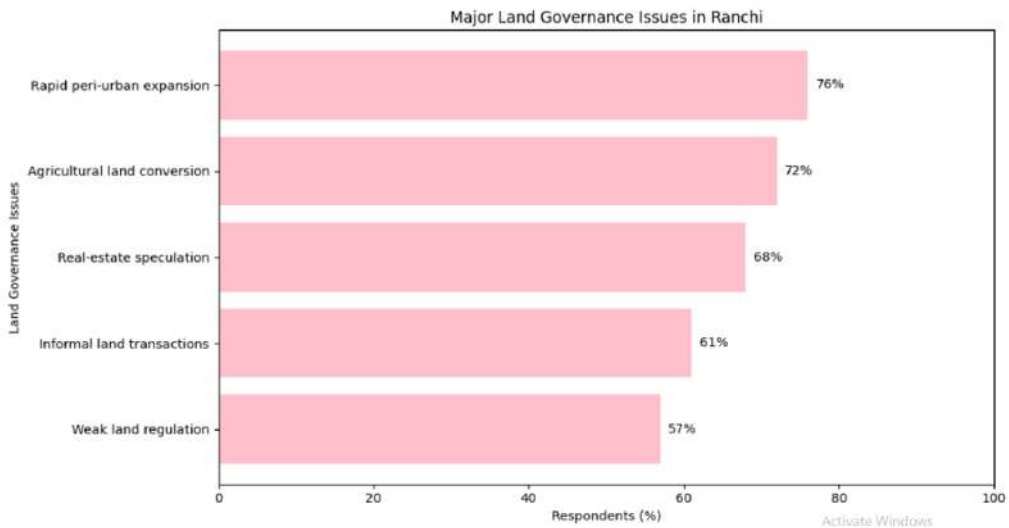


Figure 5 : Major Land Governance Issues in Ranchi

Crime Dynamics and Public Safety

The study establishes a strong link between rapid urbanisation and emerging crime patterns in Ranchi. Population concentration, migration, commercial crowding, and weak surveillance have collectively shaped urban crime dynamics, with incidents spatially concentrated in dense commercial and transport corridors. Survey data reveal that 73 percent of respondents associate high population density with rising crime, while 71 percent link commercial

crowding to theft and snatching, and 66 percent identify traffic congestion as a factor facilitating roadside crime. Migration and informal settlement growth, reported by 58 percent, have weakened social cohesion, aligning with Shaw and McKay's Social Disorganization Theory. Similarly, Cohen and Felson's Routine Activity Theory is supported, as congested spaces increase offender–target interaction amid weak guardianship (cited by 62 percent). These findings underscore the need for smart governance—CCTV surveillance, smart policing, spatial crime mapping, improved lighting, and data-driven mechanisms—to enhance urban safety.

Table 8 : Urban Crime Factors in Ranchi+

Urban Crime Factor	Respondents (%)
High population density	73
Commercial crowding	71
Traffic congestion	66
Weak surveillance	62
Migration-related issues	58

Source: *Field Survey, 2025.*

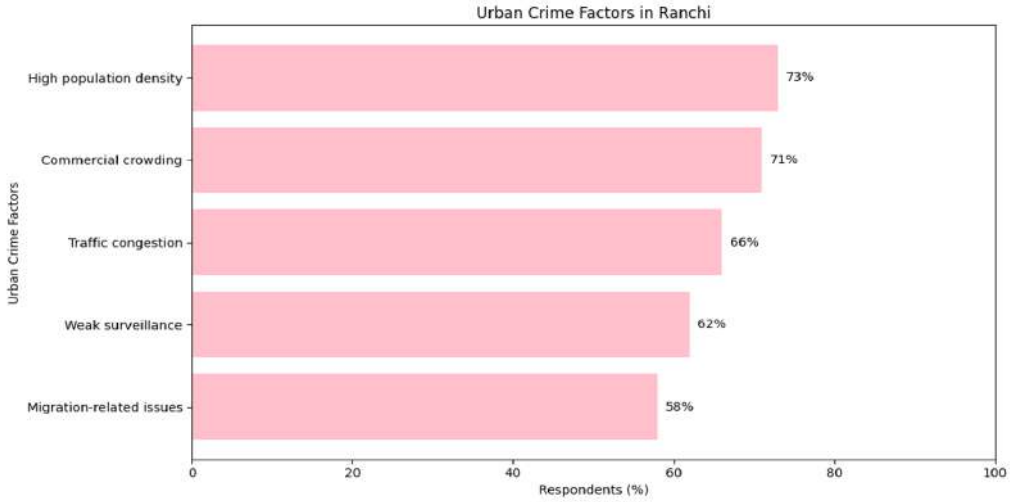


Figure 6 : Urban Crime Factors in Ranchi

Evaluation of Existing Governance and Institutional Capacity

Post-2000 urbanisation in Ranchi, accelerated by Jharkhand's statehood, has intensified governance challenges amid rapid demographic, administrative, and infrastructural growth. Urban expansion has outstripped the capacity of existing systems, placing severe pressure on

transport, drainage, waste management, housing, and public infrastructure. Field data reveal that 82 percent of respondents cite weak infrastructure as the top governance concern, and 79 percent associate problems with rising traffic congestion. Peri-urban areas have witnessed unplanned residential and commercial growth, with 73 percent of respondents reporting poor land-use regulation as a major issue. Governance fragmentation is evident: 61 percent perceive weak inter-agency coordination, and 66 percent identify flawed urban planning as a driver of unplanned development. Additionally, 69 percent highlight inadequate waste management. These patterns reflect uneven urbanisation, where policy implementation remains fragmented and institutional capacity lags behind growth.

Table 9 : Major Urban Governance Challenges in Ranchi

Governance Challenge	Respondents (%)
Weak infrastructure	82
Traffic congestion	79
Poor land-use regulation	73
Inadequate waste management	69
Weak urban planning	66
Poor coordination among agencies	61

Source: *Field Survey, 2025.*

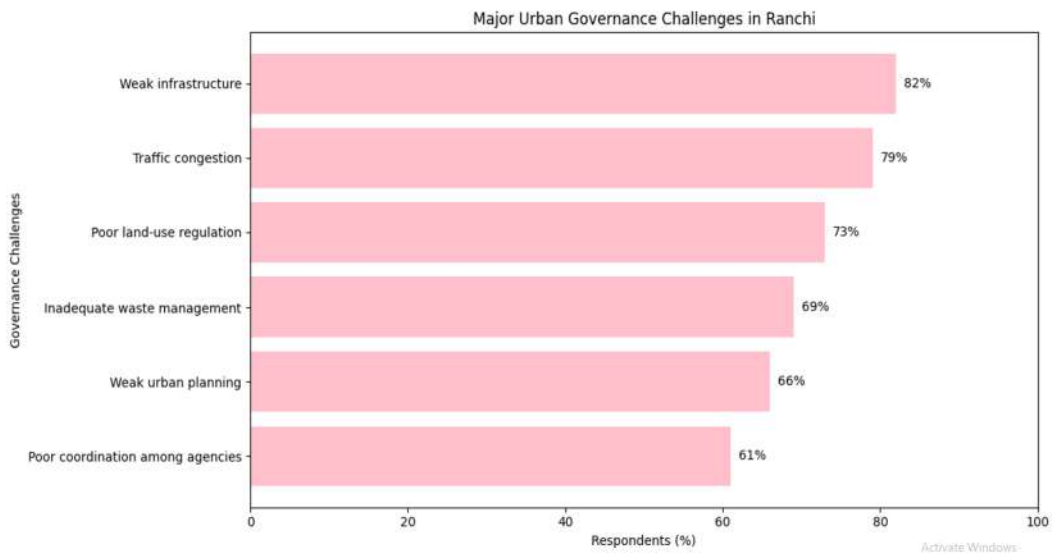


Figure 7 : Major Urban Governance Challenges in Ranchi

The study's findings align with prior research on Indian cities, where weak institutional capacity, fragmented governance, and service deficits commonly accompany rapid growth. Theoretical implications include support for Urban Governance Theory (emphasising institutional coordination, technology, and citizen participation), Social Disorganization Theory, and Routine Activity Theory in the context of a developing state capital. The study addresses a gap in emerging-city research by demonstrating that secondary state capitals require context-specific governance models attuned to rapid peri-urban growth, limited institutional capacity, and socio-spatial change.

Policy Interventions and Mitigation Strategies

Decentralized and Ward-Level Frameworks

Sustainable urban governance in Ranchi requires strengthening participatory and decentralised mechanisms. The 74th Constitutional Amendment Act provides a framework for empowering Urban Local Bodies and ward-level institutions. Ward committees and citizen platforms can improve communication between residents and authorities, ensuring that development strategies reflect ground realities rather than administrative priorities alone. Decentralisation enhances accountability, participation, and institutional responsiveness.

Traffic management remains a critical priority. Essential interventions include public transport improvement, smart signalling, scientific parking management, and promotion of non-motorised transport such as cycling and pedestrian pathways. Integrated urban transport planning can reduce private vehicle dependence and mobility stress.

Land governance reforms are equally vital. Strict enforcement of land-use regulations, anti-encroachment measures, and transparent land-record systems can control unplanned expansion and speculative transactions. Monitoring peri-urban development and regulating informal transactions can prevent infrastructural imbalances.

Urban safety requires smart governance approaches—CCTV surveillance, smart policing, crime hotspot mapping, and improved street lighting—to reduce opportunistic crimes through data-driven enforcement. Urban planning must also integrate the informal sector through designated vending zones, participatory relocation, pedestrian planning, worker registration, and dialogue with municipal authorities.

Smart and Technology-Driven Interventions

Rapid urbanisation in Ranchi has generated interconnected governance challenges requiring integrated policy responses. Sustainable development depends on planning efficiency, technological integration, institutional coordination, and participatory governance. Evidence-

based spatial monitoring (drawing on published cartographic and municipal planning resources) and strict zoning regulations are essential to manage peri-urban growth and land-use conflicts.

Technology-driven solutions such as intelligent traffic systems and digital governance platforms require institutional capacity and financial sustainability. Limited municipal resources, technical manpower shortages, and rising service demands necessitate phased implementation—prioritising low-cost, high-impact interventions such as parking regulation, traffic enforcement, and public transport coordination before large-scale investments. Capacity building, spatial database maintenance, and inter-departmental coordination are critical.

Municipal finances can be strengthened through property tax reforms, user charges, public–private partnerships, and better utilisation of government schemes. Smart governance—real-time monitoring and e-governance—can enhance administrative coordination, transparency, and service delivery across urban agencies. National policy frameworks such as the Smart Cities Mission, AMRUT, and the National Urban Transport Policy provide supporting structures for intelligent infrastructure, digital governance, and sustainable mobility.

Table 10 : Integrated Governance Strategies for Sustainable Urban Development in Ranchi

Existing Challenge	Conventional Approach	Revised Inclusive Strategy
Traffic congestion	Smart signals and monitoring systems	Smart technology + public transport improvement + stakeholder participation
Land-use transformation	GIS monitoring only	Spatial planning + community consultation + strict zoning regulation
Urban crime	CCTV surveillance	CCTV + community policing + improved street-level participation
Infrastructure stress	Large-scale infrastructure projects	Participatory planning + priority-based investment
Informal activities	Regulation and removal	Integration through planned vending and transport systems

Source: Authors' synthesis based on survey findings and policy analysis.

Conclusion and Future Directions

This study demonstrates that post-2000 urbanisation has profoundly transformed Ranchi's socio-economic and spatial structure. Following Jharkhand's statehood, the city emerged as a

major administrative, commercial, and educational hub, triggering population growth, peri-urban expansion, and mounting governance pressure. Existing governance systems are under severe strain. Built-up expansion, rising vehicular density, infrastructure deficits, and weak institutional coordination have intensified challenges within the Ranchi Municipal Area. Traffic congestion is acute along major corridors; land-use transformation and speculative real estate have reshaped peri-urban fringes; and urban crime patterns correlate with population density, migration, commercial crowding, and inadequate surveillance. These issues are interconnected outcomes of rapid growth and weak planning.

Integrated frameworks—evidence-based spatial planning, smart infrastructure, digital governance, sustainable mobility, and data-driven management—are essential for resilience. Success depends on municipal capacity, financial resources, and trained personnel, with technology as a supportive tool within broader institutional reform. Decentralised mechanisms involving ward committees, community organisations, and informal sector representatives can ensure inclusive development by blending top-down planning with bottom-up participation.

Methodologically, the study uses an integrated framework that combines household perception data with secondary demographic, infrastructure, transport, land-use, and crime information. Stratified sampling across zones captures spatial variation, while descriptive, inferential, and qualitative methods provide a comprehensive analysis applicable to other emerging cities. Theoretically, the findings support Urban Governance Theory and extend Social Disorganization and Routine Activity Theories to a developing state capital, contributing evidence from an understudied category of Indian urban centres.

Despite key insights, this study has limitations: findings reflect selected wards rather than the entire metropolis; perception-based indicators may introduce response bias; ward-level secondary data constrained fine-grained temporal analysis; and dimensions such as environmental sustainability and economic inequality remain unexplored. Claims regarding spatial transformation rely on published secondary cartographic records and municipal planning maps rather than original satellite-derived land-use/land-cover classifications generated for this study.

Future research should employ multi-temporal remote sensing and GIS for spatial-temporal analysis of land-use changes, conduct longitudinal studies across emerging capitals, and integrate climate resilience, sustainability indicators, smart city performance metrics, and participatory governance models. Ultimately, Ranchi's experience underscores that sustainable development demands integrated governance, spatial planning, institutional capacity, technology, finance, and citizen engagement, offering lessons for rapidly growing cities.

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LIVELIHOOD STATUS AND CHALLENGES OF VEGETABLE SELLERS IN PATNA MUNICIPAL CORPORATION AREA

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ABSTRACT

This study investigates the dynamics of livelihood diversification and migration in Supaul district, Bihar, one of the most flood-prone regions of India. Drawing on primary household survey data from six villages, the analysis highlights how environmental stress, particularly recurrent floods from the Kosi River, interacts with socio-economic vulnerabilities such as land fragmentation, caste hierarchy and poverty to shape livelihood strategies. Findings reveal that non-farm income has become the dominant source of livelihood, contributing nearly 80% of household income, while agriculture and off-farm activities play a marginal role due to frequent flood-induced disruptions. Migration emerges as a central adaptive mechanism, with landless and marginal farming households—especially those belonging to Scheduled Castes and Extremely Backward Castes—showing the highest intensity of outmigration. Village-level disparities underscore the influence of infrastructure, market access, and social networks in enabling or constraining diversification opportunities. The study applies the Sustainable Livelihoods Framework to illustrate how diversification across farm, off-farm, and non-farm activities strengthens resilience, though unevenly across caste and landholding categories. It concludes by emphasizing the need for inclusive, climate-resilient livelihood strategies that combine skill development, rural infrastructure, and social protection to reduce vulnerability and enhance sustainability in Bihar's flood-prone rural economy.

Keywords : *Livelihood, environmental stress, Outmigration, Vulnerability*

Introduction

Vegetable selling is an important part of informal economy, providing employment and income to a large number of people. Vegetable sellers perform important role in the urban food system by making fresh produce accessible to consumers, while relying on daily sales to meet their household needs. However, vegetable selling is affected by perishability of vegetables, fluctuating prices, competition, access to working capital and the availability of suitable vending space and storage.

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Livelihood refers to the means through which individuals or households secure the necessities of life-food, shelter, clothing, and a sense of social well-being. Hence, it is truly defined as capabilities, assets (both material and social) and activities required for a means of living (DFID, 1999). It is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation (Chambers & Conway, 1992). It underscores the multi-dimensional nature of livelihood, encompassing economic, social, and environmental aspects. In the present study, this perspective provides a broad framework for examining the socioeconomic characteristics, financial circumstances, occupational conditions and perceived challenges of vegetable sellers. The analysis is exploratory and is based on a small purposive sample and therefore focuses on the experiences of surveyed respondents.

In India, the sale of vegetables is an essential component of both rural and urban economies which offers income and employment to a number of people involved in the production, transportation and marketing. Agriculture and allied activities in Bihar form the backbone of rural livelihood and a large proportion of rural and peri-urban populations rely on vegetable selling as a vital source of income. Their livelihoods are influenced by seasonality, uncertainty and vulnerability, fluctuations in demand, perishability of goods, competition and regulatory pressures from municipal authorities.

Patna, the capital city of Bihar, is an important urban center linked to vegetable-producing areas in its hinterland. The Patna Municipal Corporation (PMC**)** area serves as the primary node of vegetable trade, where produce from surrounding districts of Patna- Vaishali, Saran and Nalanda flows daily. These vegetable sellers operate through different arrangements, including mobile vending and fixed stalls. Their working conditions and livelihood security may vary according to the type of selling arrangement, the amount of capital available, procurement channels and access to customers. Understanding these conditions is relevant to inclusive urban planning and the improvement of livelihoods in the informal economy.

Study Area

The study was conducted in Patna Municipal Corporation (PMC) area, the largest urban local body in Bihar which lies between 25°6'N latitude to 85°13'E longitude, along the southern bank of the River Ganga. It covers an area of 109.218 km^2. The city is divided into six (6) administrative circles and 75 administrative wards with a population of 1.7 million as per Census of India, 2011. The PMC area includes both planned and unplanned settlements where vegetable selling is a major occupation in dense markets such as Mithapur, Kankarbagh, Rajendra Nagar, Kadamkuan, Boring Road, Ashok Rajpath, Mushallahpur and Gandhi Maidan. These markets cater a wide consumer base ranging from daily wage earners to middle-income households. The geographical location of Patna, fertile hinterland and

continuous urban expansion make it a significant site to examine the dynamics between urban livelihood and informal economy.

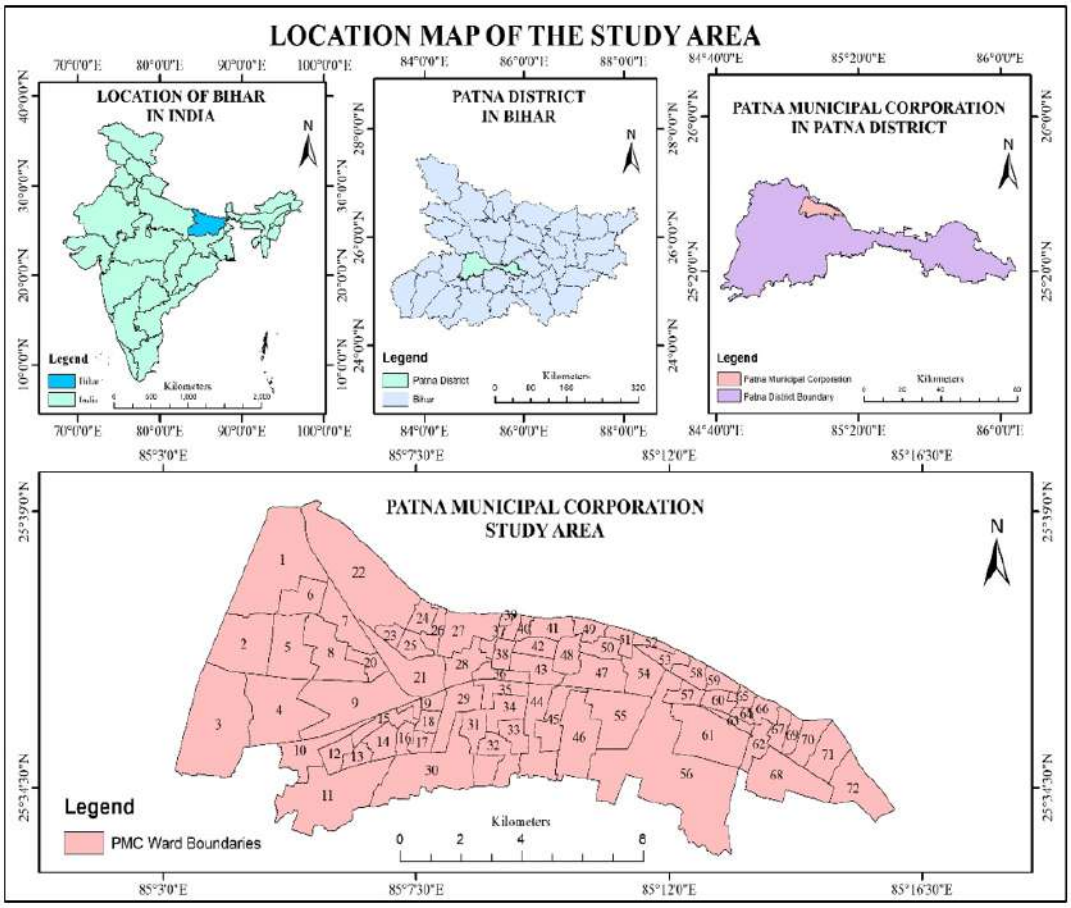


Figure 1 : Study Area

Aims and Objectives

The study aims to analyse the livelihood status and challenges faced by vegetable sellers in Patna Municipal Corporation area. The main objectives of the study are as follows;

1. To study the socio-economic profile of vegetable sellers in the study area.
2. To assess their livelihood status and occupational conditions.
3. To identify major challenges faced by the vegetable sellers, and
4. To suggest measures for improving their livelihood security.

Data Collection and Methodology

The present study is based on primary sources of data collected through a structured schedule and interview with 57 vegetable sellers from various wards of the Patna Municipal Corporation (PMC) area. The purposive sampling method has been used to include both mobile vendors and fixed stall sellers and data were collected on various aspects of socio-economic characteristics, income, expenditure, working conditions and challenges faced in sustaining their livelihood and coping strategies.

For analytical purposes, respondents were classified by the nature of vending into two categories of: (i) mobile vendors, who sell vegetables from pushcarts or as head-load hawkers and move through residential lanes and roadside locations, and (ii) fixed-stall sellers, who operate from a stationary stall or fixed position in a market. Of the 57 respondents, 32 (56.1 per cent) were mobile vendors and 25 (43.9 per cent) were fixed-stall sellers (Table-1). The study is confined to these two street-level vending types, which together constitute the informal vegetable retail trade; formal retail outlets such as shopping malls were not covered, as their operators are not part of the urban informal economy to which this study addresses.

Table 1 : Distribution of Respondents by Type of Vending

Type of Vending	Respondents (n)	Share (%)
Mobile vendors (cart / head load)	32	56.1
Fixed-stall sellers	25	43.9
Total	**57**	**100.0**

Source: *Primary Survey, October 2025.*

The data were processed using IBM SPSS and descriptive statistics of mean, percentage and standard deviation were used to interpret the results. To identify the severity of challenges faced by the vegetable sellers, a 5-point Likert scale (1 = Not a Challenge to 5 = Severe Challenge) was used. Mann–Whitney U tests were conducted to compare the distributions of challenge ratings between mobile vendors and fixed-stall sellers. Moreover, various cartograms and maps have been prepared for the representation of facts and findings.

Results and Discussion

Socio-Economic Profile

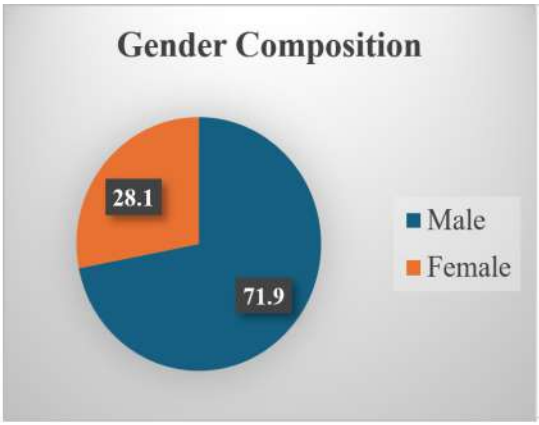
The Socio-economic profile of the vegetable sellers are shown in Table-2 which signifies that the occupation is male dominated as out of 57 respondents, about 72 per cent are male and 28

per cent female (Fig.2). It is due to the fact that while females mainly remain engaged in household-adjacent stalls or assist in family-run shops, males manage outdoor vending and wholesale procurement. This gender imbalance is typical in India's informal retail sector where physical mobility, safety concerns, and cultural constraints limit women's participation (Tiwari, 2021; MoHUA, 2022). Age distribution reveals that about 44 per cent of vendors belongs to the 31- 40 years age group and about 21 per cent to 41- 50 years, showing that vegetable selling is generally pursued during economically productive years (Fig.3). The occupation thus represents a stable livelihood activity, not a temporary. Similar age profiles were found among urban street retailers in Kolkata (Chakraborty, 2020).

Table 2 : Socio-Economic Profile of Vegetable Sellers

Background Characteristics	Per centage Share	Background Characteristics	Per centage Share
Gender		Higher Secondary	1.8
Male	71.9	Graduation and above	7.0
Female	28.1	**Category**	
Age		UR	0
21 - 30	15.8	OBC	91.2
31 - 40	43.9	SC	7
41 - 50	21.1	ST	1.8
51 - 60	8.8	**Residence**	
Above 60	10.5	Rural	28.1
Marital Status		Semi- urban	19.3
Married	86	Urban	52.6
Unmarried	5.3	**Family Type**	
Widow	8.8	Nuclear	54.4
Highest Education Qualification		Joint	45.6
		Household Size	
No formal education	17.5	1 – 3 members	8.8
Primary	28.1	4 – 6 members	54.4
Secondary	45.6	7 – 9 members	36.8

Source: *Based on Field Survey, October 2025*



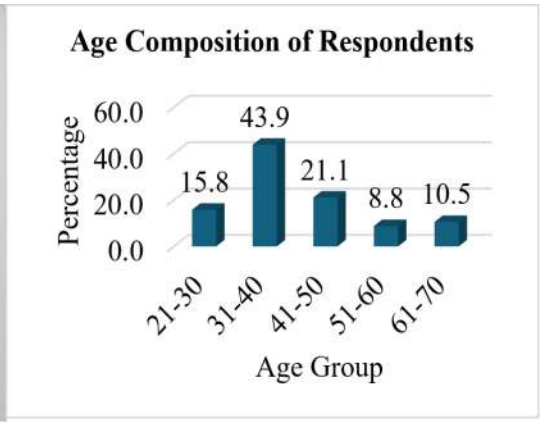
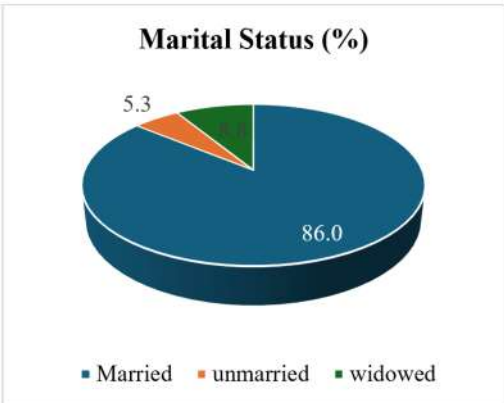


Fig 2 : Gender Composition of Respondents **Fig 3 : Age Composition of Respondents**

The analysis finds 86 per cent of respondents as married, while about 9 per cent widow, and only about 5 per cent as unmarried (Fig.4). The dominance of married participants signifies a family-oriented livelihood where daily earnings sustain their household consumption and children's education. As per the Periodic Labour Force Survey, such self-employment is common among married individuals in urban India due to limited wage employment opportunities (PLFS, 2023-24). Education is essential for occupational mobility and access to institutional support. However, educational levels among respondents are relatively low as 17.5 per cent had no formal schooling, about 28 per cent completed primary, about 46 per cent secondary and only 7 per cent has completed graduation (Fig.5). Lower literacy hampers digital payment adoption and awareness of schemes. Shop-based sellers tend to be slightly more educated than mobile vendors, explaining their better access to credit and customer networks. Educational deprivation thus acts as a structural barrier to economic advancement.



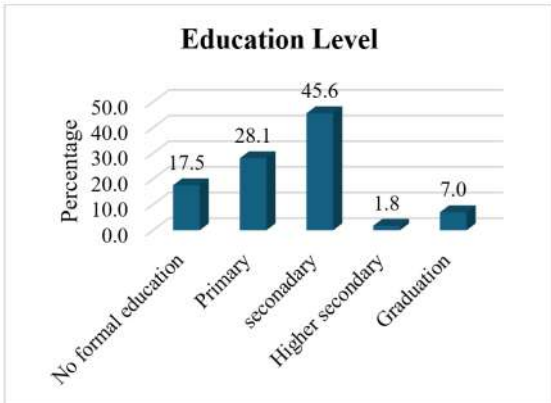


Fig. 4: Marital Status of Respondents **Fig. 5: Education Level of Respondents**

Social composition shows that about 91 per cent belongs to OBC group, 7 per cent SC, and about 2 per cent ST group (Fig.6). Retail vegetable selling, irrespective of mobility, remains dominated by socially and economically weaker sections. National Sample surveys report also authenticates that over 80 per cent of street vendors in India come from backward or scheduled groups (NSSO 2021; NASVI 2019). Most of the respondents (about 53 per cent) reside permanently within PMC limits, while 28 per cent commutes from rural peripheries and about 19 per cent from semi-urban areas. More than half of the respondents have been living in the city for more than 10 years, implying deep urban settlement rather than seasonal migration. Vegetable retailing is therefore, embedded in urban livelihood systems contributing to both food distribution and employment stability.

About 54.4 per cent live in nuclear families and 45.6 per cent in joint families. Average family size is large (5-7 members) for 72 per cent of the respondents, compared with India's urban average of 4.4 persons (NFHS-5). Larger households heighten dependency ratios and encourage family labour participation. In many fixed-stall and shop establishments, spouses or older members assist with procurement or sales, indicating that vegetable retail is often a family micro-enterprise rather than individual self-employment.

Table 3: Financial Conditions of the Vegetable Sellers

Indicator	Category	Respondents (%)
Monthly household income	Below ₹10,000	8.8
	₹10,001–15,000	19.3
	₹15,001–20,000	8.8
	₹20,001–25,000	43.9
	Above ₹25,000	19.3
Monthly household expenditure	Below ₹10,000	19.3
	₹10,001–15,000	43.9
	₹15,001–20,000	17.5
	Above ₹20,000	19.3
Savings pattern	Regular	45.6
	Irregular	45.6
	No savings	8.8
Bank account	Yes	100.0

Source: Based on Field Survey, October 2025.

The financial condition of the vegetable sellers shows that the most frequently reported monthly household income category was ₹20,001-25,000 (43.9%). At the same time, 43.9% reported monthly household expenditure of ₹10,001-15,000. Regular savings were reported by 45.6%, while an equal proportion reported irregular savings; while only 9% reported no savings. Although all respondents reported having a bank account (Table 3).

Occupation and Livelihood Conditions

The analysis finds that vegetable selling was the main occupation for 91.2% of the respondents (Table 4). Nearly half of the respondents (47.4%) have been engaged in the activity for five to ten years. Mobile cart/head-load vendors accounted for 56.1% as compared to 43.9% operating from fixed stalls. The vegetable selling occupation is characterised by long working hours and absence of weekly rest. About 54.4% respondents work for 6-8 hours per day, 36.8% work for 8–10 hours, and 8.8% work for more than 10 hours daily, while 82.5 per cent work for all 7 days per week. Such continuous work without rest days points towards lack of labour regulation. Fixed-shop owners report longer working hours due to extended business timings (early morning to late evening), while mobile vendors spend much time traveling to wholesale markets and managing unsold stock. This continuous labour engagement yields only modest and irregular income, often insufficient for saving or reinvestment. Nearly 65% of sellers purchase from wholesale mandis from mainly Mithapur, Rajendra Nagar and Kankarbagh markets, while 35% take directly from farmers. Direct procurement from farmers is hindered by absence of organized farmer- vendor network, lack of cold storage and transport facilities.

Table 4 : Occupation and Livelihood Conditions of Vegetable Sellers

Indicator	Category	Respondents (%)
Main occupation	Vegetable selling is main occupation	91.2
Duration in vegetable selling	1 - 5 years	36.8
	5 - 10 years	47.4
	More than 10 years	15.8
Nature of selling	Mobile cart/head-load	56.1
	Fixed stall	43.9
Working hours per day	6 - 8 hours	54.4
	8 - 10 hours	36.8
	More than 10 hours	8.8
Working days per week	4 - 5 days	17.5
	6 - 7 days	82.5
Source of vegetables	Wholesale market	64.9
	Direct from farmers	35.1

Indicator	Category	Respondents (%)
Transport	Rickshaw	47.4
	Auto	35.1
	Boat	17.5
Seasonal income variation	Yes	91.2
Secondary source of income	Yes	47.4
Access to storage	No	93.0
Market infrastructure	Very poor or poo r	36.8
	Average	52.6
	Good	10.5
Average daily sales	Below ₹1,000	36.8
	₹1,001 - 1,500	17.5
	₹1,501 - 2,000	8.8
	₹2,001 - 3,000	8.8
	Above ₹3,000	28.1
Average daily profit	Below ₹500	54.4
	₹501 - 1,000	35.1
	₹1,001 - 1,500	10.5

Source: *Based on Field Survey, October 2025.*

The major transport modes include rickshaw (47 per cent), auto (35 per cent) and boat (18 per cent). Some shop owners use small goods carriers to transport vegetables from wholesale markets early in the morning. Vendors covering longer distances (up to 20 km daily) face higher transport costs, product spoilage and physical exhaustion. Poor road connectivity, traffic congestion and lack of dedicated loading zones near markets worsen these issues.

The income pattern reflects moderate but unstable earnings as 44 per cent earn Rs. 20,001 - 25,000 per month, about 19 per cent earn more than Rs. 25,000 per month and about 9 per cent earn less than Rs. 10,000 per month. The monthly expenditure however remains high as approx. 44 per cent spend Rs. 10,001 to 15,000, and about 19 per cent spend more than Rs. 20,000. The analysis shows that 54 per cent earn less than Rs. 500 per day, 35 per cent between Rs. 500 to 1000, and only 11 per cent more than Rs. 1000 per day. Thus, net savings are minimal. About 45.6 per cent save regularly, 45.6 per cent irregularly, and about 9 per cent do not save at all. Vegetable sellers with fixed shop generate slightly higher income and stable savings compared to mobile vendors due to regular customer base and reduced mobility costs. Yet, across all types, economic vulnerability is evident.

For 91 per cent of respondents, vegetable selling (shop, stall or cart) is their main source of livelihood; only 9 per cent treat it as secondary income. This highlights the occupational

reliance of entire households on this sector. In numerous families, vegetable selling is an intergenerational occupation - transferred from parents to children - indicating both economic continuity and limited mobility into alternative sectors.

More than 36% rated the existing market infrastructure as poor or very poor, while only 10.5% rated it good. Many fixed stalls are set up under temporary shelters that lack electricity, clean water, and sanitation facilities. Even registered markets lack proper drainage and storage. For shop-based sellers, electricity and rent costs are additional burdens. Hence, the infrastructural environment remains weak, contributing to product wastage, customer inconvenience, and unhealthy working conditions.

Major Challenges of Vegetable Sellers

Vegetable sellers—across vending, stall and shop categories—face interlinked economic, physical and institutional challenges. The mean severity analysis, based on a five-point scale (1- 5), identifies the major issues reported by the respondents. These issues have been ranked in descending order of their mean scores ranging from the most severe to the least severe, reflecting their relative severity as perceived by the respondents (Table-5). The major challenges may be enumerated therefore as follows;

1. **Lack of cold storage and preservation facilities:** Over 63 per cent of the vegetable sellers marked it as "severe challenge" as lack of cold storage hence unsold produce must be sold cheaply or discarded, leading to direct income loss. Even shop owners with refrigerators can store only limited quantities. According to NABARD (2023), Bihar has cold storage capacity for only 10 per cent of its total horticultural output, one of the lowest in India. Implementing small, decentralized refrigeration units in near vending machine clusters could decrease waste and increase revenue.

2. **Lack of social security and insurance outreach:** Most of the sellers reported lack of any form of health or life insurance (61 per cent). Since most of them operate without business registration, they are excluded from government insurance schemes. Health emergencies often lead to indebtedness. Even shopkeepers, having regular income, are not registered under small business categories, leaving them outside the canvas of formal social protection.

3. **Limited access to credit and loans:** Despite bank account coverage to all, very few sellers receive institutional loans. Over-dependence on moneylenders (about 44 per cent) exposes them to high interest rates and debt cycles. Credit access could help sellers to upgrade stalls, improve storage and purchase in bulk for better margins.

4. **Seasonal price fluctuations:** Since vegetables are highly perishable, hence price variation in different seasons creates economic instability. During off-seasons, price rises

sharply in wholesale markets and during peak season retail prices crash. Sellers are forced to sell below cost to clear perishable stock. The fluctuation therefore, directly affects them, destabilising their monthly income.

Table 5 : Mean Score of Challenges faced by the Vegetable Sellers

Challenge	Overall Mean Score	Rank
Lack of cold storage/preservation	4.33	1
Lack of social security/insurance	4.31	2
Limited access to credit	3.95	3
Lack of awareness of govt schemes	3.86	4
Seasonal price fluctuation	3.82	5
Lack of proper market space	3.81	6
High competition in market	3.78	7
Price exploitation by wholesalers	3.61	8
Health issues due to workload	3.40	9
Harassment by local authorities	3.38	10
Limited access to customers	3.21	11
Poor transportation	2.98	12

Source: *Based on Field Survey, October 2025*

5. **Lack of proper market space and vending zones:** The sellers have reported for inadequate vending or market space. Many fixed stalls function illegally on footpaths or roadside corners without municipal licenses. As per the Street Vendors (Protection of Livelihood and Regulation of Vending) Act, 2014, every city must allocate vending zones however, Patna's vending plan is yet to be fully implemented. Consequently, sellers face frequent displacement and loss of business space.

6. **Price exploitation by wholesalers:** More than half the respondents reported unfair pricing by wholesalers, who manipulate rates depending on daily demand. Small-scale sellers with limited capital cannot buy in bulk and hence pay higher prices.

7. **Harassment by local authorities:** About 40 per cent of the vegetable sellers faces harassment, fines or forced eviction drives by municipal staff or police. Unlicensed street vendors are particularly vulnerable. Even fixed-stall sellers without formal approval have risk for displacement during encroachment clearance drives. Such insecurity discourages business investment and undermines livelihood dignity.

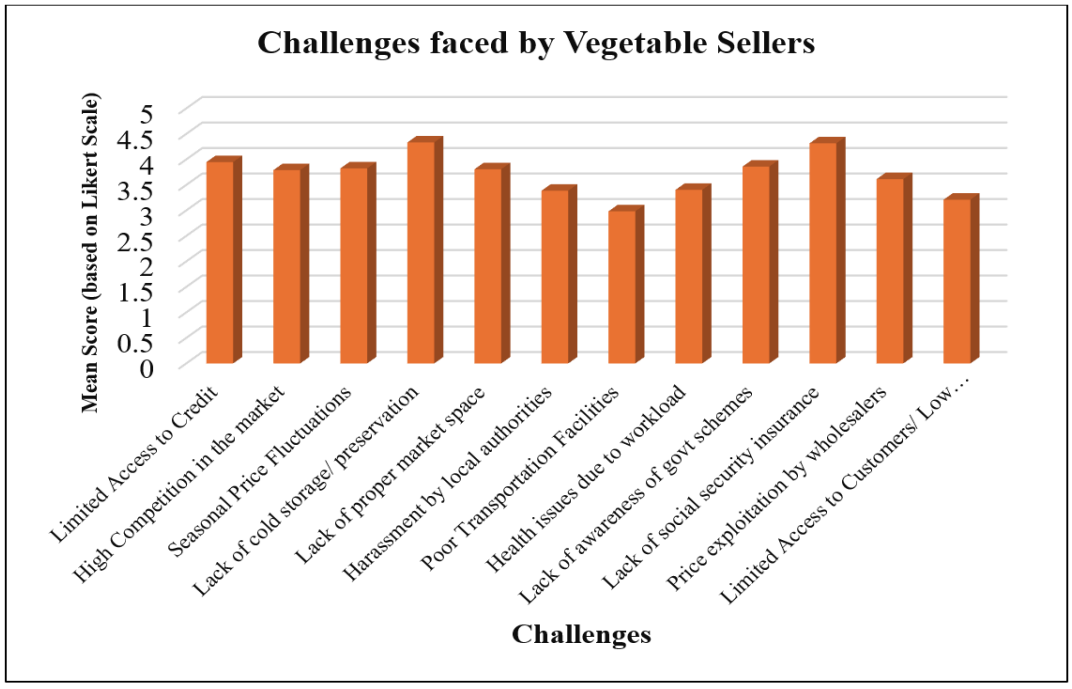


Fig. 6 : Mean Score of Challenges faced by the Vegetable Sellers

8. **Health issues due to workload:** Most of the sellers experienced fatigue, joint pain and exposure-related health problems. Continuous sitting or standing, handling heavy loads and lack of hygienic surroundings cause chronic disease and other health problems. Absence of medical insurance increases their vulnerability. Sellers are compelled for long working hours and little rest, vegetable vendors face higher physical strain from pushing carts for long distances.

9. **Limited customer base and increased competition:** The expansion of organised retail, supermarket chains and online vegetable delivery services have reduced the customer base of small sellers. Now a days, consumers prefer packaged or home-delivered vegetables for their convenience. This competition forces traditional retailers to cut prices, further reducing the profit. Many shopkeepers are also complaining for increasing rents and decreasing daily footfall in traditional markets.

10. **Poor transportation and supply facilities:** Transport constraints still add costs, although they are found relatively low in the mean score. The absence of specific loading areas, traffic congestion and dependence on manual transport increase spoilage of vegetables and stress to the sellers. For sellers who use boats or rickshaw transport modes, it becomes time consuming and unreliable.

Severity of Challenges by Type of Vegetable Sellers

The severity of the twelve challenges were compared among mobile vendors (n=32) and fixed-stall sellers (n=25) using the Mann-Whitney U test. Table-6 shows the mean challenge ratings for each group and the Mann–Whitney U test results. Higher mean scores indicate that a challenge was rated more severely on the five-point scale.

Table 6 : Severity of Challenge by Type of Vegetable Sellers (Mean Scores and Mann-Whitney U Test)

Challenge	Mobile vendors mean (n=32)	Fixed stalls mean (n=25)	Mann–Whitney Test (p)
Harassment by local authorities	3.97	2.64	0.001
High competition in the market	4.06	3.44	0.019
Seasonal price fluctuations	4.03	3.56	0.023
Limited access to customers/low demand	2.88	3.64	0.028
Poor transportation facilities	3.28	2.6	0.045
Lack of social security/insurance	4.22	4.44	0.127
Lack of proper market space	4.13	3.4	0.141
Limited access to credit	4.06	3.8	0.155
Health issues due to w orkload	3.25	3.6	0.402
Price exploitation by wholesalers	3.66	3.56	0.529
Lack of cold storage/preservation	4.38	4.28	0.821
Lack of awareness of government schemes	3.84	3.88	0.95

Source: *Calculated by authors based on Field Survey, October 2025.*

A comparative analysis of the severity of challenges faced by mobile vendors and fixed-stall vegetable sellers is shown in Table-6 which is based on their mean scores and the Mann–Whitney U test. The findings highlight differences in the challenges experienced by these two categories of vegetable sellers. The results indicate that harassment by local authorities is a major concern for mobile vendors, with a mean score of 3.97 as compared with 2.64 for fixed-stall sellers ($p = 0.001$). Similarly, high market competition (4.06 against 3.44; $p = 0.019$) and seasonal price fluctuations (4.03 against 3.56; $p = 0.023$) are more severe for mobile vendors. Poor transportation facilities also represent a greater challenge for mobile vendors (3.28) than that of the fixed-stall sellers (2.60), with a statistically significant

difference ($p = 0.045$). These findings suggest that mobile vendors face greater challenges, especially in relation to market competition, price instability, regulatory pressure and transportation.

However, limited access to customers and low demand are greater concerns for fixed-stall sellers, whose mean score is 3.64 as compared with 2.88 for mobile vendors ($p = 0.028$). This indicates that fixed-stall sellers experience difficulties in attracting customers despite operating from relatively permanent locations.

However, no statistically significant differences are observed between the two groups regarding social security and insurance, market space, access to credit, health issues, price exploitation by wholesalers, cold storage, and awareness of government schemes ($p > 0.05$). Notably, the lack of social security and insurance receive high mean scores in both groups (4.22 and 4.44, respectively), indicating a common concern.

Overall, the findings demonstrate that the nature and severity of challenges vary according to the type of vegetable seller. Therefore, targeted interventions addressing the specific needs of mobile vendors and fixed-stall sellers are necessary to improve their working conditions and livelihood security.

Findings and Suggestions

The overall analysis of the present study finds the following major findings;

1. Vegetable selling as an occupation is dominated by middle-aged men from OBC group, with low education and large households. It is the main occupation for more than 90% of the households.
2. The study finds that the vegetable sellers have low income, minimal savings and frequent borrowing reflect insecure livelihoods.
3. It is found that the overall major challenges reflecting the infrastructure gap such as absence of cold storage, poor sanitation and lack of vending zones reduce efficiency of the sellers.
4. Mobile vendors are facing higher challenges for market competition, seasonal price fluctuations, market-space constraints, harassment and transportation difficulties than fixed-stall sellers, and
5. Fixed-stall sellers face main challenges related to limited access to customers, while both groups rated storage and high social-security concerns.

Thus, the findings reveal that retail vegetable selling in Patna Municipal Corporation Area is a livelihood of survival rather than growth. The sector sustains urban food security but fails to ensure the sellers' economic security. As a consequence, most of the sellers borrow money

from informal lenders. They extend working hours to balance income fluctuations, dependence on family and peer support in times of crisis, shift their vending spots to avoid eviction or competition.

In the light of the above findings and the feedbacks of the respondents the following suggestions could be made to enhance livelihood security and sustainability of the vegetable sellers in the study area as;

1. Improve access to affordable shared storage and preservation facilities near major vending and market clusters.
2. Provide hygienic vending spaces with clean water, drainage, waste disposal, shade and secure space for selling.
3. Awareness and capacity building in terms of information campaigns on welfare schemes and digital literacy.
4. Implementation of schemes for health issues and social protection.
5. Promoting SHG/Cooperative for strengthening the capital, marketing and other facilities.

Conclusion

The study finds that vegetable selling in Patna Municipal Corporation area is a lifeline for a number of low-income families but it functions under the conditions of high insecurity. The livelihood status of sellers shows limited access to economic assets, weak institutional support and dependence on informal credits. In spite of their essential contribution to the city's food system, they remain marginalised in urban development policies. Their regular struggle to secure space, avoid displacement and cope with price volatility demonstrate the contradictions of urban livelihood sustainability. The comparison between mobile vendors and fixed-stall sellers shows that Mobile vendors report higher ratings for several challenges associated with market competition, seasonal price fluctuations, harassment and transportation, whereas fixed-stall sellers report greater concern about access to customers. Both groups identified storage and social protection as important issues. To overcome these challenges, requires an inclusive policy framework which recognize the informal economy as an important component of urban livelihoods. To stabilise their income and enhance their livelihood resilience steps like providing credit access, infrastructural support as well as including them in the planning of the municipality should be undertaken. It will not only help to improve their status, rights and welfare and overall socio-economic conditions but also achieve broader development objectives as Sustainable Development Goals (SDG Goal 1- No Poverty, SDG Goal 2- Zero hunger, SDG Goal 8- Decent Work and Economic Growth). Therefore, empowering vegetable sellers will lead to a more equitable and sustainable urban economy.

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ASSESSING URBAN HEAT ISLAND INTENSITY AND GREEN SPACE DISTRIBUTION USING GIS : A STUDY OF PATNA MUNICIPAL CORPORATION AREA

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ABSTRACT

Rapid urbanization has significantly transformed land use patterns in many Indian cities, resulting in substantial environmental impacts, particularly the intensification of the Urban Heat Island (UHI) effect. This study assesses the relationships among urban expansion, green space distribution, and surface temperature dynamics in the Patna Municipal Corporation Area over a period of 25 years from 2000 to 2025 using geospatial techniques. Multi-temporal Landsat satellite imagery (Landsat-5, Landsat-8, and Landsat-9) was used to analyze land-use and land-cover (LULC) changes at five-year intervals. Supervised classification was applied to generate LULC maps, categorizing the landscape into built-up area, vegetation, water bodies, and barren/open land. Classification accuracy was evaluated using confusion matrix analysis to ensure reliability of the results. To investigate vegetation distribution and urban expansion patterns, the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) were calculated. Land Surface Temperature (LST) was derived from the thermal bands of Landsat imagery to examine spatial variations in urban thermal conditions. Furthermore, hotspot analysis using the Getis-Ord Gi* statistic was employed to identify statistically significant clusters of high and low temperature zones across the study area. The results reveal a substantial increase in built-up areas accompanied by a decline in vegetation cover during the study period, indicating rapid urban growth within the municipal boundary. Areas with higher NDBI values correspond to elevated surface temperatures, while zones with higher NDVI values exhibit relatively lower temperatures, highlighting the cooling role of urban green spaces. Hotspot analysis further confirms that high temperature clusters are predominantly concentrated in densely built-up regions with limited vegetation cover. The study demonstrates the effectiveness of remote sensing and GIS techniques in evaluating urban land transformation and its influence on thermal environments. The findings emphasize the importance of incorporating green infrastructure and sustainable land-use planning strategies to mitigate urban heat island effects and improve environmental resilience in rapidly growing cities.

Keywords: *Geographical Information System, Land Surface Temperature, Land Use Land Cover, Normalized Difference Built-up Index, Normalized Difference Vegetation Index, Urban Heat Island.*

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Introduction

Rapid urbanization is one of the most transformative global trends of the 21st century, with more than half of the world's population now residing in urban areas (2018). In India, this transition is particularly pronounced as towns and cities swiftly convert into metropolises and megacities, creating significant pressure on land resources and ecological systems (Tiwari & Kanchan, 2024). While urban expansion drives economic growth, it often results in unplanned development and the widespread replacement of natural landscapes with impervious surfaces (Roy & Roy, 2024; Tiwari & Kanchan, 2024). This modification of the land surface significantly alters the local microclimate, leading to the phenomenon known as the Urban Heat Island effect, where urban areas experience substantially higher temperatures than their surrounding rural or peri-urban counterparts (Das et al., 2024; Roy & Roy, 2024).

The intensity of UHI is intrinsically linked to Land Use and Land Cover changes, characterized by the proliferation of concrete structures and a systematic reduction in green cover (Mukherjee & Singh, 2020; Rahman & Mark, 2025). Impervious surfaces, often measured through the Normalized Difference Built-up Index, absorb and re-radiate solar radiation, thereby increasing Land Surface Temperature (Debnath et al., 2025; Gupta, 2024). Conversely, Urban Green Spaces and water bodies provide critical ecosystem services by facilitating evapotranspiration and shading, which create "Urban Cool Islands" that mitigate thermal stress (Roy & Roy, 2024; Shah et al., 2021). Monitoring these dynamics is essential for achieving Sustainable Development Goal 11, which aims to make cities inclusive, safe, resilient, and sustainable (Tiwari & Kanchan, 2024).

Patna, the capital of Bihar and a major administrative and economic hub in eastern India, serves as a critical case for studying these environmental shifts. Located in the humid subtropical zone of the Indo-Gangetic Plain, the city faces extreme summer temperatures frequently exceeding 40°C. Between 2001 and 2011, the Patna Municipal Corporation recorded a substantial population growth of approximately 22.2% (Pradesh, 2011). Recent projections suggest the population may reach 2.46 million by 2025, further intensifying the demand for residential and commercial infrastructure (2018).

Previous research in the PMC has demonstrated that areas with low Normalized Difference Vegetation Index are increasingly concentrated in the central and northern urban cores, while high vegetation density is restricted to the southeastern and southwestern margins (Akram et al., 2024). Multi-temporal analysis indicates that the built-up area in Patna has nearly doubled over the last 25 years, rising from approximately 39.96 km^2 in 2000 to an estimated 78.40 km^2 by 2025. This rapid expansion has been accompanied by a drastic decline in open land and a significant increase in mean LST, which has risen from roughly 34°C to over 42°C in the same period.

Despite the growing awareness of urban warming, there is a need for a comprehensive, integrated assessment of how specific spatial distributions of green spaces influence heat intensity across the PMC's diverse wards. Remote Sensing and Geographic Information Systems provide powerful tools for mapping these multi-temporal variations in NDVI, NDBI, and LST (Yadav et al., 2023). This study aims to utilize geospatial techniques to evaluate the spatio-temporal changes in LULC and assess the correlation between built-up intensity and thermal hotspots. By analyzing these relationships, the research seeks to provide actionable insights for urban planners to enhance microclimate resilience through strategic green infrastructure development.

Objective

- To analyze the spatio-temporal changes in Land Use and Land Cover (LULC) in Patna Municipal Corporation between 2000 and 2025.
- To assess the spatial distribution of urban green spaces and built-up areas using vegetation and built-up indices.
- To evaluate the pattern and intensity of Urban Heat Island by analyzing Land Surface Temperature and identifying thermal hotspots within the study area.

Study Area

The study focuses on Patna Municipal Corporation (PMC), the capital city of Bihar, India, located in the eastern part of the Indo-Gangetic Plain. Geographically, the city lies between approximately 25°30′N and 25°38′N latitude and 85°05′E and 85°15′E longitude, along the southern bank of the river Ganga. The municipal corporation covers an area of about 108.87 km² (Patna Municipal Corporation, n.d.) and represents the primary administrative, economic, and educational center of the state. Due to its strategic location and rapid urban development, Patna has experienced significant demographic and spatial expansion in recent decades.

Patna is recognized as one of the major urban centers in eastern India. It is ranked among the most populous cities in the country, listed as the 19th most populous urban agglomeration in India based on national urban population statistics (United Nations, 2018; Government of India urban statistics). Continued economic growth, administrative importance, and improved connectivity have accelerated urbanization in the city.

In the 2011 census, the city recorded a population of 1,68,422. Based on demographic estimates compiled from urban population databases and United Nations World Urbanization Prospects, the population of Patna is estimated to reach approximately 2.46 million by 2025 and may exceed 2.7 million by 2030. These projections highlight the increasing demographic pressure on land resources, infrastructure, and environmental conditions within the city.

Patna experiences a humid subtropical climate characterized by hot summers, a monsoon season from June to September, and mild winters. Summer temperatures frequently exceed 40°C, making the city particularly vulnerable to the Urban Heat Island effect. Rapid urban expansion, increasing built-up surfaces, and a reduction in vegetation cover have further intensified thermal stress in the urban environment.

Given its rapid population growth, expanding built-up area, and rising environmental challenges, Patna Municipal Corporation provides an important case study for examining the relationship between land use/land cover change, green space distribution, and urban heat island dynamics using remote sensing and GIS techniques.

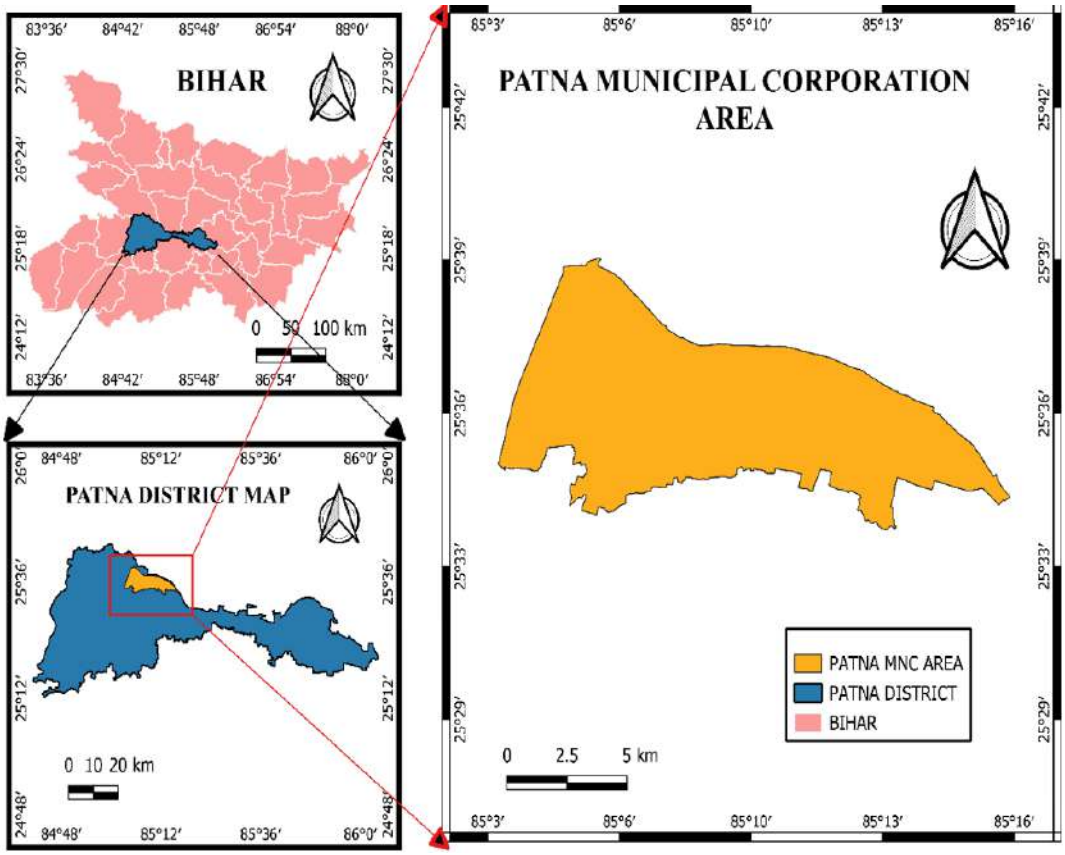


Figure 1 : Study area: Patna Municipal Corporation Area.

Methodology & Data Sources

This study employs an integrated remote sensing and Geographic Information System (GIS) approach to analyze land use/land cover (LULC) dynamics, vegetation distribution, built-up

expansion, and land surface temperature (LST) in Patna Municipal Corporation for the period 2000–2025. Multi-temporal Landsat satellite data at five-year intervals (2000, 2005, 2010, 2015, 2020, and 2025) were used for the analysis. Landsat-5 TM data were utilized for the years 2000–2010, while Landsat-8 OLI/TIRS and Landsat-9 OLI-2/TIRS-2 data were used for 2015–2025. Landsat Collection-2 Level-2 Surface Reflectance products were used for LULC classification and spectral index calculations (NDVI and NDBI), whereas Landsat Collection-2 Level-1 thermal data were used for deriving Land Surface Temperature (LST). All datasets were acquired from the USGS Earth Explorer platform, ensuring minimal cloud cover and similar seasonal conditions (pre-monsoon month of May) for consistency.

Table 1 : Dataset and source

Dataset	Satellite/Sensor	Spatial Resolution	Study Period	Source	Computing Platform
Patna Municipal Corporation Boundary (Shapefile			2000-2025	Patna Municipal Corporation Website	QGIS
Landsat 5 Collection 2 Level 1 and 2	Landsat 5 TM	30 m	May 2000	USGS	QGIS AND ArcGIS
Landsat 5 Collection 2 Level 1 and 2	Landsat 5 TM	30 m	May 2005	USGS	QGIS AND ArcGIS
Landsat 5 Collection 2 Level 1 and 2	Landsat 5 TM	30 m	May 2010	USGS	QGIS AND ArcGIS
Landsat 8 Level 1 and 2	Landsat 8 OLI/TIRS	30 m	June 2015	USGS	QGIS AND ArcGIS
Landsat 8 Level 1 and 2	Landsat 8 OLI/TIRS	30 m	May 2020	USGS	QGIS AND ArcGIS
Landsat 9Level 1 and 2	Landsat 9 OLI/TIRS-2	30 m	May 2025	USGS	QGIS AND ArcGIS

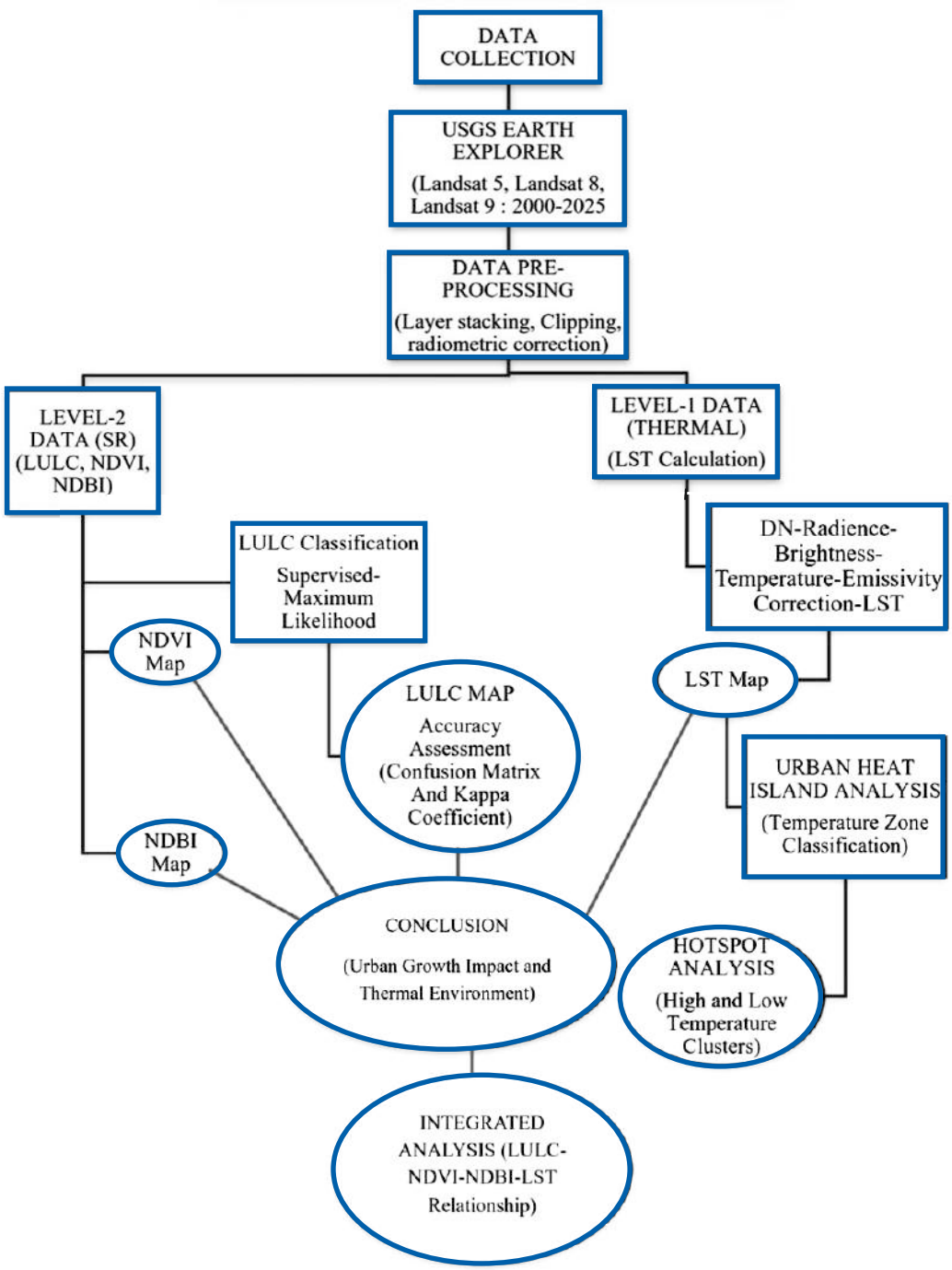


Figure 2 : Research Methodology

Pre-processing of satellite imagery included layer stacking, radiometric correction, and clipping of images to the boundary of Patna Municipal Corporation. False Color Composite (FCC) images were generated (4-3-2 for Landsat-5 and 5-4-3 for Landsat-8/9) to assist in visual interpretation and training sample selection. Supervised classification using the Maximum Likelihood algorithm was applied to generate LULC maps for each selected year. The land cover was categorized into four classes: built-up area, vegetation, water bodies, and barren/open land. Classification accuracy was evaluated using randomly generated validation points and high-resolution reference imagery, and a confusion matrix was used to compute overall accuracy and Kappa coefficient.

Spectral indices were calculated to quantify vegetation and built-up characteristics. The Normalized Difference Vegetation Index (NDVI) was derived using near-infrared and red bands to assess vegetation density and spatial distribution of green spaces. The Normalized Difference Built-up Index (NDBI) was calculated using shortwave infrared and near-infrared bands to identify built-up areas and monitor urban expansion. Temporal changes in NDVI and NDBI were analyzed to assess land-cover transformation over time.

NDVI

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

NDBI

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

Land Surface Temperature (LST) was estimated from the thermal bands of Landsat imagery. The process involved conversion of digital numbers to spectral radiance, followed by calculation of brightness temperature using sensor-specific thermal constants, and subsequent correction for land surface emissivity derived from NDVI values. The resulting LST maps were classified into temperature zones to examine spatial patterns of urban heat.

Steps to Calculate Land Surface Temperature (LST)

STEP 1: Convert DN to Spectral Radiance

$$L_\lambda = M_L \times Q_{cal} + A_L$$

Where:

- L_λ = spectral radiance
- M_L = radiance multiplicative scaling factor
- Q_{cal} = pixel DN value
- A_L = radiance additive scaling factor

STEP 2: Calculate Brightness Temperature

The formula is: $$BT = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

Where:

- BT = brightness temperature (Kelvin)
- K_1 = thermal conversion constant
- K_2 = thermal conversion constant
- L_λ = spectral radiance

The K_1 and K_2 values are available in the metadata.

STEP 3: Calculate NDVI

$$\boxed{NDVI = \frac{NIR - Red}{NIR + Red}}$$

STEP 4: Calculate Proportion of Vegetation (Pv)

$$\boxed{P_v = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2}$$

STEP 5: Calculate Land Surface Emissivity (LSE)

A widely used NDVI-based formula is:

$$\boxed{\varepsilon = 0.004P_v + 0.986}$$

Where:

- $\mathcal{E}$ = land surface emissivity
- P_v = proportion of vegetation.

STEP 6: Calculate Final LST

The land surface temperature formula is:

$$\boxed{LST = \frac{BT}{1 + \left(\frac{\lambda BT}{\rho}\right)\ln(\varepsilon)}}$$

Where:

- BT = Brightness Temperature in Kelvin
- λ = wavelength of emitted radiance
- $\mathcal{E}$ = land surface emissivity
- ρ = $1.438 \times 10-2mK$

To identify spatial clusters of high and low temperature, hotspot analysis was performed using the Getis-Ord Gi* statistic in QGIS. This method enabled the detection of statistically significant hotspots and coldspots of LST within the study area.

Furthermore, correlation and regression analyses were conducted to examine the relationship among NDVI, NDBI, and LST. Random sampling points were generated across the study area, and corresponding raster values of NDVI, NDBI, and LST were extracted using the sample raster values tool in QGIS. The extracted data were exported as a CSV file and analyzed in Microsoft Excel to compute correlation coefficients and generate scatter plots with regression lines and coefficient of determination (R^2) values.

This integrated methodological framework allows for a comprehensive assessment of urban growth, land cover transformation, and their impact on urban thermal dynamics, providing a robust basis for analyzing urban heat island effects in Patna Municipal Corporation.

Analysis, Discussion & Results

The geospatial analysis of the multi-temporal Landsat data reveals significant changes in land use/land cover, vegetation distribution, built-up expansion, and surface temperature patterns in Patna Municipal Corporation between 2000 and 2025. The analysis highlights the impact of rapid urban growth on green space reduction and increasing urban thermal intensity.

1. Land Use Land Cover Change

The multi-temporal LULC maps (Figure 3) and corresponding area statistics (Table 2 & 3) reveal a substantial transformation in the land use land cover of the study area between 2000 and 2025. Visual interpretation of the classified maps indicates that in 2000, the landscape was comparatively less urbanized, with built-up land and open land occupying large portions of the area, while vegetation was distributed in scattered patches, and water bodies were limited in extent. By 2025, the spatial pattern had changed considerably, with built-up land becoming the dominant class across most parts of the study region. A major reduction in open land and a fluctuating trend in the extent of vegetation cover and water bodies were also observed.

Table 2 : Land Use Land Cover Area Statistics (2000-2025)

Year	LULC Class (Area in Square Kilometers)			
	Built-up	Vegetation	Water Bodies	Open Area
2010	39.9573	27.0369	1.1385	39.0267
2005	41.6691	32.3595	2.3949	30.7359
2010	49.1364	17.2818	2.7477	37.9935
2015	62.7993	20.1717	3.2517	20.9367
2020	65.3247	19.8189	1.3266	20.6892
2025	78.4026	18.8217	0.4761	9.459

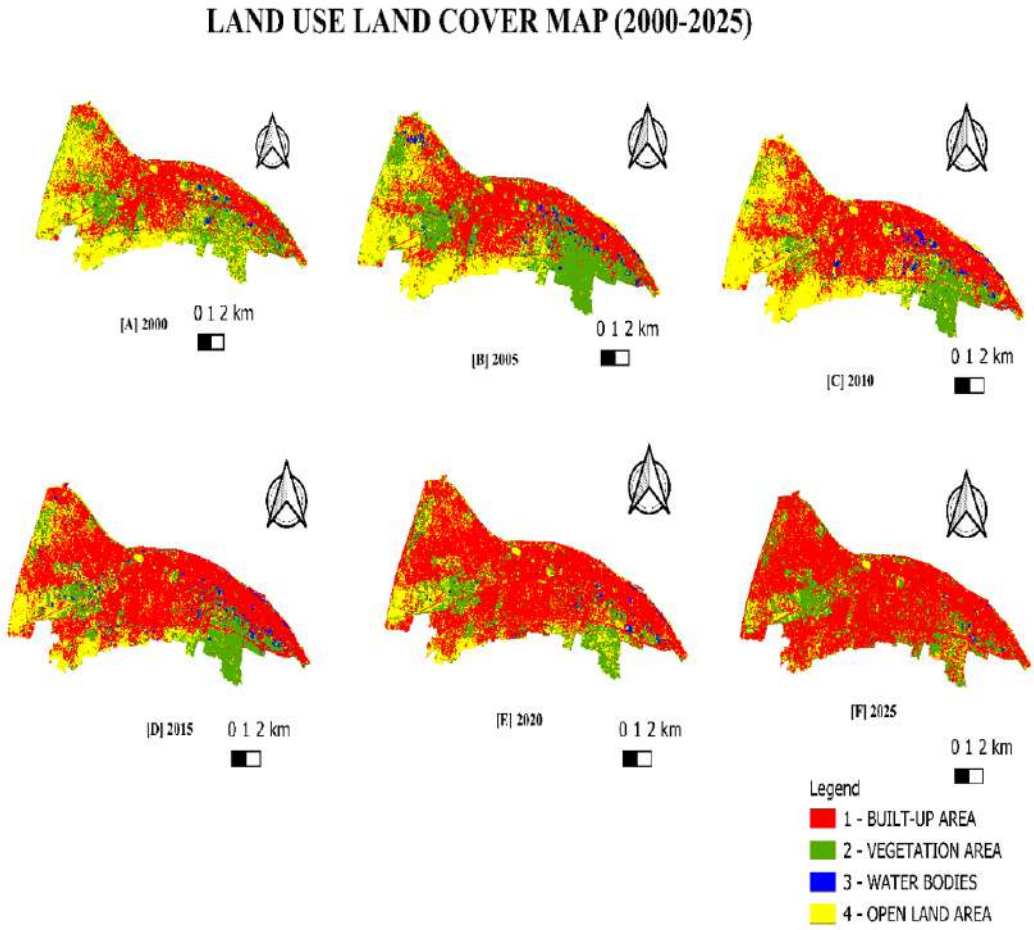


Figure 3 : LULC Map of Patna Municipal Corporation from 2000-2025

Table 3 : Patna Municipal Corporation: Land Use Land Cover Change (2000-2025)

LULC CLASSIFICATION	Δ CHANGE	2000%	2025%	Δ %
1 - BUILT-UP AREA	38.45 sq. km.	37.28772278	73.16446341	35.87674063
2 -VEGETATION AREA	-8.22 sq. km.	25.2305444	17.56420809	-7.666336318
3 - WATER BODIES AREA	-0.66 sq. km.	1.06243596	0.444291401	-0.618144558
4 - OPEN LAND AREA	-29.57 sq. km.	36.41929686	8.827037105	-27.59225976

(a) Built-up area - The built-up area exhibits a continuous and substantial increase throughout the study period, rising from 39.96 km² in 2000 to 78.40 km² in 2025, with a net gain of 38.44 km², indicating nearly a doubling of built-up land over 25 years. The most rapid expansion occurred between 2010 and 2015, when the built-up area increased sharply from 49.14 km² to 62.80 km², reflecting intensified urban growth and land conversion. Most of this growth and expansion occurred towards the west (Danapur & Khagaul) and towards the southern boundary of the PMC, south of NH 22 (Anisabad, Beau, Ranipur, Ram Krishna Nagar, Khemni Chak, Sheikhpura, Sipara). The expansion continued till 2025 in the same direction. A significant number of schools, hospitals, residential apartments, housing societies, and private houses were built in these areas. Since Patna is the largest city and the capital city of the state, people migrate here in large numbers from nearby rural areas and smaller towns, and they have an overwhelming desire to own a house in Patna, which has fuelled this rapid expansion in built-up area.

(b) Vegetation Cover- The vegetation cover shows a fluctuating but overall declining trend. It increased from 27.04 km² in 2000 to 32.36 km² in 2005, then declined sharply to 17.28 km² in 2010and slightly recovered to 18.82 km² in 2025, resulting in a net loss of 8.21 km² over the study period. Urban expansion always takes place at the cost of land under vegetation and agricultural land. Development of residential colonies, educational institutions, hospitals, commercial areas, roads and other infrastructure within the PMC boundary has taken place by encroaching the land under vegetation cover.

(c) Water bodies - Water bodies, which constitute the smallest land cover class in terms of area, exhibit high temporal variability, with an overall decreasing trend: increasing from

1.14 km² in 2000 to a peak of 3.25 km² in 2015, then declining to 0.48 km² in 2025, resulting in a net reduction of 0.66 km². Many ponds within the city have now been converted into built-up areas. There was a large wetland area in Mithapur, south of the Railway line. In the mid to late 2000s, the Government bus stand was first shifted to this area, and then gradually this entire area was filled up and converted into an education hub. Premier institutions like Chanakya National Law University, NIFT Patna, and Aryabhatta Knowledge University were built here.

(d) Open Land- Open land area has experienced the most drastic decline, shrinking from 39.03 km² in 2000 to 9.46 km² in 2025, with a significant net loss of 29.57 km². This land use category has been the primary target for urban expansion. Most of this land was in the western and southern part of the PMC area and has now been converted into built-up area.

Table 4 : Accuracy assessment results and Kappa Coefficient

Year	Total Pixels	Correctly Classified	Overall Accuracy (%)	Kappa Coefficient
2000	4,929	4,889	99.19	0.9855
2005	5,163	5,127	99.30	0.9889
2010	3,795	3,774	99.45	0.9913
2015	2,876	2,844	98.89	0.9831
2020	4,912	4,855	98.84	0.9750
2025	4,120	4,062	98.59	0.9454

The accuracy assessment results indicated that the LULC classification was highly reliable across all years under investigation. The total accuracy of the LULC classification ranged from 98.59% to 99.45%, and the Kappa index ranged from 0.945 to 0.991. These findings indicate a very high level of consistency between the classified LULC maps and the reference data, indicating that the classified LULC maps are suitable for spatio-temporal change analysis and future prediction of LULC.

Overall, the LULC transformation clearly demonstrates a dominant transition pattern of open land and vegetation being converted into built-up areas, highlighting a significant shift from natural and semi-natural landscapes to artificial surfaces driven by increasing anthropogenic activities.

Normalized Difference Vegetation Index (NDVI)

The spatio-temporal analysis of NDVI from 2000 to 2025 reveals significant changes in vegetation cover and health within the study area. NDVI values were classified into five

categories, namely non-vegetation, very low vegetation, low vegetation, moderate vegetation, and dense vegetation, to assess the distribution and transformation of vegetation over time.

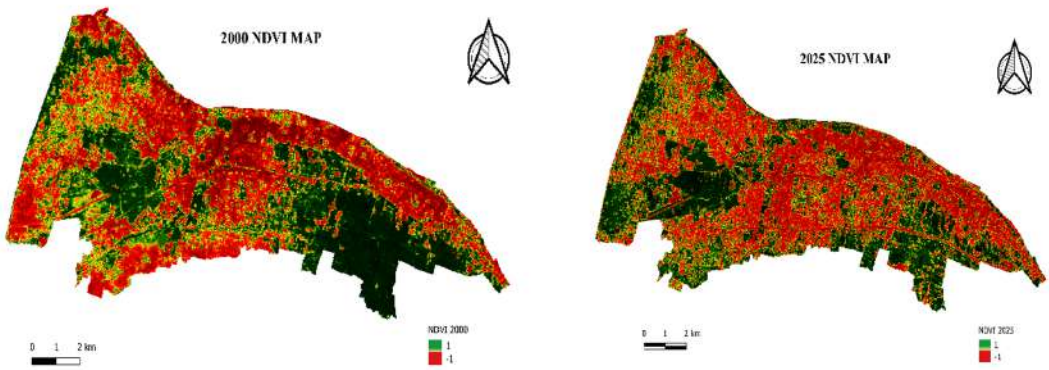


Figure 4 : NDVI Map of 2000-2025

In 2000, the study area exhibited relatively higher vegetation density, with a considerable proportion of land falling under moderate (0.25–0.38) and dense (>0.38) vegetation classes. The spatial distribution of vegetation was more continuous, indicating a stable ecological condition with limited anthropogenic disturbance.

By 2005, a slight decline in vegetation quality was observed, marked by an increase in very low vegetation (0.00–0.12) and a reduction in dense vegetation areas. This period represents the initial phase of vegetation degradation, likely associated with gradual land-use changes and increasing human activities.

The trend became more pronounced in 2010, where moderate vegetation areas showed further decline and fragmentation. The expansion of low vegetation (0.12–0.25) and non-vegetation classes indicates increasing environmental stress and possible urban expansion. Vegetation patches became more scattered, reflecting landscape fragmentation.

In 2015, a significant shift in vegetation dynamics was observed. Non-vegetation and very low vegetation classes expanded considerably, while moderate and dense vegetation shrank sharply. This period marks a critical phase of land transformation, likely driven by rapid urbanization and infrastructural development.

The year 2020 shows continued degradation, with the dominance of low NDVI values across large parts of the study area. Dense vegetation is nearly absent, and moderate vegetation is confined to limited pockets, indicating severe ecological stress and declining vegetation health.

By 2025, the study area reached a critical stage, characterized by widespread dominance of non-vegetation and very low vegetation classes. Vegetation is highly fragmented and restricted to peripheral regions. This reflects intense anthropogenic pressure, including urban expansion, industrialization, and land-use conversion.

NDVI Trend and Change Analysis

The integrated analysis of NDVI trend, spatial distribution, and change detection from 2000 to 2025 reveals complex vegetation dynamics within the study area. The NDVI trend graph indicates a slight increasing trend, with mean NDVI values rising from approximately 0.105 in 2000 to 0.147 in 2025, representing an overall increase of about 40%. The calculated annual NDVI change rate of +0.00168 further supports this gradual upward trend.

However, spatial analysis of NDVI maps and the NDVI change map presents a contrasting scenario. Despite the increase in mean NDVI values, there is a significant decline in moderate and dense vegetation classes, accompanied by an expansion of low and very low vegetation categories. This indicates that the observed increase in NDVI is primarily due to the proliferation of sparse vegetation rather than an actual improvement in vegetation health.

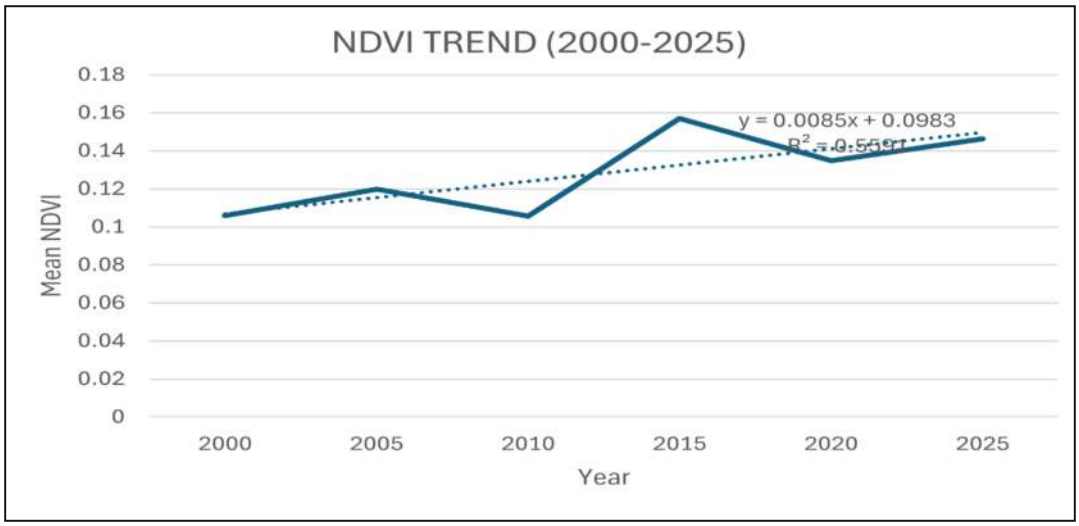


Figure 5 : NDVI Trend Graph (2000-2025)

The NDVI change map highlights that a large portion of the study area experienced negative NDVI change, indicating vegetation loss. These areas are predominantly concentrated in urbanizing and central regions, suggesting strong anthropogenic influence, including urban expansion and land-use transformation. In contrast, only limited areas exhibit positive NDVI change, indicating localized vegetation gain due to plantation or regeneration activities.

The trend analysis shows fluctuations, with a peak in 2015 followed by a decline and partial recovery. This variability suggests the influence of climatic factors such as rainfall, as well as agricultural practices. The coefficient of determination (R^2 = 0.5591) indicates moderate correlation, reflecting variability in vegetation dynamics over time.

Overall, the combined analysis reveals that while NDVI values show a marginal increase, vegetation quality and ecological integrity have declined. This highlights the limitation of mean NDVI as a sole indicator and emphasizes the importance of integrating spatial and temporal analyses. The findings clearly indicate increasing environmental stress and the need for sustainable land-use planning and vegetation conservation strategies.

Normalized Difference Built-up Index (NDBI)

The Normalized Difference Built-up Index (NDBI) was used to assess the spatial and temporal expansion of built-up areas in Patna Municipal Corporation from 2000 to 2025. The NDBI values range from -1 to +1, where higher positive values indicate built-up surfaces, while lower and negative values correspond to vegetation and water bodies.

The NDBI map of 2000 shows that built-up areas were relatively limited and scattered, primarily concentrated in the city's central area. Large portions of the study area exhibited lower NDBI values, indicating the dominance of vegetation and open land during this period. In 2005, a slight increase in built-up areas is observed, with expansion occurring around the existing urban core.

A significant increase in NDBI values is evident in 2010 and 2015, indicating rapid urban growth and horizontal expansion of built-up surfaces. The built-up areas become more continuous and extend toward peripheral regions, particularly along major transport corridors and developing zones. This period marks a transition from compact urban form to more dispersed urban expansion.

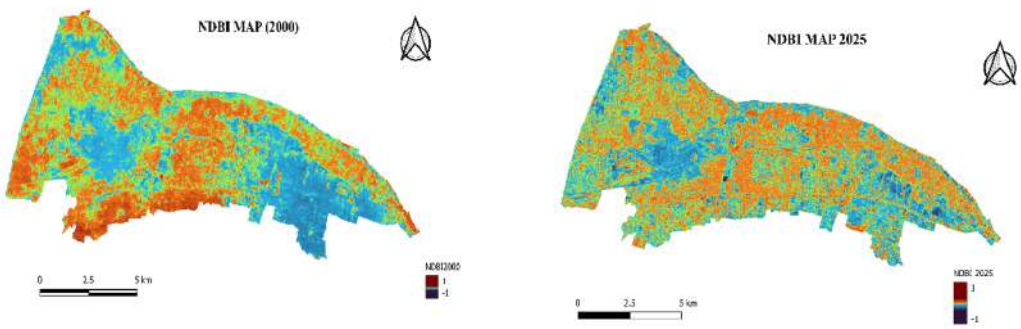


Figure 6 : NDBI Map of 2000 and 2025

By 2020 and 2025, the NDBI maps clearly show a substantial increase in high-value zones, representing dense built-up areas. The spatial distribution indicates that urban expansion has intensified across the municipal area, with significant conversion of vegetation and open land into impervious surfaces. The built-up areas have become more widespread and interconnected, forming continuous urban patches.

The temporal analysis of NDBI demonstrates a consistent increase in built-up intensity over the 25 years, reflecting rapid urbanization and infrastructure development in Patna. The expansion of built-up areas corresponds closely with areas of higher land surface temperature observed in LST analysis, indicating the contribution of impervious surfaces to urban heat island formation.

Overall, the NDBI analysis highlights the transformation of land use patterns and the increasing dominance of built-up surfaces, which play a crucial role in altering the urban thermal environment and intensifying heat stress in the study area.

Built-up Index (NDBI) Trend Analysis

The temporal variation of the mean Normalized Difference Built-up Index (NDBI) from 2000 to 2025 indicates a significant and continuous increase in built-up intensity within Patna Municipal Corporation. The mean NDBI value increased from approximately 0.002 in 2000 to about 0.075 in 2025, reflecting rapid urban expansion over the study period.

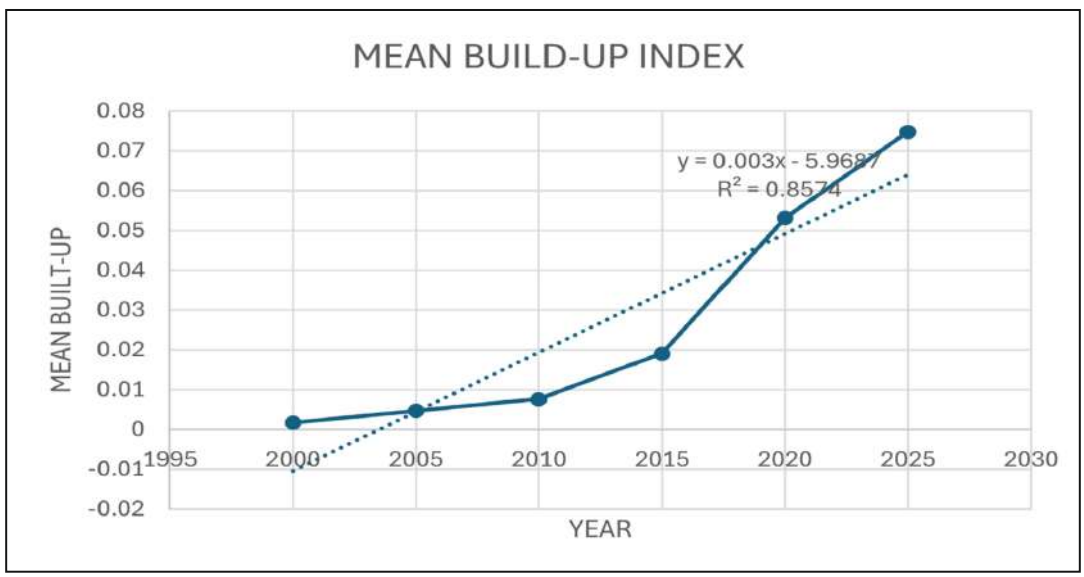


Figure 7: Mean Built-up Index Graph (2000-2025)

A gradual increase is observed between 2000 and 2010, indicating moderate urban growth during the early phase. However, a sharp rise in NDBI values is evident after 2015, particularly between 2015 and 2025, suggesting accelerated urbanization and increased conversion of vegetation and open land into built-up surfaces.

The positive slope of the trendline further confirms the continuous expansion of impervious surfaces over time. The high coefficient of determination ($R^2 \approx 0.86$) indicates a strong relationship between time and increasing built-up intensity, highlighting the consistent nature of urban growth in the study area.

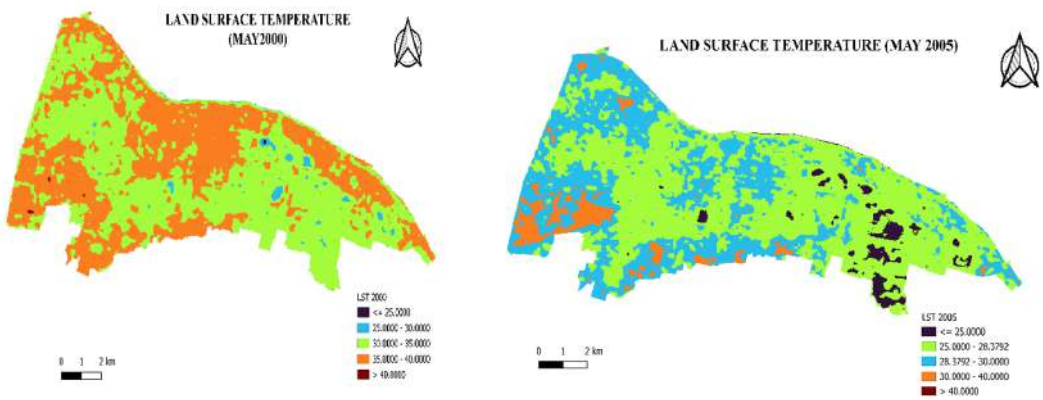
This increase in NDBI values corresponds closely with the rise in land surface temperature observed in the LST analysis, suggesting that urban expansion plays a significant role in intensifying the Urban Heat Island effect.

Land Surface Temperature

The LST maps (Figure 8) reveal a clear increasing trend in surface temperature over the study period, indicating the growing intensity of urban heat island effects associated with rapid urbanization.

In 2000, the LST values ranged approximately between 24°C and 36°C, with lower temperatures observed in vegetated areas and along the river Ganga, while relatively higher temperatures were concentrated in scattered built-up zones. By 2005 and 2010, a gradual increase in temperature was observed, with expanding moderate to high temperature zones corresponding to increasing urban development.

A significant rise in LST was observed after 2015, with temperatures increasing to approximately 26°C to 40°C. The spatial distribution shows that high-temperature zones became more continuous and concentrated in the central and western parts of the city, indicating intensified built-up expansion and reduction in vegetation cover.



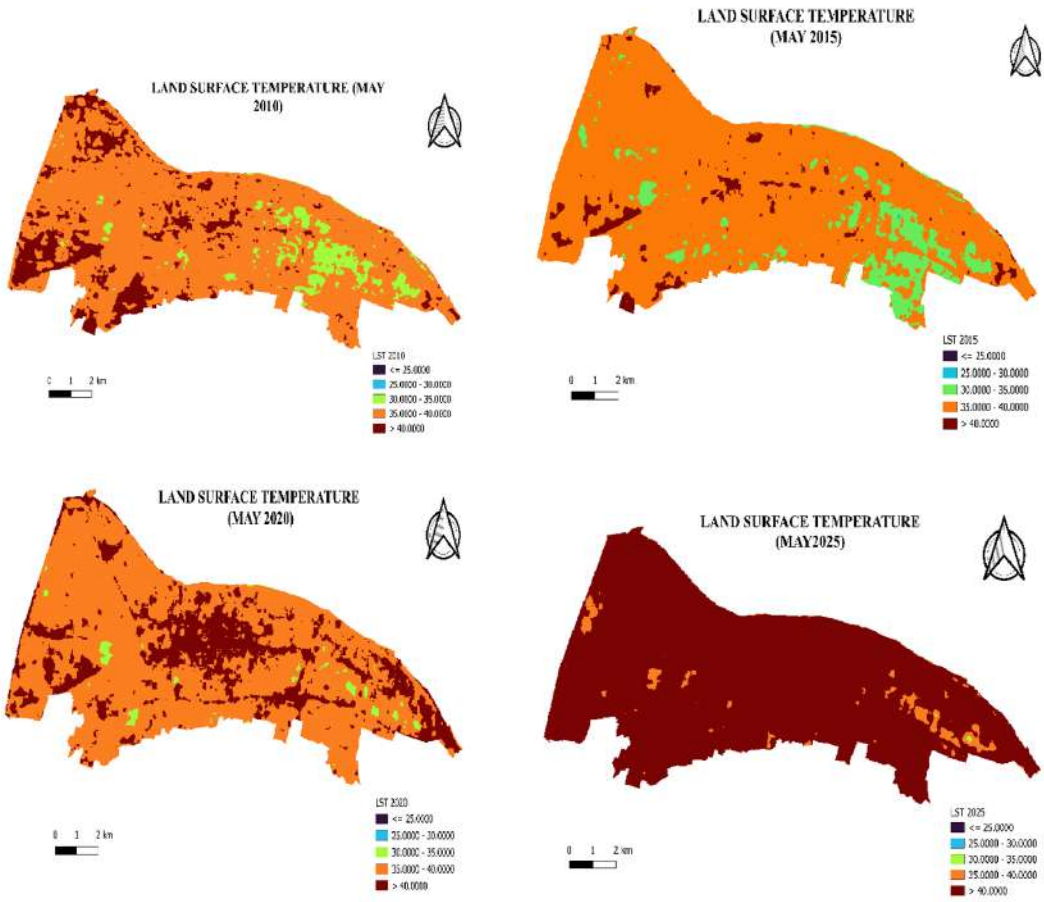


Figure 8 : Land Surface Temperature Map (2000,2005,2010,2015,2020,2025)

By 2020 and 2025, the LST values further increased, reaching approximately 28°C to 42°C or higher in some locations. The high-temperature zones expanded significantly, forming large contiguous clusters across densely built-up areas. In contrast, relatively lower temperatures were consistently observed in areas with higher vegetation density and near water bodies, highlighting the cooling effect of green spaces and surface water.

The temporal analysis clearly demonstrates that areas with increasing built-up density exhibit higher LST values, while vegetated regions maintain lower temperatures. This pattern confirms the strong influence of land-use/land-cover changes on urban thermal dynamics. The continuous increase in surface temperature over the past 25 years indicates the intensification of urban heat island effects in Patna Municipal Corporation.

Mean LST Trend Analysis

The temporal variation of mean Land Surface Temperature (LST) for the month of May from 2000 to 2025 indicates a clear increasing trend over the study period. The mean LST decreased slightly from approximately 34°C in 2000 to around 28°C in 2005, followed by a significant rise to about 38°C in 2010. A slight fluctuation was observed in 2015; however, the overall trend shows a continuous increase in temperature thereafter.

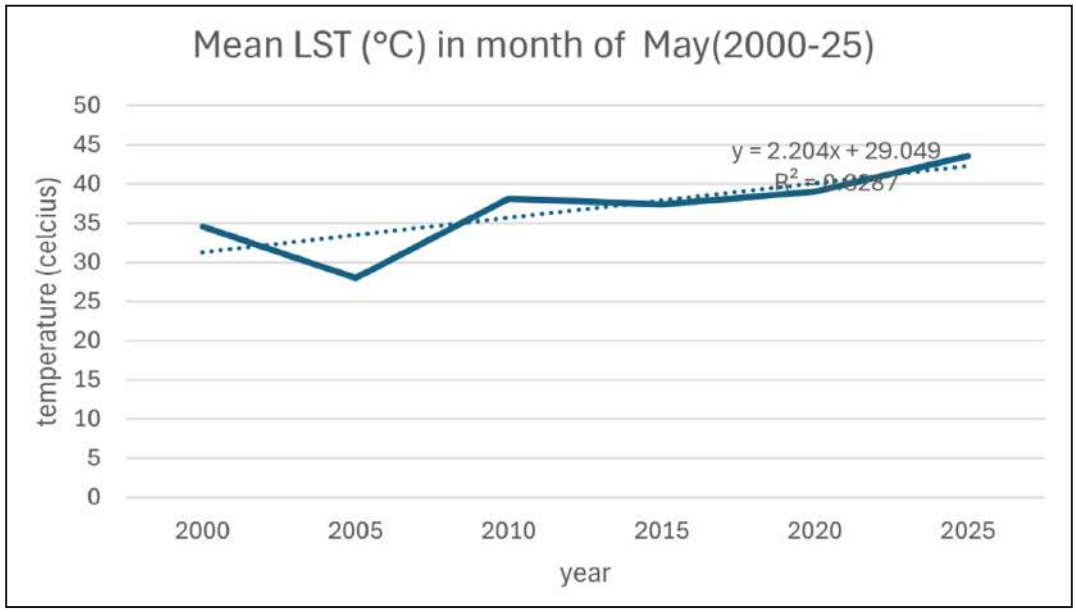


Figure 9: Mean Land Surface Temperature Graph (2000-2025)

By 2020 and 2025, the mean LST reached approximately 40°C and 43°C, respectively, indicating a substantial rise in urban surface temperature. The linear trendline further confirms this increasing pattern, with a positive slope suggesting consistent warming over time. The coefficient of determination ($R^2 \approx 0.63$) indicates a moderate to strong relationship between time and increasing temperature.

This rising trend in LST can be attributed to rapid urban expansion, increased built-up surfaces, and a reduction in vegetation cover within the Patna Municipal Corporation. The results clearly demonstrate the intensification of the Urban Heat Island effect over the 25 years.

Hotspot and Coldspot Analysis (2000–2025)

Hotspot analysis using the Getis-Ord Gi* statistic was performed to identify statistically significant clusters of high and low land surface temperature (LST) in Patna Municipal

Corporation from 2000 to 2025. The results reveal a clear spatial and temporal evolution of thermal hotspots and coldspots associated with urban growth and land cover transformation.

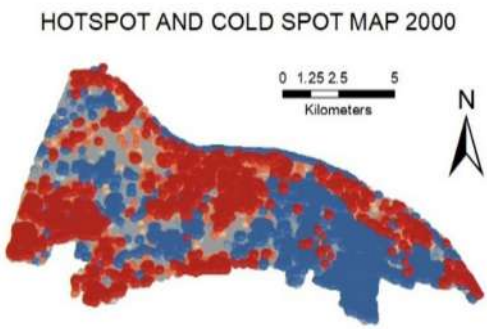
In 2000, hotspots were relatively scattered and limited in extent, primarily concentrated in localized built-up areas. Coldspots were more dominant, particularly in vegetated regions and along the river corridor, indicating lower surface temperatures in areas with higher moisture and vegetation cover.

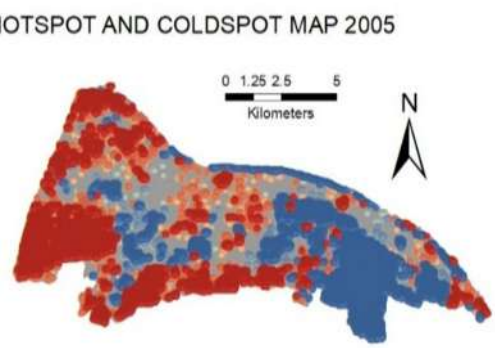
By 2005 and 2010, the spatial extent of hotspots increased noticeably, with clusters becoming more pronounced and expanding outward from the urban core. This expansion corresponds with increasing built-up areas and a reduction in vegetation, indicating the early stages of urban heat island development.

A significant transformation is observed in 2015 and 2020, where hotspots become more continuous and widespread across the central and western parts of the city. High-confidence hotspots (95% and 99%) dominate these regions, reflecting intensified urbanization and increasing impervious surface cover. At the same time, coldspots become more fragmented and restricted to peripheral areas and regions with remaining vegetation or water bodies.

By 2025, hotspot clusters show maximum spatial expansion, forming large contiguous zones across densely built-up regions. The dominance of high-confidence hotspots indicates strong spatial clustering of elevated temperatures. In contrast, coldspots are significantly reduced and confined to limited areas, primarily along the river and outer fringes of the city.

The temporal progression of hotspot expansion clearly demonstrates the intensification of the Urban Heat Island effect over the 25 years. The spatial correspondence between hotspot zones, high NDBI values, and low NDVI values further confirms that built-up expansion and vegetation loss are the primary drivers of increasing surface temperature.





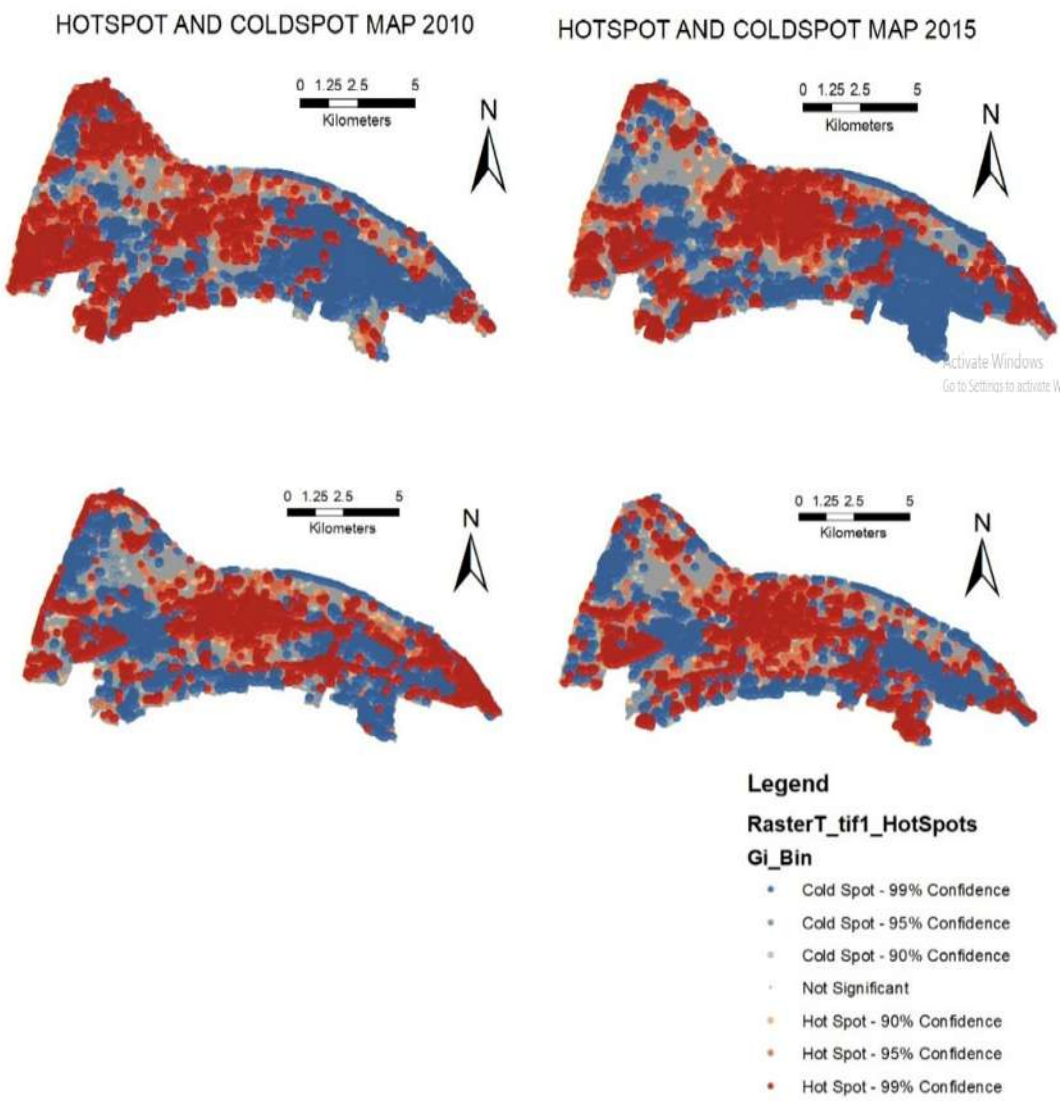


Figure 10 : Hotspot and Coldspot Map (2000, 2005, 2010, 2015, 2020, 2025)

Overall, the hotspot analysis highlights the growing thermal imbalance within the urban landscape and emphasizes the critical role of green spaces in mitigating heat stress. The findings suggest the need for targeted urban planning interventions, such as increasing urban greenery and preserving natural land cover, to reduce the intensity of urban heat island effects in Patna Municipal Corporation.

INTEGRATED ANALYSIS (LST, NDBI, AND NDVI)

NDVI–LST Relationship Analysis

The scatter plot analysis between NDVI and Land Surface Temperature (LST) reveals a negative relationship, as indicated by the downward slope of the regression line (y = -4.498x + 45.594). This suggests that areas with higher vegetation density tend to exhibit lower surface temperatures due to the cooling effects of evapotranspiration and shading.

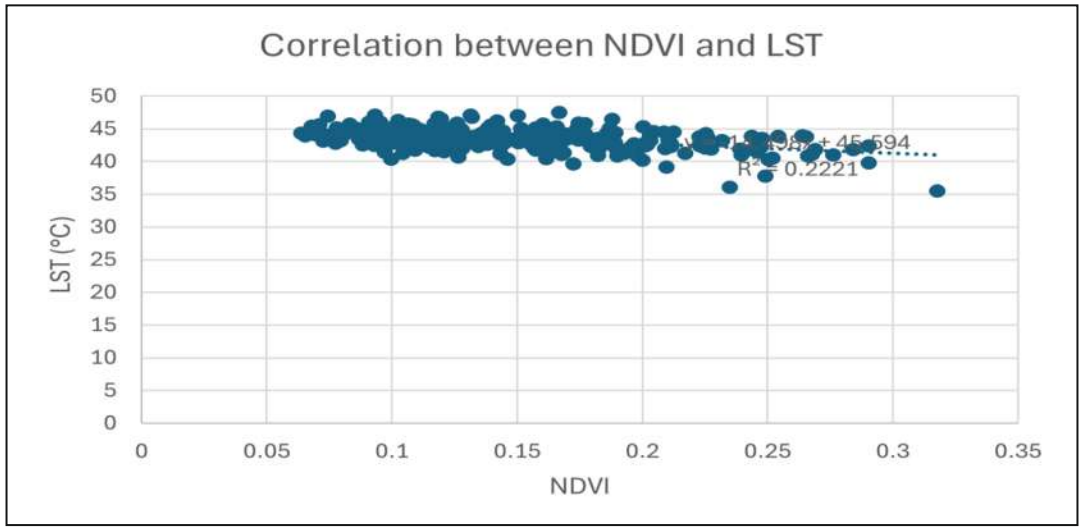


Figure 11 : Correlation Graph between NDVI and LST

However, the coefficient of determination (R^2 = 0.2221) indicates a relatively weak to moderate relationship between NDVI and LST. This suggests that while vegetation plays an important role in regulating surface temperature, other factors such as built-up intensity, surface materials, and urban morphology also significantly influence thermal patterns in the study area.

Overall, the results confirm that vegetation contributes to reducing urban heat, but its influence is spatially variable and interacts with other urban factors.

NDBI–LST Relationship Analysis

The scatter plot analysis between NDBI and Land Surface Temperature (LST) reveals a positive relationship, as indicated by the upward slope of the regression line (y = 19.316x + 43.589). This suggests that areas with higher built-up intensity tend to exhibit higher surface temperatures due to increased heat absorption and retention by impervious surfaces such as concrete and asphalt.

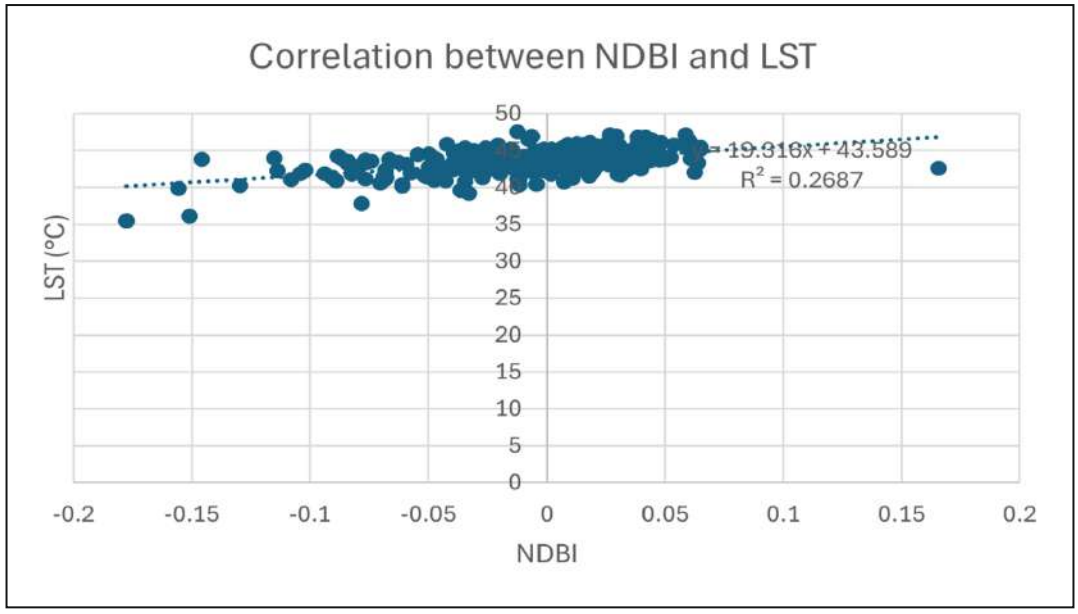


Figure 12 : Correlation Graph between NDBI and LST

The coefficient of determination ($R^2 = 0.2687$) indicates a moderate relationship between NDBI and LST. Although the relationship is not very strong, it clearly demonstrates that built-up areas contribute significantly to elevated land surface temperatures. The relatively moderate R^2 value suggests that additional factors such as vegetation cover, surface moisture, and urban morphology also influence temperature distribution.

Overall, the results confirm that increasing built-up density plays a key role in intensifying urban heat island effects in Patna Municipal Corporation.

Table 5 : Integrated Relationship between NDVI, NDBI, and LST

PARAMETER	CORRELATION (r)	RELATIONSHIP
NDVI VS NDBI	-0.849782242	NEGATIVE
NDBI VS LST	0.518365222	POSITIVE
NDVI VS LST	-0.471277625	NEGATIVE

The combined analysis of NDVI, NDBI, and Land Surface Temperature (LST) reveals a clear relationship between land cover characteristics and urban thermal patterns. The results indicate a negative relationship between NDVI and LST, and a positive relationship between NDBI and LST, highlighting the contrasting roles of vegetation and built-up surfaces in influencing urban temperature.

Areas with higher NDVI values consistently exhibit lower LST due to the cooling effects of evapotranspiration and shading provided by vegetation. In contrast, areas with higher NDBI values correspond to elevated LST, indicating the dominance of impervious surfaces that absorb and retain heat.

The regression analysis shows that although both NDVI and NDBI influence surface temperature, the relationship is moderate, suggesting that urban thermal dynamics are controlled by multiple interacting factors, including land use composition, surface materials, and spatial configuration of the urban landscape.

The spatial patterns observed in hotspot analysis further support these findings, where high-temperature clusters are associated with low NDVI and high NDBI zones, while cooler areas correspond to regions with higher vegetation cover.

Overall, the integrated analysis confirms that vegetation plays a critical role in mitigating urban heat, whereas the expansion of built-up areas contributes significantly to the intensification of urban heat island effects in Patna Municipal Corporation.

Conclusion

The present study analyzed the spatial and temporal dynamics of land use/land cover (LULC), vegetation cover, built-up expansion, and land surface temperature (LST) in Patna Municipal Corporation during the period 2000–2025 using remote sensing and GIS techniques. The results of the present study clearly indicate significant urban transformation within the Patna Municipal Corporation Area over the past 25 years (2000-2025), characterized by a substantial increase in built-up areas and a corresponding decline in vegetation cover.

The LULC and NDBI analyses reveal continuous expansion of impervious surfaces, particularly after 2015, reflecting rapid urbanization and infrastructural development. In contrast, NDVI analysis indicates a reduction in vegetation density, especially in the central and rapidly developing western and southern zones of the city. These changes in land cover have a direct impact on the urban thermal environment.

The LST analysis demonstrates a consistent increase in surface temperature over time, confirming the intensification of the Urban Heat Island (UHI) effect. The mean LST values show a significant upward trend, with higher temperatures concentrated in densely built-up areas, while lower temperatures are associated with vegetated and water-covered regions.

The correlation and regression analyses further establish a negative relationship between NDVI and LST, and a positive relationship between NDBI and LST. Although the strength of these relationships is moderate, the results clearly indicate that vegetation plays a crucial role

in reducing surface temperature, whereas built-up expansion contributes to increased thermal intensity. The hotspot analysis also supports these findings, identifying high-temperature clusters in areas with low vegetation and high built-up density.

Despite these important findings, the study has certain limitations. The analysis is based on medium-resolution Landsat data (30 m), which may not capture fine-scale urban heterogeneity and micro-level thermal variations. The use of single-date imagery (pre-monsoon month of May) may not fully represent seasonal variations in surface temperature. Additionally, the correlation analysis is limited to NDVI and NDBI, while other influential factors such as surface materials, urban morphology, population density, and anthropogenic heat emissions were not explicitly considered. The moderate correlation values also indicate that urban thermal patterns are influenced by multiple interacting variables beyond vegetation and built-up intensity.

Overall, the study highlights that rapid urban growth and the conversion of natural land cover into impervious surfaces have significantly altered the thermal environment of Patna Municipal Corporation.

The findings emphasize the urgent need for sustainable urban planning strategies, including the preservation and expansion of green spaces, implementation of urban greening initiatives, and promotion of climate-resilient infrastructure to mitigate the adverse impacts of urban heat island effects.

Future research should focus on integrating high-resolution satellite data, incorporating socio-economic and morphological parameters, and conducting seasonal and long-term climate analysis to better understand urban thermal dynamics. The study demonstrates the effectiveness of integrating remote sensing, GIS, and spatial statistical techniques in assessing urban environmental change and provides valuable insights for policymakers and urban planners to develop strategies for sustainable and climate-responsive urban development.

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IMPACTS OF URBAN FLOODING IN BIHAR: A COMPARATIVE AND TEMPORAL ANALYSIS OF URBAN FLOODS IN PATNA MUNICIPAL CORPORATION

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ABSTRACT

India has faced severe urban flooding in recent times, mainly caused by heavy monsoon rains, overflowing rivers and poor drainage infrastructure. Patna faces a similar situation. The problem of urban flooding in Patna mainly stems from hasty urban expansion, which encroaches on the city's natural drainage pathways, thus reducing the land's capability to absorb rainfall and increasing surface runoff. The paper is based on both primary and secondary data. Primary data were obtained from household surveys in Patna Municipal Corporation using the stratified random sampling method with reference to the 2019 urban flooding. This study aims to assess the living conditions of people in the flood areas and the impact of flooding on their movement, and to conduct a comparative assessment of the 2019 and 2025 flood situation in Patna Municipal Corporation, focusing on differences in flood extent, duration, and impact on residential areas.By combining physical indicators with social and functional indicators, this study captures flood risk as a multi-dimensional urban problem rather than an isolated hazard event.The study highlights an 8 percent increase in flooded areas in 2025. This study also finds that there was a 2.8 per cent increase in the damage caused to automobiles and an 8.3 percent increased disruption to traffic movement, whereas there was a 1.3 percent decrease in the damage caused to infrastructures, a 1.9 percent decrease in internal flooding of properties and 0.4 percent decrease in the population that lost income due to floods. This paper further deals with the problems and challenges faced by the residents of Patna during the floods and emphasizes on actions necessary by government as well as local population to deal with the problem of urban flooding.

Keywords: *Urban floods, Heavy Monsoons, Poor Drainage.*

Introduction

Urban flooding is "flooding that occurs in urban areas when rainfall, overflowing water bodies, or other water sources exceed the ability of the city's drainage system to channelize or absorb water, causing rapid accumulation, often far from rivers or traditional floodplains, making it different from rural flooding." The U.S Federal Emergency Management Agency (FEMA)

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defines it as property inundation in built environments caused by rain falling on increasingly impervious surfaces and overwhelming drainage infrastructure. Recent trends show urban flooding is becoming more frequent and severe worldwide. China and India have the largest amounts of people exposed to flooding, at 395 million and 390 million people respectively. Studies report a substantial rise in high-intensity rainfall and cloud bursts, with some cities recording about a 42 percent increase in average annual rainfall over a decade (2015-2024), which strains outdated drainage systems. By 2030, at least 517 million city dwellers are projected to be exposed to riverine flood risks, which highlights the growing vulnerability.

Several factors contribute to urban flooding. Some of those factors are natural, and some are man-made. Some of the natural urban flood causing factors are physiography of the watershed, geology,meteorological factor and seepage inflows while some of the anthropogenic flood-causing factors are uncontrolled irrigation, rainfed system, rapid growth and urbanisation, disappearance of natural drainage systems and failure of waste management systems.

In recent times, several authors have studied urban flooding and its mitigation. Agasnalli and Kumar (2021) noted that rapid urbanisation and climate change intensify urban flooding, and that a shift from conventional engineering solutions to multidisciplinary planning involving land use, stormwater management, energy efficiency, finance, and institutional coordination is required. Rashiq and Prakash (2023) noted that Patna's 2019 flood resulted from the interaction of prolonged rainfall and soil saturation with anthropogenic pressures including urbanisation, vegetation loss, floodplain encroachment, unplanned growth and inadequate drainage.(Ravindra et al., 2024) mentioned that Patna's 2019 floods severely contaminated drinking water, with arsenic creating substantial health risks, particularly for children and recommended regular monitoring, bacteriological testing and chlorination. GIS and hydrological modelling are important tools for flood-risk evaluation, real-time data, institutional coordination and governance (Verma et al., 2025).An integrated study of social-sensing data with agent-based modelling to assess flood exposure demonstrated that block-level assessments can overestimate risk, thereby supporting building-level mapping, high-resolution analysis and improved representation of human behaviour (Zhu et al., 2025).

Although existing literature has extensively examined the causes, impacts, health consequences, assessment techniques and management strategies associated with urban flooding in Indian cities, no reviewed study specifically focuses on comparative assessment of the 2019 and 2025 flood situations within the Patna Municipal Corporation. Existing studies on Patna have primarily examined the natural and anthropogenic causes of the 2019 flood or its effects on drinking-water quality. They have not sufficiently examined differences in flood extent, duration, residential impacts, living conditions and disruption of people's movement between the two flood events.

Objectives

Based on the identified research gap, this study aims

1. To identify the causes of urban flooding in Patna Municipal Corporation area
2. To assess the living conditions of people in the flood areas and the impact of flooding on their movement.
3. To conduct a comparative assessment of the 2019 and 2025 flood situation in Patna Municipal Corporation focusing on differences in flood extent, duration, and socio-economic impact on residential areas.

Hypotheses

To fulfil these objectives, this study is guided by two hypotheses: (1) The socio-economic impact of the 2025 flood was significantly greater than that of the 2019 flood in Patna Municipal Corporation, and (2) Older parts of town experience significantly greater urban flooding impacts than newer areas.

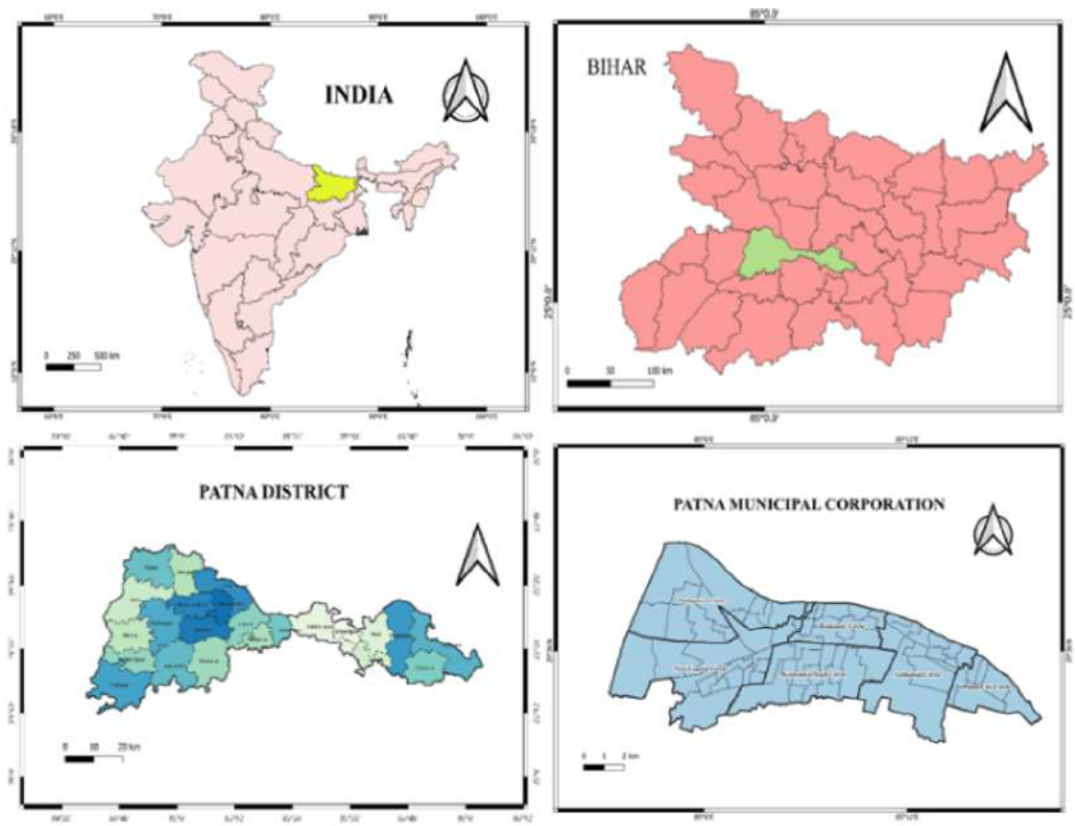
Database and Methodology

The study is a longitudinal research work and is carried out in three stages in 2019 and 2025. During the **Pre-Field Survey**, preliminary and preparatory work was done to develop a clear understanding of urban flooding and its impacts. A detailed review of relevant articles, research journals, books and other literature was carried out. During the Field Survey, a household-level survey of urban flooding impacts was conducted in Patna Municipal Corporation using a stratified random sampling design. In 2019, 150 households were surveyed: 25 households in each of the six administrative circles of Patna MC. The same sampling strategy and the same geographic strata were repeated in 2025 when another 150 households, 25 households per circle were surveyed. The combined dataset therefore comprises **300 independent samples collected during the two surveys**. Repeating the survey in the same circles permits comparative analysis of socio-economic outcomes and flood impacts over time. Stratified Random Sampling ensured proportional geographic coverage across administrative circles and reduced sampling bias. Google Forms were used as and when necessary. In addition, QGIS software was used to prepare the cartographic output for this study, including the base map of the study area, the spatial distribution of population and the ward-wise flood inundation maps for both 2019 and 2025. To perform the inundation assessment, all 75 administrative wards under the PMC were evaluated and grouped into their respective administrative circles to enable a circle-wise comparative analysis. The **Post-Field Survey** involved the systematic compilation and analysis of the collected data. Both qualitative and quantitative methods were used to interpret the responses and identify the

trends and impacts of urban flooding. The findings are presented through suitable figures, tables and charts to improve clarity and facilitate understanding. Finally, hypothesis testing and validation were carried out using the Chi-square test to determine the statistical significance and ensure that the study results are valid and reliable.

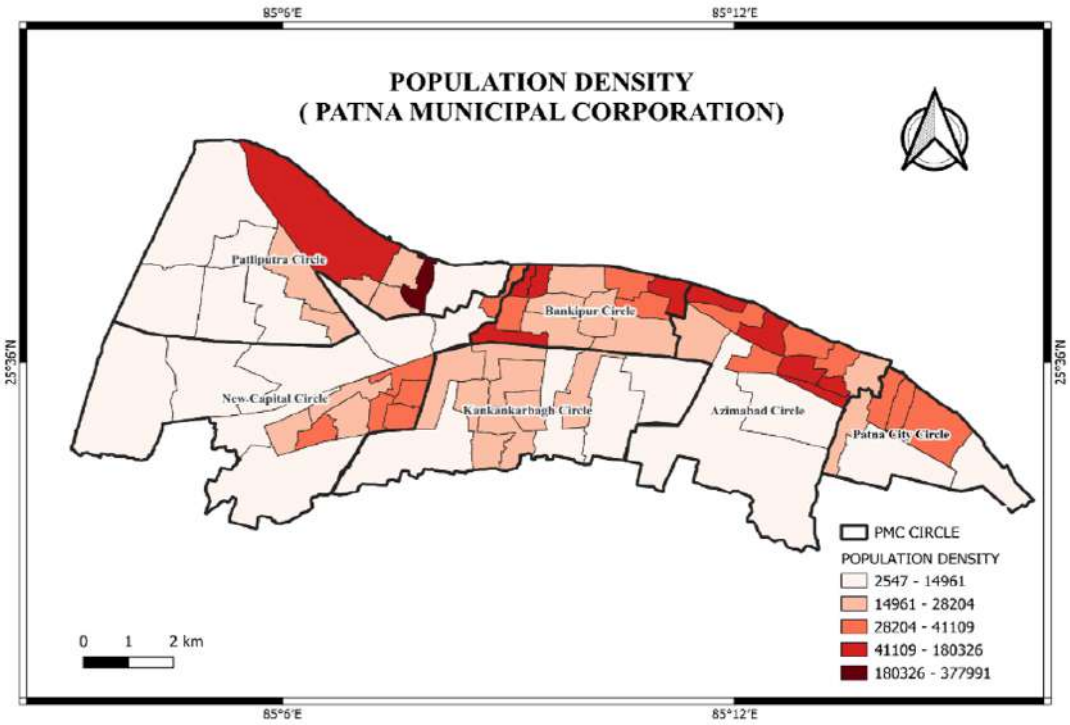
Study Area

PMC is the civic body that governs Patna, the capital city of Bihar. It was established on 15th August 1952, in accordance with The Patna Municipal Corporation Act, 1951. This civic administrative body administers an area of 109.2 km² and has a population of 37,41,652 (Census, 2011). PMC has a total of 75 wards which are under the executive control of six circles, namely: **(1) Azimabad Circle, (2) Bankipur Circle, (3) Kankarbagh Circle. (4) New Capital Circle, (5) Patliputra Circle, and (6) Patna City Circle.**



Source: *Map prepared by researcher*

Figure 1 : Study Area – Patna Municipal Corporation



Source: *Map prepared by researcher*

Figure 2 : Spatial Distribution Map of Urban Population (Census, 2011)

Demographic Composition of the respondents:

Across both survey periods, youth and young adults aged between 18 to 30 years formed the predominant respondent group. Rising slightly from 41.6 per cent in 2019 to 43.8 per cent in 2025. The middle-aged group (31-50 years) maintained a stable presence in 2019 (37.2 per cent) and 2025 (35.4 per cent), and the older adults (above 50 years) represented 21.2 per cent and 20.8 per cent, respectively. The gender composition remained balanced across both cross-sections with female participation slightly increasing from 44.5 per cent in 2019 to 47.1 per cent in 2025.

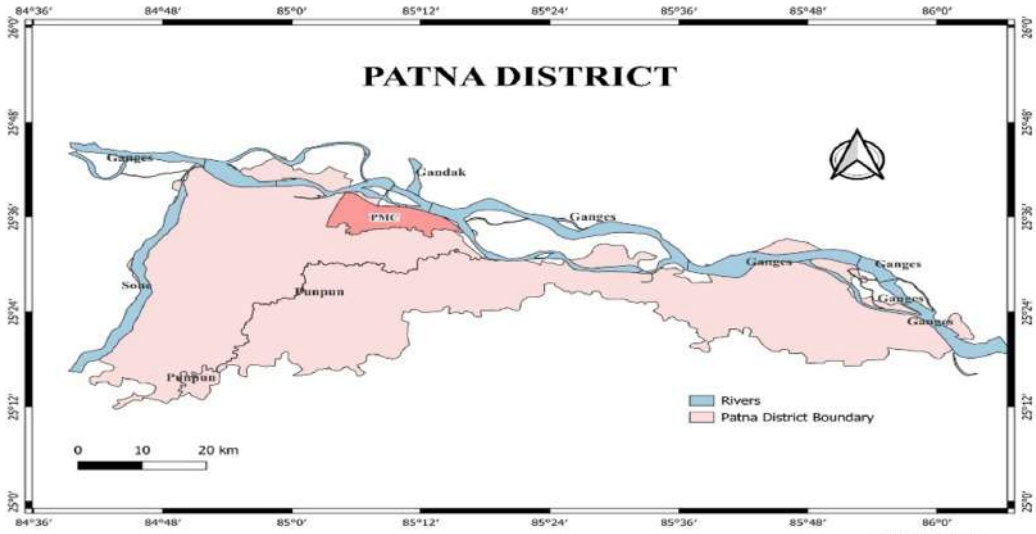
Socio-Economic Composition: The socio-economic classification of respondents showed distinct income variation, as low-income households formed the majority in 2019 at 48.5 per cent, followed by middle-income (36.8 per cent) and high-income groups (14.7 per cent). By 2025, the low-income share reduced to 42.1 per cent, while middle-income and high-income groups expanded to 41.3 per cent and 16.6 per cent, respectively.

Analysis:

Causes of Urban Flooding in Patna MC, Bihar

Patna is located on the natural levee of the River Ganga. Topographically, it is almost a flat basin. Some parts of the city, like Rajendra Nagar and Kankarbagh, lie in the lower portion of a saucer-shaped basin surrounded by the River Ganga and its tributaries. The northern margin of the river is high land, a natural levee, which gives the outlet neither for flooding nor for draining out the water. Moreover, in 1977, the embankment construction scheme started so that there would be no threat of flooding. In fact, Patna is a city that is influenced by three rivers, Besides the River Ganga, the River Son in the West and the Punpun in the East and South provide a natural frontier to the other end of the saucer-shaped topography. These flood-prone rivers cause flash floods and enter the city, resulting in urban flooding, especially during the time of copious rainfall within a few hours. One hidden factor of flooding in Patna is that when the Ganga overflows, water seepage reaches the saucer-shaped landforms of the city, due to the porous characteristics of the soil. That is why the southern part of the area has emerged as the jalla area (waterlogged area).

Further, poor drainage infrastructure, rapid unplanned urbanization, encroachment of natural waterwaysand blocked drains fail to handle heavy rains effectively, aggravating the problem. The sediment deposition causes changes in river course and frequent flooding.



Source: *Map prepared by researcher*

Figure 3 : Geographical Location of Patna Municipal Corporation within Patna District showing the surrounding river network (Ganges, Sone, Punpun and Gandak)

About 64 per cent of the city has slopes below 3 per cent, which favours lengthy water stagnation. Rapid and unplanned urbanization in the city has transformed the natural water-absorbing surfaces into impervious surfaces. Built-up area grew by roughly 286 per cent between 1980 and 2000 and by another 23 per cent between 2005 and 2019, whereas the agricultural and vegetation land declined. This has increased the city's impervious cover to around 57 per cent of the total area. Conversion of wetlands, ponds and low-lying floodplains into residential and commercial zones has reduced the infiltration capacity of rainwater. Studies show that between 2010 and 2015, runoff in Patna increased from 16.8 per cent to 23.7 per cent as LULC shifted towards more built-up areas. Densely built wards in Patna combine a high built-up index (NDBI) with low vegetation (NDVI), which makes them highly sensitive to flooding. Overall, the interaction of flat topography, high imperviousness, loss of green/blue infrastructure, and poor drainage design makes large parts of Patna Municipal Corporation highly prone to frequent and severe urban flooding.

Patna Municipal Corporation experienced severe urban flooding both in the year 2019 and 2025.The devastating urban flooding in September 2019 in Patna was caused by a combination of record-breaking rainfall (177 mm in 48 hours), overflowing Ganga, Son, Gandak, and Punpun, the release of 2.75 lakh cusecs of water and severe man-made and infrastructure failures. During July 2025, a total of 333.2 mm of rainfall was recorded in urban Patna in a span of 24 hours (July 27-28, 2025).With low-lying neighbourhoods submerged and rainwater mixed with sewage flooding homes and shops, both residential and commercial activity came to a standstill.

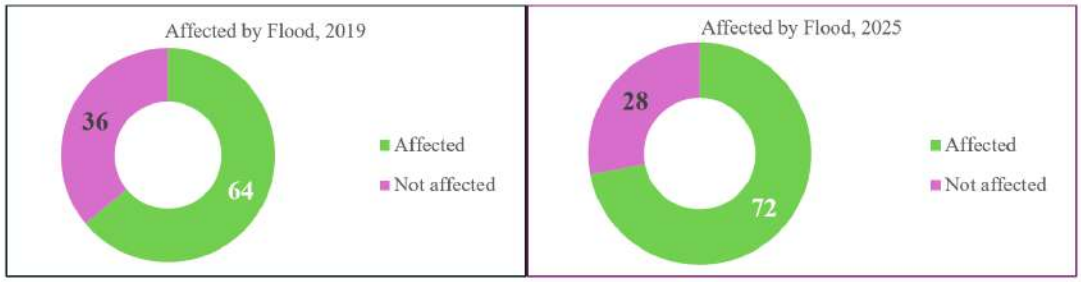
Results and Discussions

The current study shows that urban land use/land cover (LULC) and surface characteristics (saucer-shaped topography) are central to Patna Municipal Corporation's flood vulnerability.

Patna Municipal Corporation experienced varying degrees of flood impact during 2019 and 2025, especially in low-lying areas near the Ganga, major canals and major urban drains. The Digha-Ganga beltwhich was vulnerable to rising river levels, backflow and embankment pressure, was inundated. Patna city, Gulzarbagh and eastern neighbourhoods were highly affected by flood because of dense settlement and narrow drains. Rajendra Nagar and Kankarbagh faced severe urban waterlogging caused by intense rainfall, impermeable surfaces and overloaded drainage structures. With a population of 1,684,222 (Census, 2011), even limited flooding caused serious impacts in densely populated wards.

Effects of Urban Flooding in 2019 and 2025 in Patna MC

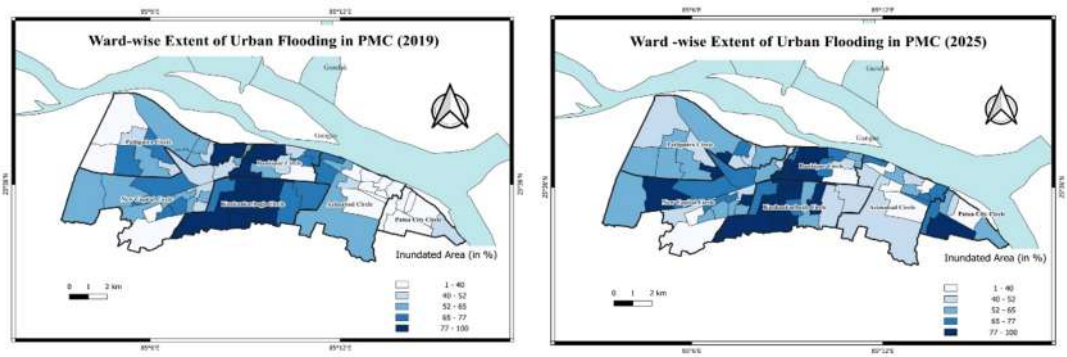
Urban flooding affects the population in various ways. Many people suffer economic losses, damage to physical infrastructure, health risks and disruption of basic services and livelihoods.



Source: *Sample Survey*

Figure 4

It can be seen from fig 4 that 64 per cent of residents of PMC were affected by urban flooding in 2019, whereas 72 per cent of residents suffered the impact of urban flooding in 2025.



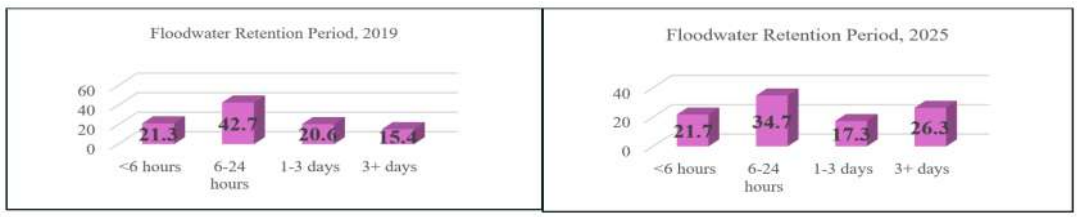
Source: *Map prepared by researcher*

Figure 5

A comparative spatial analysis between the 2019 and 2025 flood inundation maps of Patna Municipal Corporation reveals distinct shifts in urban vulnerability across administrative circles. During both floods, central and south-central zones, particularly Kankarbagh and Bankipur circles, remain severely affected, with 65-100 per cent of the area consistently submerged due to low-lying topography and high urban density. However, notable peripheral dynamics emerge between the two years. AzimabadCircle shows significant mitigation by transitioning from moderate to high inundation (52-77 per cent) in 2019 to the lowest exposure (1-52 per cent) by 2025. In contrast, Patna City Circle experiences a sharp escalation as in 2019 the circle faced low flood inundation (1-40 per cent), which jumped to the maximum inundation bracket (77-100 per cent) in 2025. Meanwhile, the Patliputra circle maintains low to moderate flooding with slight northern elevation, and New Capital Circle shows localized intensification on its western flank.

The primary cause behind the 2019 disaster was intense, short-duration cloudburst rainfall that exceeded 177 mm in just 48 hours, operational failures, siltation at major pumping stations at Saidpur and Pahari and closed river sluice gates that trapped the rainwater inside the city. However, in 2025, flooding was driven by high water levels in Ganga causing a backwater effect due to which water was held back into the city outfalls along with rapid urban expansion, construction works that paved over natural retention ponds and overwhelmed the drainage networks. While targeted municipal desilting and pump upgrades between the two events successfully lowered waterlogging levels in Azimabad circle but the overall flood dynamic changed a centralized crisis into an eastward redistribution of risk leaving the older, high-density wards severely submerged, thus disrupting daily life, property and local mobility in areas that had previously remained safe.

Urban Floodwater Retention Period



Source: *Sample Survey*

Figure 6

During 2019 urban flooding, 42.7 percent respondents had to face floodwater retention for a period of 6-24 hours, whereas 15.4 percent faced retention for more than 3 days. During the current urban flooding, water retention for a longer period of time was seen as 26.3 percent respondents faced flooding in their localities for more than 3 days, which sometimes reached even 10 days at once.

Structural Damage to Property

One of the major problems faced by people during urban floodingis severe damage to their personal belongings, infrastructure, vehicles, shops and household items.



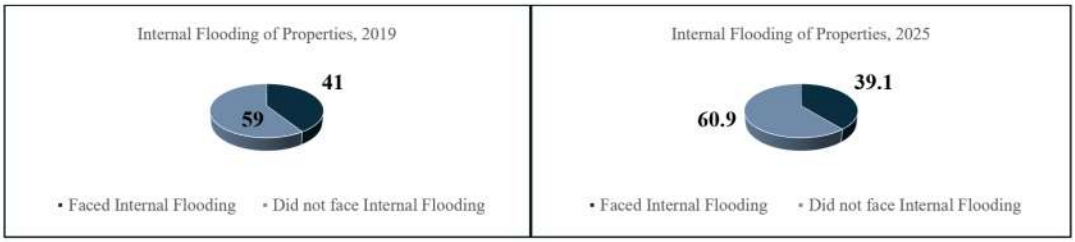
Source: *Sample Survey*

Figure 7

Structural damages caused by urban flooding to properties was more or less the same during 2019 and 2025 floods being 36 percent and 34.7 percent respectively.

Internal Flooding of Properties

Failure of drainage system and sewer overflow allows water to enter homes, buildings, and basements. Internal flooding is a very common problem faced by people during urban floods.



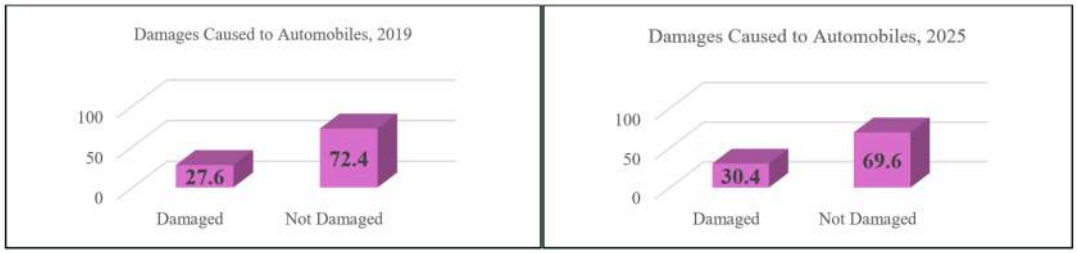
Source: *Sample Survey*

Figure 8

41 percent respondents in 2019 and 39.1 percent respondents in 2025 faced flooding in their houses, which is also more or less the same indicating towards the poor flood management in the area.

Damage to Automobiles due to Flood

Automobiles are also heavily affected during urban flood. Prolonged exposure to water leads to rust, damages to interiors and electronic system. People who own the vehicles often face financial burden.



Source: *Sample Survey*

Figure 9

27.6 percent respondents' automobiles were damaged due to urban flooding in 2019, whereas this number rose to 30.4 percent during the 2025 flood.

Disruption of Transport Connectivity

Waterlogged roads, traffic jams, delayed buses and trainscause severe disruption in transport connectivity during urban flooding. People found it difficult to commute and the emergency services like ambulances were delayed.



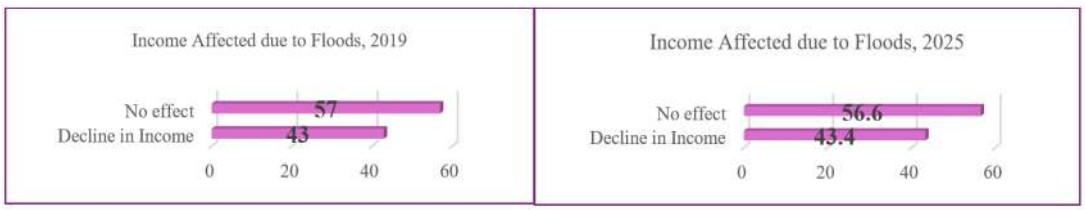
Source: *Sample Survey*

Figure 10

Disrupted transportation connectivity was extensive during both the floods. In 2019, 43.8 percent respondents had to face disrupted transportations, whereas during 2025 floods, these numbers rose to 52.1 percent respondents.

Impact of Flooding on Income Generation

Workers often cannot go to work due to water logged roads and transport problems. Thus, affecting the income of the residents.



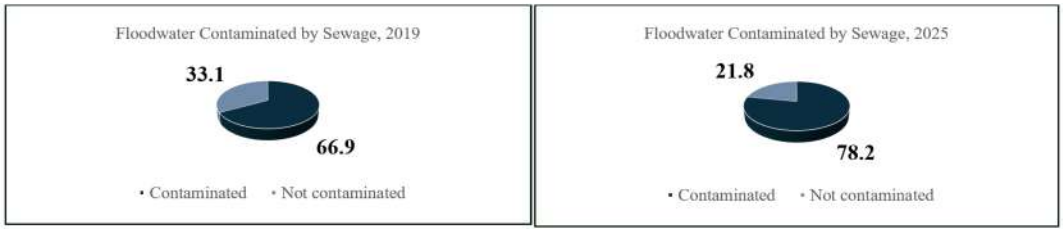
Source: *Sample Survey*

Figure 11

Income of 43 percent respondents was affected in 2019 floods and income of 43.4 percent respondents was affected in 2025 floods which is approximately the same. 8.6 percent respondents completely lost their income during the current flooding.

Sewage-contaminated Floodwater

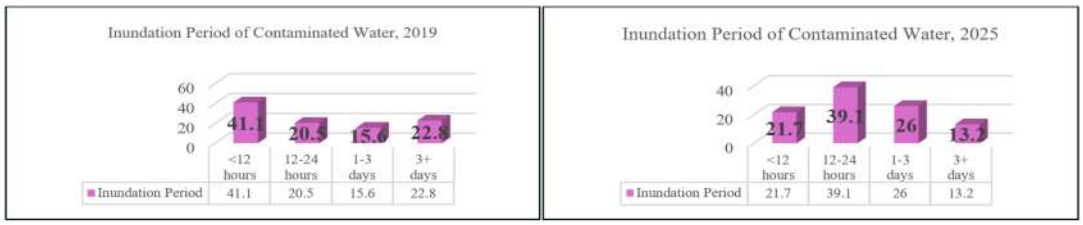
Sewage-contaminated floodwater poses severe health risks due to the presence of pathogens like E. coli and viruses such as hepatitis A. Contaminated water could lead to gastrointestinal illness, skin infections, and diseases like typhoid and others.



Source: *Sample Survey*

Figure 12

In 66.9 per cent of respondents' localities, sewage mixed with floodwater,which created both environmental and human health hazards and in 2025 floods, in 78.2 per cent of respondents' localities, floodwater was contaminated by sewage.



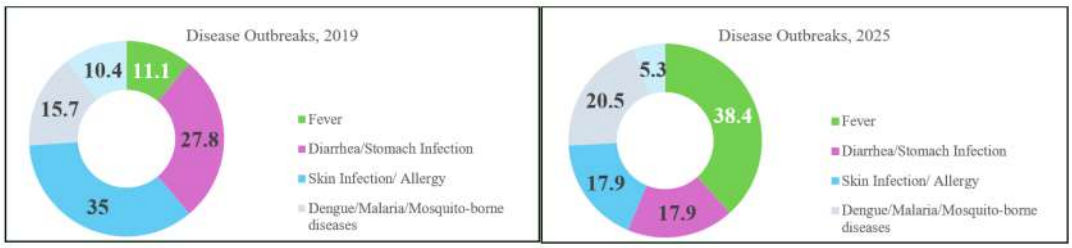
Source: *Sample Survey*

Figure 13

This sewage water stayed in 41.1 percent respondent's locality for less than 12 hours in 2019, whereas a rise in retention duration was seen as the sewage water stayed for 12-24 hours in 39.1 percent respondent's localities in 2025.

Disease Outbreaks due to Urban flooding

Exposure to sewage-contaminated water during urban floods causes major health issues among the affected population. Increase in mosquito borne diseases, skin infections, fever, stomach infections are common due to continuous use to dirty water.

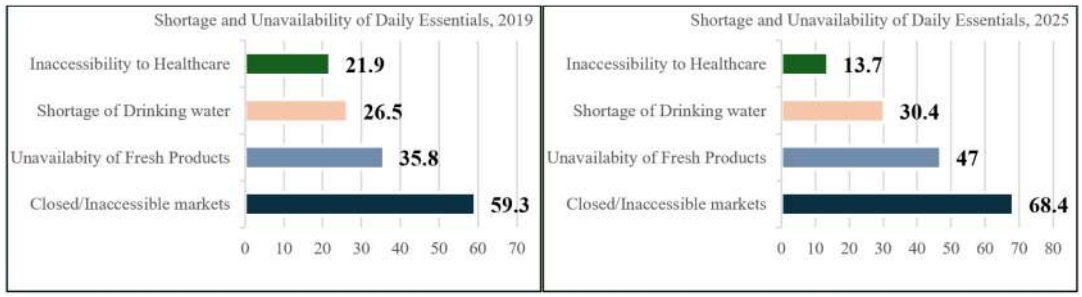


Source: *Sample Survey*

Figure 14

Disease outbreaks such as fever, stomach infection, allergies and skin infection, dengue, malaria and other mosquito-borne diseases, typhoid were common during both the floods.

Shortage and Unavailability of Daily Essentials



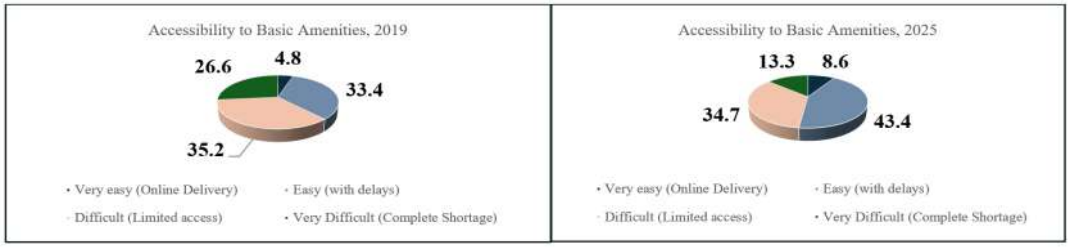
Source: *Sample Survey*

Figure 15

It is evident from the figure that the 2025 flood produced greater disruption in the availability of daily essentials than the 2019 flood. The proportion of respondents reporting closed or inaccessible markets increased from 59.3 percent in 2019 to 68.4 percent in 2025. In contrast, inaccessibility to healthcare declined from 21.9 percent in 2019 to 13.7 percent in 2025. Overall, the results show that 2025 flood caused a more severe disruption to markets, food supplies and the availability of drinking water.

Availability Rate of Basic Amenities

People living in areas with minor waterlogging obtain basic amenities relatively easily as compared to the people living in heavily flooded and low-lying areas.



Source: *Sample Survey*

Figure 16

It can be observed from the figure that although the 2025 flood affected access to basic amenities more widely, the severity of complete unavailability was lower mostly because of alternate supply and delivery mechanisms such as online delivery systems.

Disruptive Consequences of Urban Flooding

Urban flooding causes immediate damage to homes, roads, services and public health, which can further trigger long-term social and environmental impacts.

Table 1

Consequences of Urban Flooding	2019	2025
Health Problems	60.4	73.9
Damage to Property	36	34.7
Disrupted Water Supply	44.3	47.8
Disrupted Transportation	43.8	52.1
Shortage of Drinking Water	26.5	30 .4
Sewage Contaminating Flood Water	66.9	78.2
Delayed Garbage Collection	68	69.5
Waterlogging inside/outside houses	57.2	60.8

Source: *Sample Survey, 2019, 2025*

The table clearly demonstrates that the most reported consequences were more pronounced during the 2025 flood than the 2019 flood. Health problems increased from 60.4 per cent to 73.9 per cent, and sewage contamination of floodwater rose from 66.9 per cent to 78.2 per cent. Similarly, incidents of disrupted transportation, disrupted water supply leading to shortage of drinking water and waterlogging inside and outside the house also increased during the 2025 floods. However, damages caused to properties declined marginally. The greater severity of 2025 flood was reflected primarily in health, sanitation and mobility rather than property losses.

Actions taken by the Government

Relief operations are carried out by the government,which includes providing food, clean drinking water and temporary shelters. In addition, they evaluate the damages and plan long-term flood management and prevention strategies.



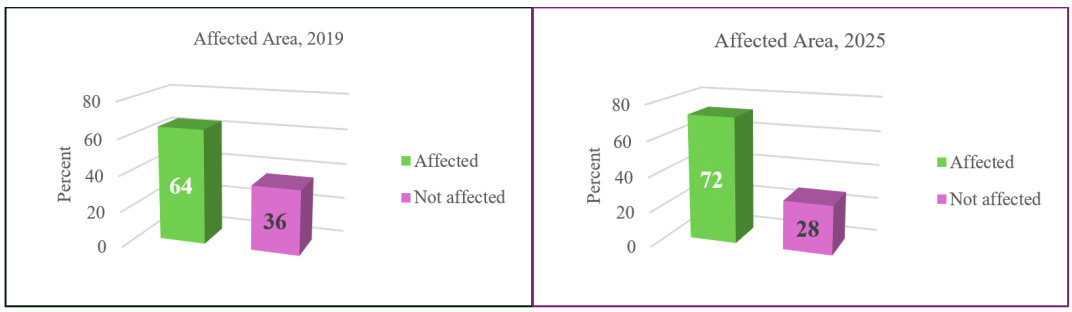


Source: *Sample Survey*

Figure 17

Government intervention was more visible during the 2025 flood than the 2019 flood. The proportion of respondents reporting that government action had been taken increased from 32.4 percent in 2019 to 47.8 percent in 2025, however more than half of the respondents in 2025 still perceived that no government action had been taken indicating towards continuing gaps in emergency response system.

The study further confirms Hypothesis 1 through the chi-square test and fig 18.



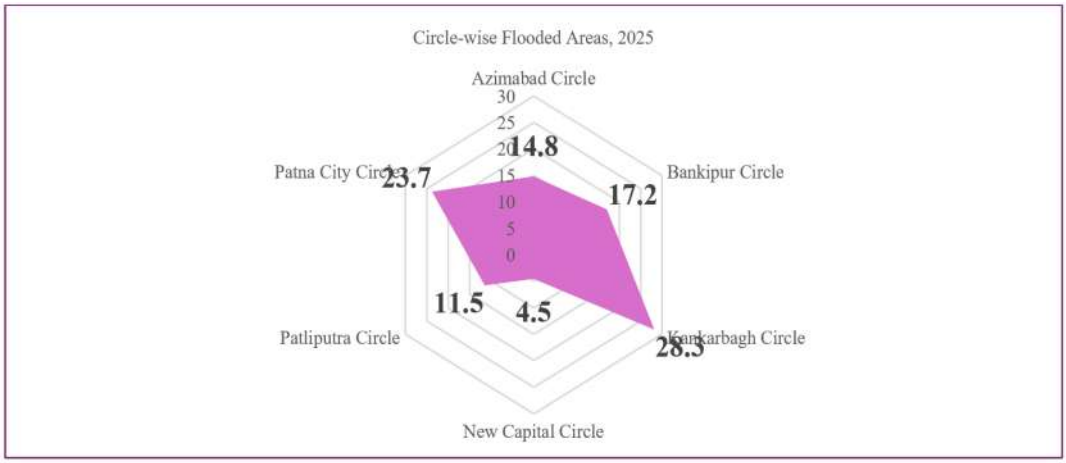
Source: *Sample Survey*

Figure 18

Considering the data collected during 2019 urban flooding as the expected value and the data collected during the 2025 urban flooding as the observed value, a chi-square test was conducted. The calculated value was 7.879, which is higher than the tabular value (5.991 at 95 per cent level of significance).In this case, the null hypothesis would be rejected, and the alternate hypothesis would be accepted, which means "The socio-economic impact of the 2025 flood was significantly greater than that of the 2019 flood in Patna Municipal Corporation".

The study further tested the second hypothesis through chi-square and proved that the older parts of town suffer significantly greater urban flooding impacts than newer areas. The

calculated value was 16.75, which is higher than the tabular value (12.592 at 95 per cent level of significance). In this case, the null hypothesis would be rejected and the alternative hypothesis would be accepted, which means "Older parts of town suffer significantly greater urban flooding impacts than newer areas".



Source: *Sample Survey*

Figure 19

Conclusion

Urban flooding remains a significant and recurring challenge worldwide, exacerbated by rapid urbanization, climate change, and inadequate drainage infrastructure.It is clear from the study that the drainage system of Patna Municipal Corporation is not efficient enough to handle the changing monsoon pattern.The ongoing construction also added up to the problem of urban flooding.The living conditions of the population residing along the coast of the Ganga were severely affected, and the area requires some embankments and official help to improve the livelihood.Effective management of urban flooding requires a comprehensive and integrated approach, combining improved forecasting and early warning systems, sustainable urban planning, investment in resilient infrastructure, and community engagement.

Flooding events have clearly worsened living conditions for the affected population between 2019 and 2025. The percentage of the population affected rose from 64 to 72 showing an increase of 8 per cent of the population facing disruption. Floodwaters retain for six hours to over three days in many areas, prolonging the exposure. Although structural damage shows a slight decrease from 36 per cent in 2019 to 34.7 per cent in 2025, down by 1.3 per cent, internal flooding cases dropped from 41 per cent in 2019 to 39.1 per cent in 2025, a decrease by 1.9

percent suggesting some marginal improvements. These improvements are offset by worsening secondary effects such as sewage contamination, shortages of daily essentials, public health problems and government assistance often arriving too late.

Mobility and economic impacts have grown more pronounced, which raises a concern for recovery and future resilience. Automobile damage increased from 27.6 percent in 2019 to 30.4 in 2025, an increase by 2.8 percent and traffic disruption rose sharply from 43.8 percent to 52.1 percent, up by 8.3 percent, leading to constrained travel. Restricted movement undermines livelihood, delays medical care, and limits access to food and clean water, while damaged vehicles and disrupted transport impose direct financial burdens on families.

This study is significant because it moves beyond a simple description of flood impacts and provides a comparative assessment of urban flood conditions across two time points, allowing us to observe the changes and vulnerability over time. Its scientific contribution lies in showing that even where some direct physical damage appears to decline slightly, overall living conditions may still worsen because secondary impacts and service disruptions intensify. This adds evidence that urban flood assessment should not only rely on damage count but should also include the duration of inundation, mobility disruption, infrastructure stress, and public health consequences, thus contributing to a more integrated and realistic understanding of flood vulnerability in cities.

The broader implication of this study is that urban flood risk assessment must be designed to capture both direct and indirect impacts on city systems. This shows that flood management should prioritize systemic resilience, such as drainage improvement, sanitation protection, transport continuity, access to emergency supplies and faster institutional or governmental response. Such an approach can support more effective policies for protecting health, mobility and livelihoods in flood-prone areas.

Suggestions

Based on the findings of the current study, some suggestions are mentioned to improve the flooding situation and its impact in Patna Municipal Corporation:

1. Widening and modernizing major drains in flood-prone wards so that they can carry peak monsoon runoff.
2. Separating stormwater drains from sewage lines to prevent the drains from getting choked.
3. Mapping every flood-prone hotspot in wards and prioritizing those areas.
4. Installation of additional pumping stations at low-lying points and in areas where gravity drainage is weak.

5. Installation of more rainwater harvesting system in government buildings, schools and apartments to reduce runoff.
6. Using permeable pavements in footpaths and parking areas.
7. Building rain gardens along the roads and public spaces to slow runoff.
8. Improving solid waste collection frequency, especially in low-lying wards because garbage blockage is a major cause of drain failure.
9. Using GIS based drainage planning so that the new roads, flyovers and colonies are designed according to the slope, runoff and drainage capacity.
10. Preservation and restoration of wetlands like buffer areas around the city to act as natural sponges during intense rainfall.
11. Setting up a ward-wise emergency response system.

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AN ANALYSIS OF INEQUALITY IN PHYSICAL HEALTH STATUS OF WOMEN : A GEOGRAPHICAL STUDY OF UNNAO DISTRICT, UTTAR PRADESH

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ABSTRACT

From a national development perspective woman's health reflects both her individual biology and her sociocultural, economic, and physical environments. These factors affect both the duration and the quality of her life. Advancing women's health is fundamental to achieving universal health coverage, health equity and gender equality (Iyer A, Jesani A, Fernandes A, Hirani S, Khanvilkar, 1995). Health underpins women's quality of life and enables the realization of other human rights, supporting women's full participation in social, economic and political life. While sexual and reproductive health and rights remain central – including access to contraception, fertility care and safe abortion – women's health extends far beyond these areas (WHO, 2007). It encompasses physical and mental health across the entire life course, from adolescence through older age. This study examines the socio-economic, environmental, and geographical factors driving spatial inequalities in the physical health of women in the Unnao district of Uttar Pradesh. A prominent educational gap exists, with female literacy standing at just 56.76% compared to 75.05% for males. This structural disparity directly impacts reproductive behaviour; approximately 39.8% of surveyed women married under the age of 20, a trend heavily concentrated among illiterate, rural, and historically marginalized communities. Nutritional indicators uncover a critical public health crisis, highlighted by a 36.0% Anaemia prevalence among women of reproductive age and an alarming 99.9% among pregnant women. Furthermore, maternal healthcare utilization remains restricted; only 24.8% of pregnant women registered for early antenatal care in their first trimester, and 22.8% of deliveries occurred at home without trained birth attendants. The study accomplishes that mitigating women's health disparities in Unnao requires moving beyond generic healthcare interventions to implement localized, multi-sectoral strategies that address seasonal environmental barriers, enhance rural literacy, and expand targeted nutritional and prenatal infrastructure.

Keywords : *Malnutrition, Maternal mortality, Gender discrimination, Health in equality, women health.*

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Introduction

Historically, women have also been the primary health care providers and health decision-makers for their families. Nearly two-thirds of women polled in a recent national survey indicated that they alone were responsible for health care decisions within their family, and 83 percent had sole or shared responsibility for financial decisions regarding their family's health. Women are also the primary care givers for ill or disabled family members. (Bala, M. and Monga (O.P., 2004). Approximately 15 percent of Indians who are informal care givers, an estimated 72 percent are women-many of them sandwiched between caring for an ailing relative and caring for their own children.

Women's health concern is influenced by interrelated biological, social, and cultural factors. It is generally expected that women can live longer than men it does not necessarily ensure a better quality of life. Profound studies reported that women are sicklier and more disabled than men throughout the life cycle. It has been suggested that women are particularly vulnerable, where basic maternity care is unavailable. Due to the involvement of biological factors, women are more prone to sexual exposure of contracting sexually transmitted infections (STIs), including the human immunodeficiency virus (HIV) than do men. Moreover, an early marriage and childbirth could be responsible for the prevailing wide variation in the socio-economic status. Profound studies pointed out the voluntary involvement of the community, paramedical workers, NGO, policy makers and teachers in various developmental programs for the removal of poverty and improve the literacy rate among females. Nutrition and health education should be strengthened via department of health to improve the nutritional status of mother and child, which are intimately linked. A strong and sustained government commitment is therefore needed to improve women's, health concern.

Study Area

Unnao is a major industrial district and city in Uttar Pradesh, India, located strategically between the metropolitan cities of Kanpur and Lucknow. The district is roughly a parallelogram in shape and lies between latitude 26° 8' N & 27° 2' N and longitude 80° 3' & 81° E. Its total area is 4589 per sq. km. the district has 5 tehsils and 21 developments blocks (2025). It is bounded on the north by district Hardoi, on the east by district Lucknow, on the south by district Rae Bareli and on the west by the Ganga which separates it from districts of Kanpur & Fatehpur. The Ganga and Sai, the chief rivers of the district have played an important role in fashioning the topology of the district which could be divided in to two parts- the low lands and the up land. Total population is approximately 3.1 million as per census data.

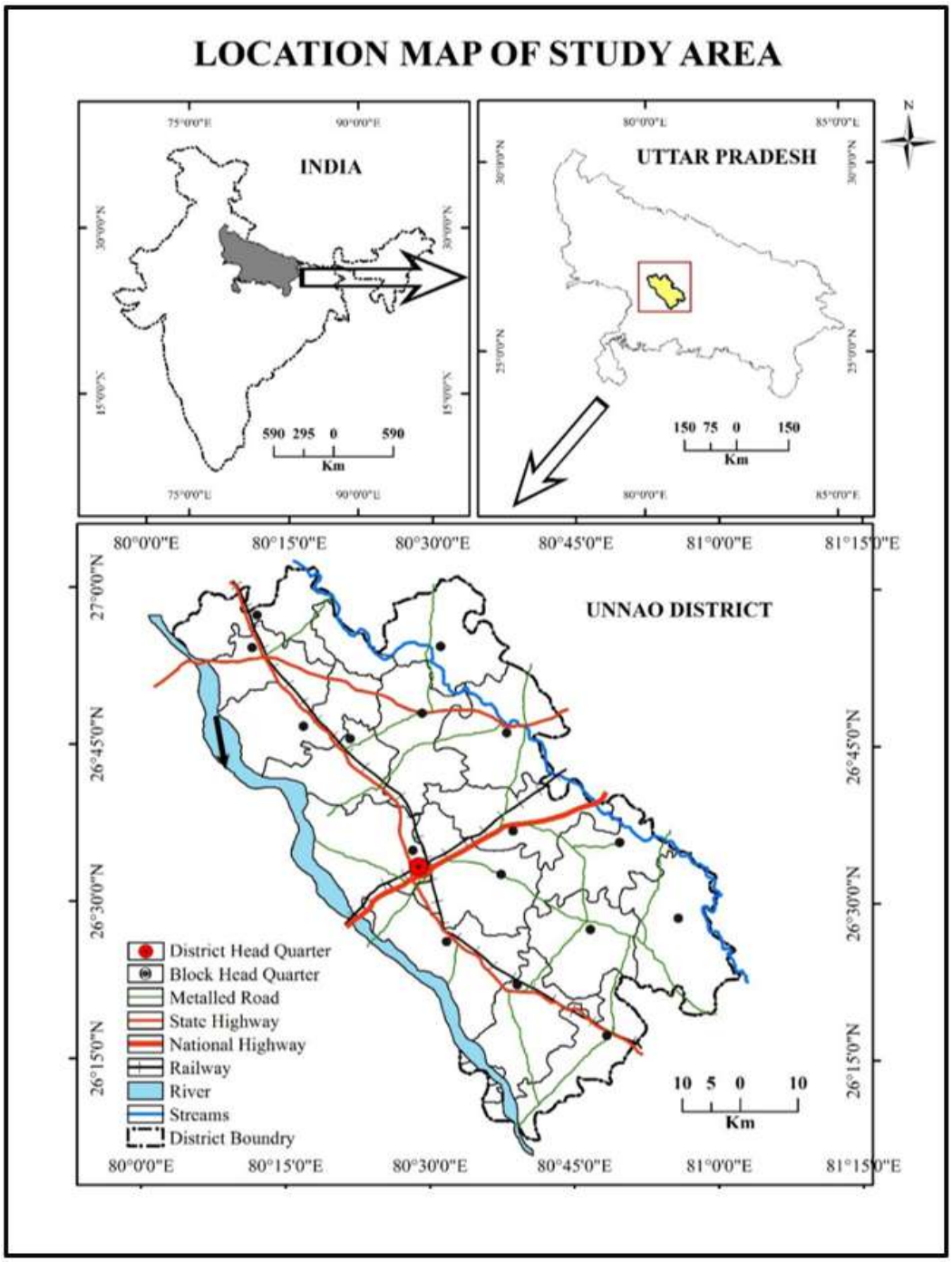

LOCATION MAP OF STUDY AREA
INDIA
590 295 0 590
Km
UTTAR PRADESH
150 75 0 150
Km
N
UNNAO DISTRICT
80°0'0"E
80°15'0"E
80°30'0"E
80°45'0"E
81°0'0"E
81°15'0"E
27°0'0"N
26°45'0"N
26°30'0"N
26°15'0"N
District Head Quarter
Block Head Quarter
Metalled Road
State Highway
National Highway
Railway
River
Streams
District Boundry
10 5 0 10
Km

Figure 1

Objectives of The Research Paper

1. To evaluate the critical determinants of maternal and reproductive health.
2. To analysis the multi-dimensional factors influencing women's health status.

Data Source and Methodology

The research methodology involved a critical review of existing literature, the analysis of both primary and secondary data, and a study of key institutional factors. National Family Health Surveys (NFHS-5 & 6) and District Level Household Survey data were also used (DLHS). National government documents/website were used to gather data related to the infrastructure and available manpower in the health sector. Primary data (Personal Survey-2020-21) collected by Questionair Method and total sample are 400 (Reproductive age, 15-49). Primary data collection was conducted through a pre-tested, structured Household questionnaire comprised of distinct modules tracking socio-demographic profiles, maternal history, and clinical or dietary indicators. To ensure an equal spatial distribution and eliminate geographical bias, this study employs a Multi-Stage Stratified Random Sampling technique based on administrative and Block-wise. In this study discussed of women health status and her related problems, with the help of different variables (mortality, fertility, No. of PHC/CHC and decision-making problems) through method of bivariate contingency tables analysed via the non-parametric Pearson's Chi-Square Test (x^2) of Independence (pp. 5, 10).

$$\chi^2 \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$$

O = Observed (the actual count of cases in each cell of the table)

E = Expected value (calculated below)

χ^2 = The cell Chi-square value

$\chi^2\sum$ = Formula instruction to sum all the cell Chi-square values

Oij – Eij = $i-j$ is the correct notation to represent all the cells, from the first cell (i) to the last cell (j).

Table 1 : Unnao District: Comprative Demographic Profile

Indicator	Unnao	Uttar Pradesh
Total Population (In Lakhs) (Census-2011)	3108367	19.96
Decadal Growth (%) (Census-2001)	15.11	20.09
Crude Birth Rate (SRS-2014)	21.8	27.2

Crude Death rate (SRS-2014)	7.1	7.7
Natural Growth Rate (SRS- 2014)	14.7	19.5
Sex Ratio (Census-2011)	907	908
Child Sex Ratio (Census 2011)	920	899
Schedule Caste Population (In Lakhs) (Census-2001)	1095465	3.51
Schedule Tribe Population (In Lakhs) (Census-2001)	3150	0.011
Total Literacy Rate (%) (Census-2011)	66.37	69.72
Male Literacy Rate (%) (Census-2011)	75.05	79.24
Female Literacy Rate (%) (Census-2011)	56.76	59.26

Source: *National Health Mission, Department of Health & Family Welfare, Uttar Pradesh: 2016-17.*

Table 1 compares key demographic and socio-economic indicators between Unnao district and Uttar Pradesh. Based on the 2011 Census of India, Unnao's population stood at 3.108 million, whereas Uttar Pradesh's was 199.6 million. Unnao's decadal growth rate (2001–2011) was 15.11%, trailing the state average of 20.09% and suggesting a more moderate population increase. Vital statistics (SRS-2014) show that Unnao's Crude Birth Rate (CBR) was 21.8 per 1,000, lower than the state's 27.2. Similarly, the district's Crude Death Rate (CDR) of 7.1 per 1,000 was slightly below the state average of 7.7. Ultimately, Unnao recorded a Natural Growth Rate (NGR) of 14.7 per 1,000, which is lower than the 19.5 per 1,000 observed across the state, indicating a slower rate of demographic expansion. With a sex ratio of 907 females per 1,000 males, Unnao district closely mirrors the state average of 908. However, a significant gender gap in education persists: while male literacy in the study area is 75.05%, female literacy lags at 56.76%, falling below the state average of 59.26%. To address these disparities, new educational initiatives are being implemented to improve women's health literacy, enhance the quality of their care, and ensure healthcare providers remain informed about their specific needs.

Table 2 : Health Care Facilities in Unnao District (2015-16)

Types of Hospital	**No.**
Primary Health Centre (PHC)	35
Other Medical Service (OMS)	73
Ayurvedic Hospitals	43
No. of Bed	148
Homeopathic Hospitals	32
No. of Bed	NA

Source: *CMO Office Unnao City/Unnao District (Uttar Pradesh).*

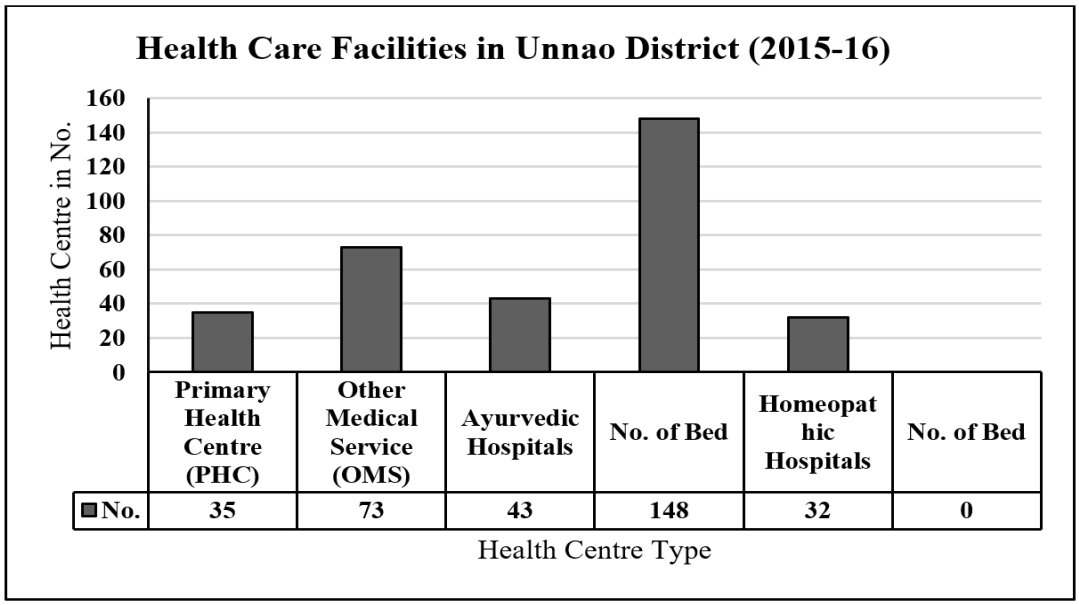


Figure : 2

Healthcare and medical infrastructure are steadily expanding within the study area. Through the collaborative efforts of both the government and the private sector, the Unnao district is seeing ongoing development. As of 2015–2016, the region was served by 35 Primary Health Centres (PHC), 43 Ayurvedic centres, and 32 homeopathic centres, with residents also utilizing private medical practitioners and hospitals. To address the significant challenge of population growth, various family welfare programs are currently in place. Additionally, the area conducts free vaccination drives to prevent disease, while the Directly Observed Treatment (DOT) programme for tuberculosis is being implemented effectively. Furthermore, several central government initiatives, including literacy campaigns and programs focused on AIDS prevention and the ASHA initiative, are operating successfully throughout the development block.

Table 3. Unnao District: Overweight/Obesity & Communicable Diseases (15-49 y) -2021

Analysis with Different Diseases	Data (%)
Anaemia Among Women of Reproductive Age (WRA)	36.0
Women with Body Mass Index (BMI) Kg/m2	26.5
BMI >25 Kg/m2 Among Women (15-49 years)	13.2
High Blood Pressure Among Women (15-49 years)	8.4
High Blood Sugar Among Women (15-49 years)	2.9

Source: *POSHAN (Partnerships and Opportunities to Strengthen and Harmonize Actions for Nutrition in India.*

The health profile of women in the study area indicates the coexistence of both nutritional deficiencies and emerging non-communicable disease (NCD) risk factors. 36.0% of women are reporting Anaemia at reproductive age (15–49 years), it's because of significant public health concern. Anaemia can adversely affect maternal health, pregnancy outcomes, work productivity, and overall quality of life. The nutritional status of women, as measured by Body Mass Index (BMI), showed that 26.5% of women had an abnormal BMI, indicating the presence of undernutrition and/or overnutrition within the population. Furthermore, 13.2% of women aged 15–49 years were overweight or obese (BMI >25 kg/m²), reflecting a growing burden of lifestyle-related health problems associated with urbanization, reduced physical activity, and changing dietary habits. 8.4% of women report the prevalence of high blood pressure in this age group (15–49 years), indicating that nearly one in twelve women was affected by hypertension. Elevated blood pressure is a major risk factor for cardiovascular diseases, stroke, and kidney disorders, emphasizing the need for regular screening, early diagnosis, and lifestyle modification.

Table 4 : Unnao District: Status of Prenatal and Delivery Care-2023-24

Analysis with Different Factors	Data (%)
Pregnancy Registered	NA
Mother and Child Protection Card	86.1
Antenatal Care (ANC) Visit-First Trimester	24.8
≥ANC Visits	11.8
ANC- Neonatal Tetanus	86.1
Consumed Iron Folic Acid (IFA) ≥ 100 Days During Pregnancy	5.1
Supplementary Food Pregnancy	NA
Institutional Delivery	68.8
Skilled Birth Attendant	70.7
Birth Registered	73.3

Source: *National Family Health Survey (NFHS Report-6), 2023-24*

Table 4 outlines indicators concerning mental health services, antenatal care (ANC), and safe delivery practices. While 86.1% of pregnant women utilize Mother and Child Protection (MCP) cards—indicating strong record-keeping coverage—early ANC utilization remains low, with only 24.8% of women registering during their first trimester. Furthermore, only 11.8% of women complete the recommended number of ANC visits, suggesting a lack of continuity in care that may heighten the risk of undetected maternal and fetal complications. Finally, the consumption of iron and folic acid (IFA) tablets for the recommended 100 days

remains critically low at 5.1%. which is the main reason is poor adherence to nutritional supplementation programs, which increases the risk of maternal anaemia, low birth weight, and adverse pregnancy outcomes. With 68.8% of women utilizing institutional delivery services and 70.7% of births attended by skilled professionals, there is a reasonable level of access to trained healthcare providers during childbirth. Additionally, 73.3% of newborns were officially registered.

Table 5 : Unnao District: Adolescent and Maternal Health -NFHS-2023-24

Maternal Health Care	Unnao	Uttar Pradesh
Women's Access to at Least One Antenatal Check-up	87.4	85.2
Anaemia in Pregnant Women	99.9	97.8
Anaemia in Adolescent Girls	91.1	92.3

Source: *National Family Health Survey (NFHS Report-6), 2023-24*

Table 5 presents various health issues encountered during adolescence and pregnancy. In Unnao, 87.4% of women received at least one antenatal check-up (ANC) during pregnancy, a figure slightly above the state average of 85.2%. However, the prevalence of anaemia among pregnant women in Unnao is alarmingly high at 99.9%, surpassing the state average of 97.8%. Similarly, 91.1% of adolescent girls in Unnao suffer from anaemia; while this is marginally lower than the Uttar Pradesh average of 92.3%, it remains a critical concern. Anaemia during adolescence significantly impairs physical growth, cognitive development, academic performance, and future reproductive health.

Table 6 : Unnao District: Place of Delivery by Respondents.

Place of Delivery	Frequency	Percent
Childless	24	6.0
Private	23	**5.8**
Government	262	**65.5**
Home	91	22.8
Total	400	100.0

Source*: Based on Personal Survey (2020-21).*

Table 6 illustrates that, to avoid complications during childbirth, it is essential for deliveries to be attended by trained personnel, such as doctors, nurses, or certified midwives (Dais). Out of 376 respondents, 22.8% reported that their deliveries were performed by untrained individuals. Regarding preferences, 65.5% of women chose government hospitals for pregnancy care, while only 5.8% opted for private facilities (Table 4.15). The National Family Health Survey (NFHS)

reports an institutional delivery rate of 68.8%, which is closely aligned with the primary data findings (71.3%). The fact that nearly one-quarter of all deliveries still occur at home underscores the urgent need to strengthen maternal healthcare services, increase awareness of safe delivery practices, and remove barriers to institutional care, particularly in underserved and rural areas. These findings highlight the critical importance of improving access to quality maternal healthcare to enhance health outcomes for both mothers and newborns.

Age at Marriage

Age at marriage defines the reproductive lifespan, indicating the period during which childbearing is biologically possible. For instance, a woman marrying at 15 and remaining fertile until 45 has a 30-year window, theoretically allowing for 15 births, although such maximums are rarely reached. The age of marriage is influenced by various socio-economic factors, including religion, caste, monthly per capita income, education, and occupation. To address early marriage, the Child Marriage Restraint Act of 1978 raised the legal minimum age for girls from 15 to 18 years. According to the NFHS-3 (2010-11), the national average age of effective marriage is 20.5 years.

Table 7 : Age at Marriage Different Factor Wise.

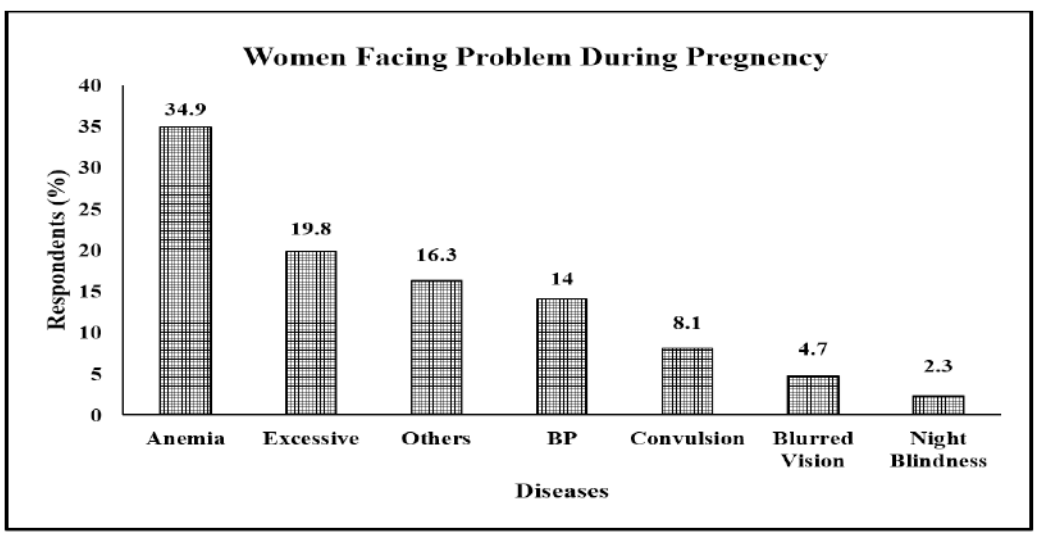
Religion	**Child less**	**< 20**	**20-25**	**> 25**	**Total**
Hindu	1.2	30.4	60.5	7.9	100
Muslim	0	94.8	5.2	0	100
$X^2 = 85.969$, df=3, P> 0.01					
Caste Wise					
GENERAL	2.2	30.7	52	15.1	100
OBC	0	47.8	52.2	0	100
SC/ST	0	45	55	0	100
$X^2 = 45.083$, df=6, P> 0.05					
Education Wise					
Illiterate	0	42.1	57.9	0	100
Primary	1.8	63.3	29.4	5.5	100
Middle	1.3	34.7	54.7	9.3	100
High School	2	14.3	79.6	4.1	100
Intermediate	0	44.4	50	5.6	100
Graduation	0	4.5	68.2	27.3	100
Others	0	0	61.5	38.5	100
Total	1	39.8	52.5	6.8	100
$X^2 = 76.376$, df=9, P> 0.05					

***Source**: Based on Personal Survey (2020-21).*

Religion-wise: Regarding religious distribution, early marriage is more prevalent among Muslim women than Hindu women. More than 50% of Muslim women are married before the age of 20. Of the remainder, 52.5% are married between the ages of 20 and 25. Among Hindu women, 60.5% are married before age 20, while 39.8% marry between the ages of 20 and 25. Most women fall into the 20–25 age bracket for marriage, followed by those under 20 and those over 25. Approximately 1.0% of women remain unmarried or have no children.

Caste-wise: Marriage patterns show significant variation across caste groups. The prevalence of caste-based marriage is higher among women from Other Backward Classes (OBC) and Scheduled Castes/Scheduled Tribes (SC/ST) compared to those in the General category (30.7%). While marriage within the 20–25 age bracket is more common among SC/ST women, the General category reports the highest percentage of marriages occurring after the age of 25 (15.1%). These disparities are largely attributed to the fact that women in the General category typically possess higher levels of education and stronger economic standing, contributing to greater awareness regarding the implications of early marriage.

Education-wise: The educational distribution data indicates a direct correlation between a respondent's level of education and their age at marriage. As shown in Table 4.3, only 14.3 percent of women with an education level beyond higher secondary were married before the age of 20, compared to 42.1 percent of illiterate women. Furthermore, approximately 4.1 percent of women with higher secondary education married after the age of 25. These findings demonstrate that educational attainment significantly influences the age at marriage, serving as a primary factor in both early and delayed marital entry.



Source: *Based on Personal Survey (2020-21).*

Figure 3

Figure 3 indicates that anaemia is the most prevalent complication, affecting 34.9% of respondents. This prevalence, impacting over one-third of the pregnant population, underscores suboptimal maternal nutritional status and insufficient iron intake during gestation. The second most frequently reported condition is excessive bleeding (19.8%), a significant obstetric complication that may elevate the risk of maternal morbidity if not addressed promptly. Remaining pregnancy-related complications account for 16.3%, reflecting a range of diverse health issues not individually categorized. Approximately 14.0% of participants reported experiencing high blood pressure during pregnancy. Pregnancy-induced hypertension represents a significant risk factor for maternal and fetal complications, including pre-eclampsia and preterm birth. Furthermore, 8.1% of respondents reported convulsions, indicating severe obstetric complications that necessitate immediate medical intervention. Visual disturbances were reported less frequently, with 4.7% of women experiencing blurred vision, a condition potentially linked to hypertension or pre-eclampsia. Night blindness, which is generally associated with vitamin A deficiency and suboptimal maternal nutrition, affected 2.3% of the cohort. Overall, as illustrated in Figure 3, Nutritional deficiencies—particularly Anaemia—and obstetric complications, such as Haemorrhage and Hypertension, constitute the primary health challenges encountered by pregnant women.

Conclusion

On the socio-economic front, India has achieved notable progress; however, advancements in maternal healthcare have remained gradual. Despite various safe motherhood and child survival initiatives, the physical availability and geographic accessibility of adequate antenatal care (ANC) services continue to be a challenge. In the study region, the public healthcare landscape exhibits a skewed spatial distribution: while alternative medicine facilities are relatively widespread (43 Ayurvedic and 32 Homeopathic hospitals), only 35 Primary Health Centres (PHCs) serve as the primary allopathic backbone, leading to significant friction of distance for remote populations. Demographically, 52.0% of women married between 20–25 years of age, yet an alarming 39.8% married under age 20 due to entrenched socio-economic deprivation and limited educational catchment.

Spatial barriers directly undermine maternal outcomes: 22.8% of women fail to achieve institutional delivery, obstructed by excessive travel distance to health centres, poorly connected rural road networks, and an acute deficit of emergency ambulance services. This spatial vulnerability is sharply magnified across the low-lying riparian flood plains (*Ganga Katri* tracts). In the active flood zones, seasonal monsoon floods, riverbank erosion, and waterlogging routinely wash out transport links, forcing displaced households onto elevated road embankments in makeshift plastic shelters. During these hydrometeorological disruptions, pregnant women endure severe environmental deprivation—facing an acute breakdown in clean potable water, staple food supply, and maternal supply chains.

Consequently, clinical and nutritional distress is heavily concentrated in these marginalized pockets: 8.5% of pregnant women suffer from systemic morbidities, 34.9% present with nutritional anaemia, and 24.5% face food insecurity, consuming only two meals daily. These compound disparities highlight how physical topography, settlement patterns, and seasonal environmental hazards intersect with social norms to determine maternal well-being. Mitigating these risks requires geographically targeted interventions—including GIS-based facility mapping, mobile riverine/boat clinics during monsoon months, decentralized iron-folic acid depots, and disaster-resilient referral transit networks to bridge the critical first-mile gap.

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WOMEN'S DIGITAL EXCLUSION: A RURAL–URBAN COMPARATIVE ASSESSMENT OF BIHAR

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ABSTRACT

The spread of mobile networks and cheap data in India has not reached all women equally, and the gap is especially visible in Bihar, one of the country's poorest and least literate states. This study measures the rural–urban divide in women's digital access and use in Bihar and examines how it varies with socio-economic, demographic and structural characteristics. We used the state-module sample of women aged 15–49 years from the fifth National Family Health Survey (NFHS-5, 2019–21; *n* = 6,350; 743 urban, 5,607 rural). Four indicators were analysed: owning a mobile phone, reading SMS messages, using the phone for financial transactions and ever using the internet. Women with neither a phone nor any internet use were classed as digitally excluded. We estimated weighted percentages, a digital cascade and design-based 95% confidence intervals, and tested associations with Pearson's chi-square. In all, 44.3% of women were digitally excluded (46.7% rural, 32.5% urban). Urban women were more likely than rural women to own a phone (61.7% vs 49.3%), to read SMS (63.6% vs 40.2%) and to have used the internet (38.4% vs 17.0%), while mobile financial use was low in both settings (7.8% vs 4.8%). The gap widened along the cascade: among phone owners, 69.6% of urban but only 44.1% of rural women could read an SMS. Education and wealth showed the steepest gradients, and the rural–urban gap in SMS reading largely disappeared within wealth quintiles. Phone ownership peaked among married women aged 25–34 years, whereas reading and internet skills were highest among younger, never-married women. Closing the gap in rural Bihar will require investment in women's functional and digital literacy, and in their control over money and mobility, alongside access to devices.

Keywords : *Digital divide; women; rural–urban disparity; mobile phone ownership; internet use; NFHS-5; Bihar*

Introduction

Digital inclusion now shapes access to education, health care, employment, financial services and public entitlements. In India, the rapid spread of mobile networks and falling data costs have narrowed some gaps in access, yet the gains have been uneven across regions, social groups and income classes. The digital divide is generally understood as "a division between

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people who have access and use of digital media and those who do not" (van Dijk, 2020, p. 1). Physical access to devices and connectivity is still a barrier for part of the world's population, but the divide does not end there. Digital inequality has been described as a sociological rather than a technological issue (Ireland & Lestari, 2025): it reflects and reinforces existing inequalities in literacy, income, gender and place, and is itself an axis of social stratification (Robinson et al., 2015).

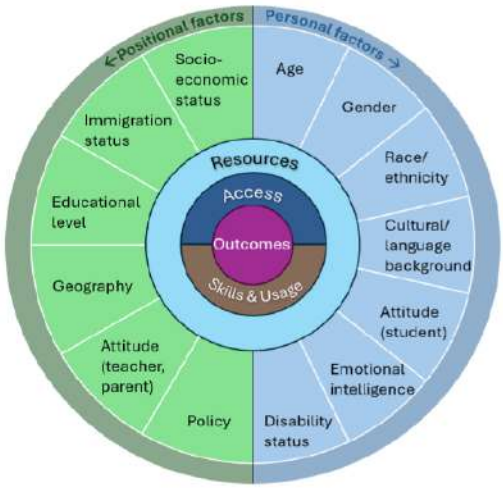
Research has accordingly moved from a single access divide to a sequence of levels. The first level concerns access (motivation, physical access, skills and usage), the second concerns the development and use of digital skills, and the third concerns outcomes, that is, whether access and skills are turned into benefits (Scheerder et al., 2017; van Dijk, 2020). Inequalities at the second and third levels can be larger than those at the first, and the first-level divide has itself shifted from physical access towards the material resources needed to use a device well (van Deursen & van Dijk, 2019).

Ireland and Lestari (2025) arrange the personal and positional factors identified in the wider literature, such as age, gender, education and socio-economic status, around these levels (Figure 1). Gender runs through all of them.

1st level: Access (motivation, physical, skills and usage access)

2nd level: Digital skills & usage (developing and applying digital skills)

3rd level: Outcomes (using access and skills to achieve objectives)



Note. From *Digital Divide: A Literature Review* (p. 6), by J. Ireland and S. Lestari, 2025, Cambridge University Press & Assessment.

Figure 1

Interpretation of van Dijk's Framework of the Digital Divide

Women and girls are more often on the wrong side of the divide. Globally, men are more likely than women to own a mobile phone or a smartphone and to use the internet, and these gaps are widest in poorer countries (UNESCO, 2024). Women's under-representation online is most severe in South Asia (Fatehkia et al., 2018), and in developing countries much of the gender digital divide reflects women's lower education, employment and income (Hilbert, 2011).

India illustrates these patterns sharply. Urban areas increasingly benefit from affordable smartphones and data, whereas rural populations face infrastructural, economic and educational barriers. Women are less likely than men to own or use digital devices, and qualitative work in rural central India shows that even women who own phones face household norms that restrict how they may use them (Scott et al., 2021).

India's digital transformation is one of the largest population-scale expansions of connectivity and technology-enabled public service delivery anywhere in the world. The gender gap within it remains wide. The Mobile Gender Gap Report 2022 estimated that women in India were 14% less likely than men to own a mobile phone, and that only 30% of women used mobile internet, compared with 51% of men, a gender gap of 41% (GSMA, 2022). The divide is sharper still in Bihar. NFHS-5 shows that 43.6% of men but only 20.6% of women aged 15–49 years in the state had ever used the internet, and that internet use among men was itself much lower in rural (39.4%) than in urban areas (58.4%; IIPS & ICF, 2021). Government initiatives such as Digital India have sought to narrow these gaps by expanding connectivity and promoting digital literacy.

Bihar faces these constraints in concentrated form. The state combines persistent poverty, low educational attainment, marked gender disparities and weak infrastructure. Together these limit both the affordability and the use of digital tools, and Bihar's digital divide is consequently more entrenched than that of many other states. NITI Aayog projected that 26.59% of Bihar's population was multidimensionally poor in 2022–23, down from 56.34% in 2013–14 (Chand & Suri, 2024), and in the NFHS-5 state-module sample analysed here, two-thirds of women (67.0%) belonged to the two poorest wealth quintiles. Literacy is low and sharply unequal by gender: NFHS-5 shows that 57.8% of women aged 15–49 years in Bihar were literate, against 78.5% of men (IIPS & ICF, 2021). Roughly two in five women in this age group therefore face basic barriers to functional digital literacy, whether or not they have a device.

Studies from India link digital exclusion to socio-economic inequality, caste and gender (Rajam et al., 2021; Tewathia et al., 2020), and document wide geographical variation in women's phone ownership and SMS literacy (Venkataramanan et al., 2021). Evidence specific

to Bihar is scarce, however, and most of it is cross-sectional or confined to a single domain such as education or gender. Two gaps follow. First, there is no systematic rural–urban comparison of women's digital access and use in Bihar based on a large, representative survey. Second, existing work usually treats access as a single yes-or-no outcome and seldom asks at which step, from owning a phone to reading messages to going online, rural women fall behind (Scheerder et al., 2017). The NFHS-5 state module allows both questions to be addressed, because it records phone ownership, SMS literacy, mobile financial use and internet use for the same women, together with indicators of their resources, mobility and position in the household.

This paper uses NFHS-5 data to examine women's digital access and use in rural and urban Bihar, and how these vary with poverty, education, social group and structural constraints. It makes three contributions: (i) it quantifies the rural–urban digital divide among women in Bihar using recent survey data; (ii) it traces where along the digital cascade the rural–urban gap opens; and (iii) it describes how socio-economic, demographic and structural characteristics are associated with each digital outcome within rural and urban areas, and draws out the implications for policy on women's digital inclusion.

Objectives

The study has three objectives:

1. To assess the extent of rural–urban disparities in women's digital access and use in Bihar.
2. To examine how these disparities vary with socio-economic and demographic characteristics.
3. To identify the structural barriers associated with women's digital exclusion.

Data Source and Sample

The study uses the women's file of the fifth National Family Health Survey (NFHS-5, 2019–21), conducted by the International Institute for Population Sciences (IIPS) for the Ministry of Health and Family Welfare with ICF, on a two-stage stratified sample of villages and urban blocks (IIPS & ICF, 2021). The Bihar file contains 42,483 women aged 15–49 years. Questions on mobile phones, SMS, mobile money and the internet were asked only in the state-module subsample, so the analysis is restricted to 6,350 women (743 urban and 5,607 rural). Information on household decision-making and husband's absence refers to the 4,688 currently married women in this subsample. All percentages are weighted with the state-module weight (sweight), sample sizes are unweighted, and the weighted estimates match

those in the NFHS-5 Bihar report (Tables 100–101). The data are anonymised and publicly available from the DHS Program, and the survey protocol was approved by the ethics review boards of IIPS and ICF.

Measures

Outcome variables. Four binary indicators form a digital ladder (Scheerder et al., 2017): owning a mobile phone that the woman herself uses (s932); being able to read an SMS message (s937, with women who cannot read at all coded 0); using the phone for financial transactions (s933, with non-owners coded 0); and ever using the internet (s934). A woman is classed as digitally excluded if she neither owns a phone nor has ever used the internet. A digital cascade measures each step among women who passed the previous one: SMS reading and mobile financial use among phone owners, and internet use among owners who can read SMS.

Independent variables. Place of residence (urban or rural) is the main explanatory variable. The socio-economic and demographic covariates are age group, education, household wealth quintile, social group (Scheduled Caste or Scheduled Tribe [SC/ST], Other Backward Class [OBC] and General), religion, marital status, weekly exposure to newspapers, radio or television, working status, sex of the household head and family type (a proxy derived from the woman's relationship to the household head).

Structural barriers. These are freedom to go alone to the market, to a health facility and to places outside the village; having money of her own; owning a house or land; acceptance of wife-beating; and, for currently married women, say in household decisions and the husband's absence from home for a month or more in the past year, which reflects male out-migration (Scott et al., 2021).

Statistical Analysis

The analysis is descriptive and bivariate and was carried out in Stata. Urban and rural women are first compared on background and structural characteristics (Table 1). The prevalence of each digital indicator and of each step in the cascade is then estimated by residence (Tables 2 and 3), with design-based 95% confidence intervals that account for clustering and stratification (Table 4). Finally, each indicator is cross-tabulated against background characteristics separately for rural and urban women (Table 5). Associations are tested with Pearson's chi-square test on the unweighted data, and $p < .05$ is taken as statistically significant.

Results

Sample Characteristics

Table 1 : Background and Structural Characteristics of Women Aged 15–49 Years by Place of Residence, Bihar, NFHS-5 (2019–21)

	Urban		Rural		Total		*p*
	%	n	%	n	%	n	
Age group							.003
15-19	18.7	146	24.5	1,365	23.6	1,511	
20-24	22.1	160	17.3	963	18.1	1,123	
25-34	29.8	213	27.1	1,536	27.6	1,749	
35-49	29.4	224	31.0	1,743	30.7	1,967	
Education							< .001
No education	23.4	189	41.6	2,317	38.5	2,506	
Primary	8.8	68	10.8	595	10.5	663	
Secondary	47.2	353	42.0	2,375	42.9	2,728	
Higher	20.5	133	5.7	320	8.1	453	
Wealth index							< .001
Poorest	12.2	92	45.7	2,481	40.1	2,573	
Poorer	17.2	133	28.9	1,636	26.9	1,769	
Middle	22.8	176	15.7	902	16.9	1,078	
Richer	24.7	202	7.3	460	10.2	662	
Richest	23.1	140	2.4	128	5.9	268	
Social Group							.031
SC/ST	24.9	183	27.5	1,550	27.1	1,733	
OBC	52.2	416	56.1	3,126	55.5	3,542	
General	22.9	142	16.3	879	17.5	1,021	
Religion							< .001
Hindu	72.5	538	83.8	4,751	81.9	5,289	
Muslim/Other	27.5	205	16.2	856	18.1	1,061	
Marital status							.495
Never married	24.2	183	23.6	1,333	23.7	1,516	
Married	72.4	539	74.3	4,149	74.0	4,688	
Widowed/divorced/separated	3.4	21	2.1	125	2.3	146	
Family type							.068
Nuclear	64.7	491	69.6	3,890	68.8	4,381	
Non-nuclear	35.3	252	30.4	1,717	31.2	1,969	

	Urban		Rural		Total		*p*
	%	n	%	n	%	n	
Weekly media exposure							< .001
No	42.6	324	73.2	4,101	68.1	4,425	
Yes	57.4	419	26.8	1,506	31.9	1,925	
Working status							.061
Not working	87.1	652	85.4	4,776	85.7	5,428	
Working	12.9	91	14.6	831	14.3	922	
Sex of household head							< .001
Male	80.3	615	74.6	4,233	75.6	4,848	
Female	19.7	128	25.4	1,374	24.4	1,502	
Freedom of movement							.005
Not alone anywhere	34.5	248	39.5	2,219	38.7	2,467	
Alone to some places	20.5	140	17.7	985	18.1	1,125	
Alone to all places	45.0	355	42.8	2,403	43.2	2,758	
Has money of her own							.001
No	43.7	338	53.1	2,926	51.5	3,264	
Yes	56.3	405	46.9	2,681	48.5	3,086	
Owns house or land							.747
No	46.6	322	44.3	2,465	44.7	2,787	
Yes	53.4	421	55.7	3,142	55.3	3,563	
Accepts wife-beating							.162
No	71.3	520	68.1	3,781	68.6	4,301	
Yes	28.7	223	31.9	1,826	31.4	2,049	
Say in household decisions							.188
None	16.0	92	13.0	587	13.5	679	
One or two	15.7	83	15.5	645	15.5	728	
All three	68.3	364	71.6	2,917	71.0	3,281	
Husband away 1+ months							< .001
No	70.5	382	55.6	2,337	58.1	2,719	
Yes	29.5	157	44.4	1,812	41.9	1,969	
Total (N)	**100**	**743**	**100**	**5,607**	**100**	**6,350**	

Note. Percentages are weighted with the state-module weight; *n* is the unweighted number of women. *p* values are from Pearson's chi-square tests on unweighted data. Social group excludes 54 women whose caste or tribe was not known. Say in household decisions and husband's absence refer to currently married women only (*n* = 4,688; 539 urban, 4,149 rural). OBC = Other Backward Class; SC/ST = Scheduled Caste or Scheduled Tribe.

Table 1 shows that urban and rural women in the state module differed most in education, wealth and media exposure. Rural women were almost twice as likely as urban women to have no schooling (41.6% vs 23.4%), and only 5.7% had higher education, compared with 20.5% in urban areas. Nearly half of rural women (45.7%) were in the poorest wealth quintile, against 12.2% of urban women, whereas 23.1% of urban women but only 2.4% of rural women were in the richest quintile. Weekly exposure to newspapers, radio or television was twice as common in urban areas (57.4% vs 26.8%). Rural women were more often Hindu (83.8% vs 72.5%) and OBC (56.1% vs 52.2%). The age distributions differed modestly, while marital status, working status and family type were broadly similar.

Structural constraints were also heavier in rural areas. Rural women were less likely to have money of their own (46.9% vs 56.3%) and slightly more likely to be unable to go anywhere alone (39.5% vs 34.5%). Among currently married women, 44.4% in rural areas had a husband who had been away from home for a month or more in the past year, compared with 29.5% in urban areas, a pattern consistent with male out-migration. Ownership of a house or land, acceptance of wife-beating and say in household decisions differed little by residence. Because rural women start from lower levels of education and wealth, part of the rural–urban digital gap is likely to reflect these differences in composition.

Digital Access and Use by Place of Residence

Table 2 : Mobile Phone Ownership, SMS Literacy, Mobile Financial Use and Internet Use Among Women by Place of Residence

	Urban		Rural		Total		*p*
	%	n	%	n	%	n	
Has own mobile phone							< .001
No	38.3	302	50.7	2,921	48.6	3,223	
Yes	61.7	441	49.3	2,686	51.4	3,127	
Can read SMS							< .001
No	36.4	294	59.8	3,322	55.9	3,616	
Yes	63.6	449	40.2	2,281	44.1	2,730	
Uses mobile for financial transactions							< .001
No	92.2	676	95.2	5,328	94.7	6,004	
Yes	7.8	67	4.8	279	5.3	346	
Ever used internet							< .001
No	61.6	476	83.0	4,654	79.4	5,130	
Yes	38.4	267	17.0	953	20.6	1,220	
Digitally excluded							< .001
No	67.5	489	53.3	2,926	55.7	3,415	
Yes	32.5	254	46.7	2,681	44.3	2,935	

Digital status							< .001
No phone, no internet	32.5	254	46.7	2,681	44.3	2,935	
Internet only	5.8	48	4.1	240	4.3	288	
Phone only	29.1	222	36.3	1,973	35.1	2,195	
Phone and internet	32.7	219	12.9	713	16.3	932	
Total	**100**	**743**	**100**	**5,607**	**100**	**6,350**	

Note. Percentages are weighted; *n* is the unweighted number of women. *p* values are from Pearson's chi-square tests on unweighted data. SMS reading and mobile financial use are measured among all women (women who cannot read, and women without a phone, are coded 0). Digitally excluded = owns no phone and has never used the internet.

Just over half of women in Bihar (51.4%) had a mobile phone that they themselves used: 61.7% in urban and 49.3% in rural areas, a gap of 12.4 percentage points (Table 2). The gap widened for functional use. Among all women, 63.6% in urban and 40.2% in rural areas could read an SMS, and 38.4% and 17.0%, respectively, had ever used the internet, so urban women were more than twice as likely to have been online. Few women used a mobile phone for financial transactions in either setting (7.8% urban, 4.8% rural).

In total, 44.3% of women were digitally excluded, with neither a phone of their own nor any internet use. Exclusion reached 46.7% in rural areas, against 32.5% in urban areas. Only 12.9% of rural women both owned a phone and had used the internet, compared with 32.7% of urban women. A small group (4.3%) had used the internet without owning a phone, which points to borrowed or shared access.

The Digital Cascade

Table 3 : Digital Cascade Among Women by Place of Residence

	Urban		Rural		Total		*p*
	%	n	%	n	%	n	
Has own mobile phone (all women)							< .001
No	38.3	302	50.7	2,921	48.6	3,223	
Yes	61.7	441	49.3	2,686	51.4	3,127	
Can read SMS (phone owners)							< .001
No	30.4	140	55.9	1,470	50.7	1,610	
Yes	69.6	301	44.1	1,216	49.3	1,517	
							<

Ever used internet (owners who read SMS)							.001
No	30.5	99	52.6	640	46.3	739	
Yes	69.5	20 2	47.4	576	53.7	778	
Uses mobile for financial transactions (phone owners)							.003
No	87.3	37 4	90.2	2,407	89.6	2,781	
Yes	12.7	67	9.8	279	10.4	346	

Note. Percentages are weighted; *n* is the unweighted number of women. Each step is measured among women who completed the step before it: phone ownership among all women (*N* = 6,350); SMS reading and mobile financial use among phone owners (*n* = 3,127); internet use among phone owners who can read SMS (*n* = 1,517). *p* values are from Pearson's chi-square tests on unweighted data.

The cascade in Table 3 shows where rural women fall behind. The rural–urban gap in phone ownership was 12.4 percentage points (61.7% vs 49.3%). Among phone owners, however, only 44.1% of rural women could read an SMS, against 69.6% of urban women, the widest gap in the cascade (25.5 points). Among owners who could read SMS, 47.4% of rural and 69.5% of urban women had used the internet, a gap of 22.1 points. Mobile financial use remained low among owners in both areas (12.7% urban, 9.8% rural). For rural women, the main barrier therefore lies in the ability to use a phone, through literacy and skills, rather than in access to a handset alone.

Precision of Rural–Urban Differences

Table 4 : Weighted Proportions and Design-Based 95% Confidence Intervals for Digital Indicators by Place of Residence

Indicator	Place of residence	Prop.	*SE*	95% CI	
Has own mobile phone	Urban	0.617	0.032	[0.554	0.681]
	Rural	0.493	0.009	[0.474	0.511]
Can read SMS	Urban	0.636	0.031	[0.576	0.696]
	Rural	0.402	0.010	[0.382	0.422]
Mobile financial transactions	Urban	0.078	0.014	[0.051	0.106]
	Rural	0.048	0.004	[0.040	0.056]
Ever used internet	Urban	0.384	0.040	[0.306	0.462]
	Rural	0.170	0.007	[0.156	0.185]
Digitally excluded	Urban	0.325	0.033	[0.261	0.389]
	Rural	0.467	0.009	[0.448	0.485]

Note. Standard errors and 95% confidence intervals are design-based and account for clustering and stratification. SMS reading and mobile financial transactions are measured among all women. Prop. = weighted proportion; *SE* = standard error; CI = confidence interval.

Table 4 reports the weighted proportions with design-based 95% confidence intervals. The intervals for urban and rural women do not overlap for phone ownership, SMS reading, internet use or digital exclusion, so these rural–urban differences are statistically significant. Internet use shows the largest relative gap (0.384 vs 0.170), and exclusion is higher in rural areas (0.467 vs 0.325). For mobile financial transactions the intervals overlap slightly (0.051–0.106 urban, 0.040–0.056 rural), so that difference is less certain. The wider urban intervals reflect the smaller urban sample (743 women).

Variation by Background Characteristics

Table 5 : Digital Access and Use Among Women by Background Characteristics and Place of Residence

	Has own mobile phone				Can read SMS				Uses mobile for financial transactions				Ever used internet			
	Urban		Rural		Urban		Rural		Urban		Rural		Urban		Rural	
	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Age group																
15-19	29.5	40	24.7	335	82.7	117	63.8	892	2.3	5	2.5	37	35.4	54	21.1	300
20-24	69.8	114	60.9	564	75.5	117	58.6	558	11.6	23	8.2	75	54.0	81	33.5	303
25-34	75.7	153	65.6	977	63.6	126	32.7	512	10.3	25	6.6	102	44.4	87	16.0	248
35-49	62.1	134	47.9	810	42.5	89	17.8	319	6.1	14	3.2	65	22.6	45	5.4	102
p	< .001		< .001		< .001		< .001		.002		< .001		< .001		< .001	
Education																
No education	51.0	87	47.8	1,046	3.0	6	1.2	31	2.1	5	2.9	69	5.6	9	4.4	97
Primary	58.2	38	55.1	324	20.1	15	19.9	120	5.4	5	4.3	23	15.1	9	11.2	67
Secondary	57.3	198	46.3	1,088	86.9	298	76.5	1,824	6.6	27	5.4	132	41.1	148	25.0	590
Higher	85.8	118	71.2	228	97.8	130	95.3	306	18.2	30	15.6	55	79.9	101	61.0	199
p	< .001		< .001		< .001		< .001		< .001		< .001		< .001		< .001	
Wealth index																
Poorest	45.2	39	44.3	1,041	22.0	18	23.1	566	2.5	3	2.7	62	4.0	5	7.9	185
Poorer	44.6	55	49.3	781	45.6	56	43.4	711	3.4	7	4.5	76	21.9	23	16.3	260
Middle	53.3	95	54.7	486	60.0	100	60.1	544	5.6	13	7.6	77	29.6	53	27.2	244
Richer	69.0	134	62.5	286	75.9	151	77.8	354	8.8	21	9.7	43	41.7	85	42.1	189
Richest	83.8	118	67.0	92	89.2	124	82.6	106	15.0	23	14.5	21	73.9	101	55.2	75
p	< .001		< .001		< .001		< .001		.003		< .001		< .001		< .001	
Social Group																
SC/ST	50.5	85	45.9	675	46.1	80	29.3	464	3.8	9	4.7	70	24.8	43	12.1	179
OBC	60.7	252	48.9	1,499	66.1	264	40.6	1,293	9.4	44	4.0	135	37.0	151	16.0	513
General	77.1	103	57.0	496	76.6	104	57.0	503	8.8	14	7.5	70	57.2	73	29.0	255
p	< .001		< .001		< .001		< .001		.078		< .001		< .001		< .001	
Religion																
Hindu	60.6	317	49.4	2,277	65.3	334	41.0	1,963	8.6	54	4.7	234	37.8	197	17.0	809
Muslim/Other	64.7	124	48.7	409	59.2	115	36.0	318	5.8	13	5.2	45	40.1	70	16.9	144
p	.698		.937		.136		.025		.116		.681		.530		.883	

	Has own mobile phone				Can read SMS				Uses mobile for financial transactions				Ever used internet			
	Urban		Rural		Urban		Rural		Urban		Rural		Urban		Rural	
	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n
Marital status																
Never married	37.2	67	19.7	268	89.5	162	69.1	937	9.3	19	3.4	50	46.7	88	23.0	323
Married	69.4	358	58.6	2,355	55.3	276	31.6	1,319	7.3	46	5.2	223	36.7	176	15.4	625
Widowed/divorced/ separated	73.7	16	52.6	63	55.2	11	19.5	25	7.7	2	5.2	6	17.2	3	4.8	5
p	< .001		< .001		< .001		< .001		.750		.060		< .001		< .001	
Weekly media exposure																
No	54.1	163	47.4	1,865	40.6	128	31.0	1,283	4.8	16	4.2	174	21.3	62	11.7	462
Yes	67.4	278	54.3	821	80.7	321	65.3	998	10.1	51	6.5	105	51.2	205	31.5	491
p	< .001		< .001		< .001		< .001		.001		< .001		< .001		< .001	
Working status																
Not working	59.7	374	48.7	2,287	65.0	399	41.8	2,034	7.1	54	4.7	234	38.7	233	17.4	844
Working	75.7	67	52.4	399	54.3	50	30.9	247	12.5	13	5.7	45	36.9	34	14.4	109
p	.003		.945		.253		< .001		.061		.528		.762		.001	
Sex of household head																
Male	59.8	350	45.4	1,876	64.5	380	41.9	1,794	7.3	49	4.6	201	38.6	221	17.5	741
Female	69.8	91	60.6	810	60.0	69	35.3	487	9.9	18	5.5	78	37.8	46	15.4	212
p	.003		< .001		.097		< .001		.029		.169		> .999		.075	
Family type																
Nuclear	59.1	281	44.2	1,667	59.4	275	35.3	1,395	6.9	38	4.3	181	32.0	150	13.0	523
Non-nuclear	66.6	160	60.7	1,019	71.3	174	51.4	886	9.5	29	6.0	98	50.3	117	26.2	430
p	.100		< .001		.001		< .001		.090		.094		< .001		< .001	
Total	**61.7**	**441**	**49.3**	**2,686**	**63.6**	**449**	**40.2**	**2,281**	**7.8**	**67**	**4.8**	**279**	**38.4**	**267**	**17.0**	**953**

Note. Percentages are weighted; *n* is the unweighted number of women in each group who report the outcome. *p* values are from Pearson's chi-square tests on unweighted data, computed separately for urban and rural women.

Table 5 shows how each outcome varies with background characteristics within rural and urban areas. Education shows the steepest gradient. Among rural women, internet use rose from 4.4% among those with no schooling to 61.0% among those with higher education, and SMS reading from 1.2% to 95.3%. Wealth had a similar effect, with rural internet use rising from 7.9% in the poorest quintile to 55.2% in the richest. The urban advantage persisted within most education and social groups: among women with secondary education, 41.1% of urban and 25.0% of rural women had used the internet, and among General-caste women the figures were 57.2% and 29.0%. Within wealth quintiles the picture was different. SMS reading was almost identical for rural and urban women in every quintile except the richest, and internet use was similar in the poorest, middle and richer quintiles, with a clear urban advantage only in the richest (73.9% vs 55.2%). Much of the rural–urban gap therefore appears to be tied to wealth.

Phone ownership peaked at ages 25–34 (65.6% rural, 75.7% urban), whereas SMS reading was highest at ages 15–19 and internet use at ages 20–24. Younger women thus tended to have the skills, while women in their late twenties and thirties more often held the phone. Married women were much more likely than never-married women to own a phone (58.6% vs 19.7% in rural areas) but less likely to read SMS (31.6% vs 69.1%) or to have used the internet (15.4% vs 23.0%). In rural areas, phone ownership was higher among women in non-nuclear households (60.7%) and in female-headed households (60.6%), which may reflect absent husbands and shared household phones; because family type is a proxy built from the relationship to the household head, this result should be read with caution. Weekly media exposure was associated with higher levels of every outcome, whereas religion made little difference to phone ownership or internet use.

Discussion

This study offers a state-specific, rural–urban assessment of women's digital exclusion in Bihar using the NFHS-5 state module. Five findings stand out. First, almost half of women aged 15–49 years were digitally excluded, and fewer than one in five rural women had ever used the internet. Second, the rural–urban gap was modest for phone ownership but doubled at the level of SMS literacy among phone owners. Third, education and wealth showed the steepest gradients; the rural–urban difference largely disappeared within wealth quintiles but persisted within education groups, particularly for internet use. Fourth, the women who owned phones were often not the women who had the skills to use them. Fifth, use of phones for financial transactions was negligible, against a background of weaker control over money and restricted mobility among rural women.

The level of exclusion is consistent with global evidence that women's under-representation online is most severe in South Asia (Fatehkia et al., 2018), and with the national NFHS-4 finding that most Indian households owned a phone while fewer than half of women had personal access (Mohan et al., 2020). Our results extend this evidence in two ways. They show the depth of exclusion in a single high-burden state, which pooled national estimates cannot reveal, and they show that the rural–urban gap is proportionally largest for the internet, the rung with the greatest potential returns. Mobile access has been associated with lower gender inequality and better reproductive and child health outcomes, particularly in the poorest settings (Rotondi et al., 2020). The concentration of exclusion among rural women therefore implies that the benefits of digitalisation are flowing to the women who need them least. This fits the view that digital inequality is itself an axis of social stratification that compounds existing disadvantage (Robinson et al., 2015).

The cascade shows where rural women fall behind. The gap in owning a handset (12.4 percentage points) was about half the gap in reading an SMS among owners (25.5 points), and a further 22 points separated rural and urban SMS-literate owners in internet use. This supports the multi-level framing of the digital divide, in which inequalities in skills and use (the second level) are distinct from, and can be larger than, inequalities in access (the first level; Scheerder et al., 2017). It also accords with evidence that the first-level divide has shifted from physical access towards the material and functional resources needed to use a device well (van Deursen & van Dijk, 2019). District-level analyses of NFHS-4 have documented wide variation in women's SMS literacy across India (Venkataramanan et al., 2021), and our findings suggest that in rural Bihar literacy is the binding constraint. Policies that prioritise device distribution or network coverage are therefore unlikely to close the gap on their own.

The socio-economic gradients mirror those reported for India, where less educated, poorer and lower-caste households lack both ICT assets and the skills to use them (Tewathia et al., 2020), and where education and income explain more than half of the caste-based digital divide (Rajam et al., 2021). They are also consistent with the argument that the gender digital divide in developing countries largely reflects women's lower education, employment and income (Hilbert, 2011). A distinctive pattern in our data is that the rural–urban gap in SMS reading, and in most quintiles the gap in internet use, almost vanished within wealth groups, whereas an urban advantage in internet use remained among women with the same level of education. Rural disadvantage thus seems partly compositional, because rural women are concentrated in the poorest quintiles, but schooling may also yield smaller digital returns in rural areas, perhaps because of poorer school quality, weaker connectivity or fewer opportunities to practise. The distinction matters for policy. Compositional gaps narrow as education and wealth rise, whereas differences in returns call for interventions in rural settings themselves. Decomposition methods for non-linear outcomes are needed to quantify these components, and the bivariate patterns reported here should be read as hypotheses for such analysis rather than as estimates of it. The caste gradient is also steep: internet use among urban General-caste women was almost five times that among rural SC/ST women (57.2% vs 12.1%), which indicates that place and caste compound one another.

To our knowledge, the separation of phone ownership from capability across the life course has not been well documented for Bihar. Married women in their late twenties and thirties were the most likely to hold a phone, whereas adolescents and never-married women were the most likely to read an SMS or to have been online. One plausible explanation is that phones are acquired at marriage or provided by husbands for household communication, while younger women have benefited from recent gains in schooling but lack a device of their own. Higher ownership among rural women in female-headed households, together with the high

prevalence of husbands' absence, is consistent with phones being provided to maintain contact with migrant men; this interpretation is inferred and needs direct testing. Qualitative work in rural central India has shown that even women who own phones face narrow expectations of use, dependence on men and norms against leisure use (Scott et al., 2021). In this setting, ownership may signal a limited, household-sanctioned form of use rather than digital autonomy.

Use of phones for financial transactions was rare in both settings, even among owners, although most women in the same sample (76.7%, weighted; not shown in the tables) reported having a bank account that they themselves used. Formal financial inclusion appears to have outpaced women's capacity, or permission, to transact digitally. Evidence from Kenya shows that mobile money can reduce poverty, with larger gains for female-headed households (Suri & Jack, 2016), and evidence from Madhya Pradesh shows that giving women direct control of their accounts increases their work and shifts gender norms (Field et al., 2021). In Bihar, where rural women were less likely to have money of their own and more often unable to go anywhere alone, account ownership without control is unlikely to deliver these benefits. These constraints are consistent with long-standing evidence that women's autonomy in north India is tightly bounded, particularly in mobility (Jejeebhoy & Sathar, 2001). The strong association between weekly media exposure and every digital outcome is also notable. Media may act as a channel of norm change as well as of information, although the direction of this association cannot be established from cross-sectional data.

Strengths and Limitations

The study has several strengths. It uses a large, population-representative survey with state-level weights, measures four distinct rungs of digital inclusion for the same women, and places structural indicators of resources, mobility and norms alongside conventional socio-economic measures. It also has limitations. The data are cross-sectional, so the associations cannot be interpreted causally.

The analysis is descriptive and bivariate: percentages are weighted, but the chi-square tests were computed on unweighted data and do not account for the complex survey design, and no multivariable adjustment was made. The urban sample was small (743 women), which widens confidence intervals and makes some within-group comparisons imprecise. Internet use was measured only as ever-use, without information on frequency, purpose or recency, and SMS literacy and phone ownership were self-reported. Family type was a proxy derived from the relationship to the household head. Finally, digital access has expanded since the survey, so current levels are likely to be higher, although the structural patterns described here are unlikely to have disappeared.

Policy Implications

Device distribution alone will not close the digital gap for women in rural Bihar. Four priorities follow from the findings. First, functional and digital literacy programmes should reach married women aged 25 years and older, who already hold phones but often cannot read messages or go online. Second, adolescent girls and young women who have the skills need access to devices of their own. Third, bank accounts opened under financial inclusion schemes should be linked to women's own control of money, so that account ownership can translate into digital financial use. Fourth, programmes need to engage households on women's mobility and phone use, since ownership in this setting does not guarantee independent use. Given the strong association between media exposure and every digital outcome, mass media could also carry digital skills content alongside messages that support women's use of technology.

Conclusion

Women's digital exclusion in Bihar is extensive and is concentrated among rural, poorer, less educated and lower-caste women. The rural–urban gap is smallest at the point of handset ownership and largest at the point of functional use. It reflects both the concentration of rural women in the lowest wealth groups and, apparently, smaller digital returns to schooling in rural areas. Ownership and capability are held by different groups of women, and digital financial use remains negligible despite widespread bank account ownership.

Moving beyond device provision, towards building rural women's functional and digital literacy and their control over money and mobility, is therefore central to closing the gap. Future research should use multivariable and decomposition methods to separate the compositional and returns components of the rural–urban gap, test the role of male out-migration directly, and estimate how much of women's digital exclusion in Bihar lies between districts.

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MAKHANA CULTIVATION AND ITS IMPACT ON ECONOMIC CONDITION OF FARMERS IN MADHUBANI DISTRICT OF BIHAR

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ABSTRACT

Foxnut or Makhana, is an important aquatic crop belonging to the Nymphaeace family. The crop is widely cultivated in India, China and Japan. The crop is highly nutritious and is in great demand across the world. In recent years, scientists have developed new varieties of Makhana and integrated farming practices to boost the economy. Foxnut farming requires intensive care and systematic management. It contributes to the livelihood of farmers and boosts the economy of the region. Madhubani district has large number of ponds, mauns, chaurs, wetlands and flood plains, which are suitable for Makhana cultivation. The favourable climatic condition, suitable soil type, good water quality, availability of human resources and cultural practices make the region ideal for this farming. Many people of the society are involved in this work but the Sahani community is highly engaged and has got benefit in uplifting the economic and social conditions in this region.

The present study highlights the economic importance, production and challenges of Foxnut cultivators in the study area. The study is based on both primary and secondary methods of data collection. Primary data were collected through questionnaire, scheduled, focus group discussions, sampling and field visit whereas secondary data were collected from books, journal, magazines, newspapers and government records.

Keywords : *Foxnut, Nymphaeace, Sahani, Nutritious, Systematic.*

Introduction

Foxnut or Gorgon nut (*Euryale ferox*), locally known as Makhana, belongs to the Nymphaeace family. It is in high demand across the world due to its nutritional, medicinal, and cultural importance. The carbohydrates, protein, fat, dietary fiber, calcium, magnesium, potassium,

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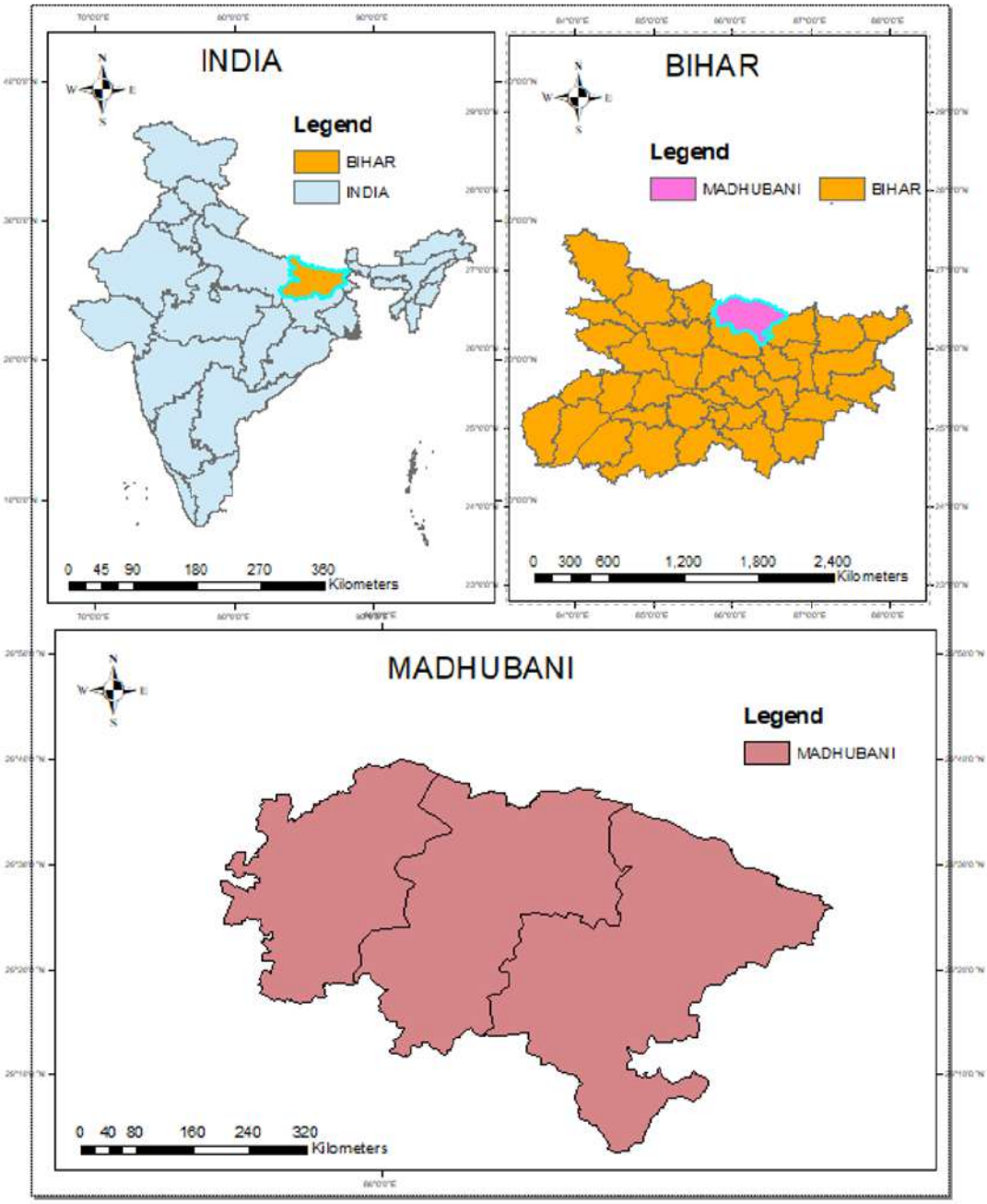
phosphorus, iron, low calorie count**,** and antioxidants present in Makhanamake the heart healthy, aiddigestion, maintain blood sugar levels, make bones stronger, decrease cell damage, and helpmaintain body weight. It is considered superior to dry fruits such as almonds, cashew nuts, walnuts, and coconuts in terms of sugar, protein, and ascorbic acid (Bilgrami et al., 1983). It is light – weighted and crunchy in taste so high demanding as snacks in the world. Makhana is also known as 'superfood'.

Makhana has been grown in Asia for centuries. The major Makhana-producing countries of the world are India, South Korea, Japan, China and Russia. It is exported to theUAE, Canada, theUSA, Australia, theUK, and many other countries across the world. In India, Makhana is growing widely in West Bengal, Odisha, Tripura, Assam, Manipur, Bihar and some parts of Uttar Pradesh. Bihar holds a leading position in foxnut farming across the world, producing about 80 percent of the world's Makhana. Darbhanga, Madhubani, Saharsa, Katihar, Sitamarhi, Kishanganj, Supaul and Purnea are the major foxnut-producingdistricts of Bihar. Despite this, the area under Makhana cultivation is reported to have declined by about 35 percent in the past few decades from 20,000 ha to 13,000 ha (Singh, 2014).

Study Area

The Madhubani district extends between latitudes25º59'N and 26º39'N and longitudes 85º43'E and 86º42'E. It is located along the northern part of the middle Gangetic plain in the foothills of the Himalayas. The district lies 80 m above mean sea level. It is surrounded by Nepal in the north, Darbhanga in the south, Sitamarhi in the west and Supaul in the east.

The region is enriched with fertile alluvial soil. The major rivers of the district are the Kamla Balan, Bhutahi Balan, Adhwara group, Trisula, Supen, Koshi and Dhaus. The drainage is divided into three categories: theKamla-Balan flood plain, theKamla-Jiwalch flood plain**,** and theKamla-Koshi flood plain. The average annual rainfall of the district is 1,200 mm. The climate here is a sub-tropical monsoon climate (Cwa). The district covers an area of 3,501 sq. km. It includes 21 blocks and 5 sub-divisions. The total population of the district is 4,487,379 (Census 2011). The district consists of 93% rural population and a remaining 7% urban population.Agriculture and allied activities are the main sources of livelihood for the people of this region. The population is fond of aquatic products such as foxnut, fish, and chestnut. These products are closely related to the culture of this region.



Source : *prepared by researcher on the basis of Arc GIS.*

Figure 1 : Map of study area

Objectives

1. To study the present status of foxnut farming in Madhubani district.
2. To analyse the impact of foxnut farming on the economy of region.

Database and Methodology

The present research is based on data procured through both primary and secondary methods. The primary data were collected through questionnaires, field visits, focus group discussions, schedules, and sampling techniques (purposive and stratified sampling). The researcher used both open-ended and close-ended questions for the field survey.

The secondary data were collected from books, magazines, journals, theses, government records, the National Research Centre for Makhana, and the District Statistics Office. Both qualitative and quantitative methods of data collection have been used. ArcMap 10.8.2 was used for the preparation of the study area map.

Result and Discussion

Bihar alone produces 85 percent of the world's Makhana. The state**has a bright future** for foxnut farming. Bihar has a total of 21,998 wetlands (including those smaller than 2.25 ha). These wetlands cover an area of 403,209 ha across the state, with small wetlands (< 2.25 ha) accounting for 17,582 ha of that total. Inland wetlands (both natural and man-made) make up approximately 95.64% of the total wetland area, while smaller wetlands (< 2.25 ha) cover the remaining 4.36%.

Bihar is flood-affected, and some parts of the state are facing severe flood havoc. **The water remains stable for about six months.** So, **a water-resistant crop** such as Makhana is very fruitful for this region.

Madhubani, Darbhanga, Sitamarhi, Kishanganj, Purnea, Saharsa, Katihar and Supaul are the major **Makhana-producing districts**. Scientists **have developed** several new seed varieties—**such as** Swarn Vaidehi, **Sabour Makhana-1,** Makhana 1, Makhana 2, Makhana 3, Makhana 4, Pragati, Janki, MR 1, MR 2, and Srijan—to ensure higher yield, low disease risk, and **better commercial viability.** Training **programs have been initiated** by the government **in** collaboration **with ICAR,** KVKs, **the** District Horticulture **Office,** NGOs, **and** private **companies.** These training **programs help farmers** overcome **the numerous** challenges they **face on** their farmland.

A regional center for Makhana was established in Darbhanga as a part of ICAR for research and scientific work. About 250 acres of land have been selected for the scientists at this center in the Korthu panchayat of Darbhanga district for farming Makhana through scientific methods.

Table 1 : Year wise Makhana production in Bihar (2012-22)

Year	Area (in ha)	Seed Production (Tones)	Pop production (Tones)
2012 - 13	13,000	20,800	9,360
2019 - 20	27,887	44,638	18,048
2020 - 21	29,584	47,534	20,634
2021 - 22	35,224	56,389	23,656

Source : *Makhana Research Institute, Darbhanga (2023).*

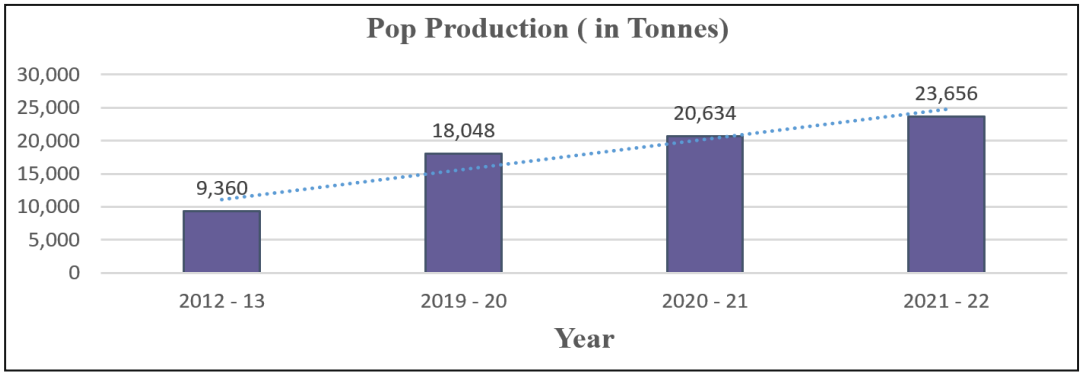


Figure 2 : Year wise pop production in Bihar

Table 2 : District wise area, seed and pop production (2021-22)

District	Area (Ha)	Total seed Production (T)	Total pop Production (T)
Darbhanga	4389	7421.4	2969
Madhubani	4160	7280.7	3012
Sitamadhi	146	277.4	112
Purnea	5549	11652.9	5234
Katihar	6043	11759	4858
Saharsa	4443	5267	2167
Supaul	5463	5182.8	2260
Madhepura	2461	2907.39	1188
Araria	1427	2639.95	1056
Kishanganj	1143	2000.25	800.1
Total	35,224	56388.79	23656.10

Source: *Makhana Research Institute, Darbhanga (2023)*

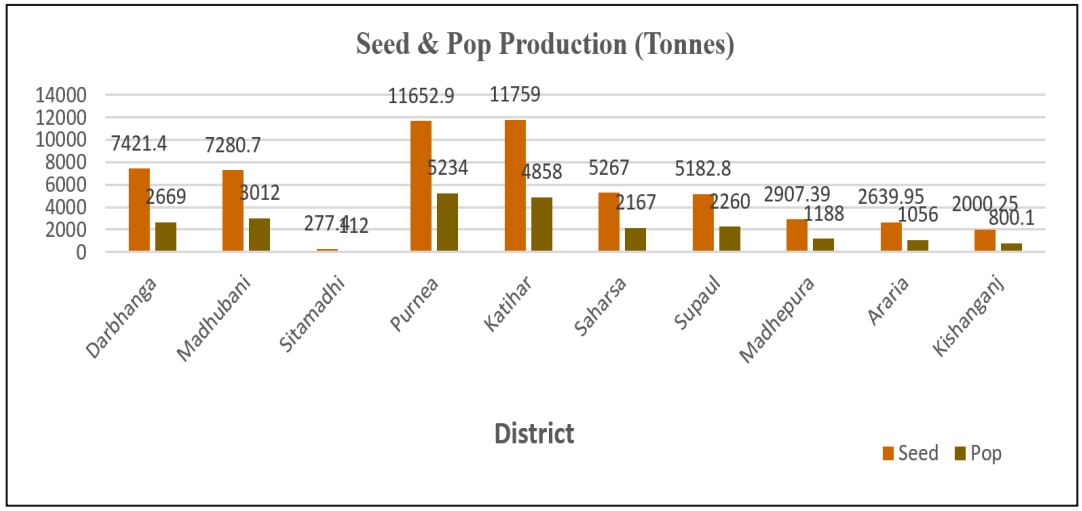


Figure 3 : Shows the district wise seed and pop production in terms of tons.

Makhana farming in study area

The Madhubani district is a hub of Makhana farming and is widely known as the "Makhana capital of India." This industry establishes a distinct cultural identity for the region. The district itself produces about 40% of the state's total Makhana supply. Approximately 2 lakh people from the region are directly or indirectly engaged in associated activities, including cultivation, harvesting, roasting, popping, packing, and marketing. This concentration is driven by an abundance of natural water bodies, such as ponds, riverine areas, wetlands, *chaurs* (shallow land depressions), and *mauns* (oxbow lakes). Favourable climatic conditions and the availability of skilled human resources make the region ideally suitable for this type of farming.

Growers in the region employ two methods of **farming: pond-based and field-based**. Furthermore, the integrated farming of **Makhana has gained significant popularity in recent years**. The cultivation cycle follows a structured timeline: **sowing occurs between October and November; plants grow from December to February; flowering and fruiting take place from March to May; harvesting occurs between June and August; and roasting and popping arecompleted fromAugustto September**. **Jhanjharpur**, Benipatti, Phulparas, Bisfi, Rajnagar, and **Andhratharhi** are the major **Makhana-producing** blocks **in the** district.

A dedicated Makhana processing unit operates in the easternAndhratharhi block through the joint cooperation of an NGO and the Central Government. Notably, 'Mithila Makhana' received its Geographical Indication (GI) tag in 2022. Dr. Rajendra Prasad Central Agricultural University (Pusa), the ICAR-National Research Centre for Makhana (Darbhanga), and Bihar Agricultural University (Sabour, Bhagalpur) are actively working in

this area to maximize production and enhance product quality. Consequently, scientists regularly introduce innovative Foxnut farming patterns within the study area.

Pattern of integrated Makhana farming widely used in study area

- Paddy – Makhana farming
- Makhana – Water chestnut farming
- Makhana – Fish farming
- Makhana – Fish – water chestnut farming

Foxnut farming in the study area is not limited to ponds, wetlands, oxbow lakes, *mauns*, and *chaurs*; it extends to farmland as well. Today, scientists encourage farmers to adopt field-based farming, where paddy is cultivated alongside Makhana. This method of farming provides a double income, combining profits from both crops. While pond-based farming is a traditional method dependent on manual practices, field-based foxnut farming relies on scientific advice, modern methodologies, and machinery. The field-based approach increases production by up to 30 percent, simplifies harvesting, and allows the crop to mature within six months.

Table 3 : Comparison between field-based and pond-based Foxnut farming

Parameter	Pond System	Field System
Season	Winter	Transplanting of seedlings in Summer
Time of sowing	December	Nursery raising in December
Water requirement	Min 3 – 4 feet	Approx. 1.5 feet
Seed requirement	80 – 90 kg / ha	20 kg. Ha
Source of water	Natural water as perennial water bodies	Irrigation water or any other source of perennial water
Fertilizers and manure	Not possible due to high depth of standing water	Can be applied very easily before and after transplantation
Weed Management	Very tedious	Very easy
Crop duration	Long to very long (8-10 months)	Short (4-5 months)
Seed yield	1.5 – 2.0 t/ha	2.6 – 3.5 t/ha
Scope for Grain and Fodder production	Not possible	Water chestnut, rice, wheat, Barseem and other field crops can be grown in rotation.

Parameter	Pond System	Field System
Possibility of maximum no. of crops in a year	Two	Three
Intensification of Cropping system	Makhana with water chestnut	Makhana-Water chestnut, Makhana-Barseem and Makhana – rice – wheat.
Crop protection measures	Very tedious	Quite feasible
Cropping Intensity (%)	In General (100%) in traditional system	200 – 300 %
Net Income	Low to Medium in traditional system	High to very high
Feasibility of Harvesting	Very tedious. It can be done only by trained labourers.	Very simple. It can be done easily even by unskilled labourers.
Capital Investment	During initial phases: high to very high.	Medium to low
Scope of horizontal expansion of Makhana cultivation	Limited scope because it would depend on the availability of natural water bodies.	Wide scope

Source : *Makhana Research Institute, Darbhanga (2022).*

Table 4 : Expenditure of Makhana farming in field-system (Per ha) in study area

Expenditure	Per Acre/ Per year	Expense per acre	Total Expense (Rs.)
Farm rent	01	12000.00	12,000.00
Preparation of Farm	01	2000.00	2,000.00
Chemical Fertilizer	01	3000.00	3,000.00
Organic Fertilizer	6.0 ton	Rs1.00/kg	6,000.00
Labor need for fertilizer use	03	Rs400/labor	1,200.00
Seed	8.0 kg	Rs180/-kg	1,440.00

Seed sowing	01 acre	40 labor, Rs 400 one labor per day	16,000.00
Irrigation	For every 5 hr, total 12 times	150/hour (750/-one times)	9,000.00
Use of Insecticides & Pesticides	01 acre	2500.00	2,500.00
Grass removal	10 labor (1 day)	400/labor/day	4,000.00
Crop harvesting	1.22 ton (use of high quality seed)	Total expense 39, 650.000 on Rs.1300 per 40 kg	39,650.00
Seed transportation	1.22 ton seed		1500.00
Lava production	0.5 ton	5.0 quintal	
Average expense of lava making Rs.4000/- per quintal lava		5 quintal *4000	20,000.00
		Total Expense	1,18,290.00
Income from lava 550/kg lava 550*500 = 2,75,000=00 total income			2,75,000.00
		Total Income	1,56,710.00

Source : *Makhana Research Institute, Darbhanga (2022).*

Impact on Farmer's economy

Makhana is highly profitable for the farmers of this region. It is a labour intensive work which generate employment. Labour is required for the preparation of ponds or farms, makhana cultivation, seed colletion, washing, drying, grading, roasting, popping, packing and transportation. Farmers contribute to the income generated from unutilized or waterlogged ponds and farms. It is a continuous process that engages farmers throughout the years. The crop can easily survive in stagnant water. The supply chain from farmers to consumers which includes collectors, processors, wholesaler and retailers generates income and employment through the circulation of the crop from farmland to the market.

The Role of establishment of Makhana Board

The union government announced for the establishment of Makhana board in his budget session 2025 in Bihar. Its headquarter has to be set up in Darbhanga. It has started to work in this region extensively. Farmers are enthusiastically adopting the makhana farming here.

Many farmers due to high earnings have started makhana farming in new farmland which were earlier used for farming other crops or are neglected due to low productivity or income. Farmers are being trained and supported by the scientists and kishan salahkar are also doing well in propagating its farming in an extensive way. Its main objective is to provide appropriate price of crop, good quality product, provide training to Makhana cultivators, facility of loan, KCC and crop insurance and pond development. The major function of Makhana board is production (provide good quality seed, training through KVK, pond development, integrated farming of fish and Foxnut), processing (establishment of cold storage, provision of subsidy for Makhana processing unit), marketing (provide 'e-commerce' facilities, Makhana market establishment , MSP, "Bihar Makhana" named brand making) and export (provide FSSAI or organic certificate easily, helpful in foreign mela). It provide insurance, pension and loan facilities to women SHGs. Makhana board is very helpful for the farmers because it remove the concept of middleman on commercial purpose. The ready product is directly send to the related company. Low cost machine reduce the dependency of farmers on labor. The board decide to prepare the hybrid seed with the support of ICAR which is climate – resistance.

Challenges of Makhana Cultivation

While there is immense scope for Makhana farming in the Madhubani district, the sector faces numerous critical challenges.

- Technological Inefficiencies: Many farmers still rely on traditional cultivation methods instead of modern machinery. This highly labour-intensive approach directly causes a decline in overall production efficiency. Furthermore, manual roasting and popping processes lower the final product quality.
- **Climatic Disruption:** Environmental changes—including shifting weather patterns, dropping pond water levels, rising temperatures, and rainfall variability—disrupt the delicate ecosystems of Makhana ponds and lower crop yields.
- Barriers Market and Logistics: A scarcity of modern storage facilities, a lack of well-organized markets, and poor transportation infrastructure limit the sector's growth. Additionally, the heavy intervention of brokers between farmers and consumers inflates retail prices while preventing farmers from receiving their fair share of the profits.
- Financial and Institutional Gaps**:** Inadequate crop insurance for damaged yields, limited farming loans, and a lack of professional branding platforms restrict local growers. Without access to structural national and international marketplaces, the commercial interest of Makhana growers continues to decline.

Conclusion and Suggestions

In conclusion, Makhana cultivation serves as the economic foundation for the aqua-farmers of the Madhubani district. The region stands as a major hub for foxnut production. Severe seasonal flooding in certain parts of the district has also prompted local communities to shift from traditional agriculture toward aquaculture. Makhana farming offers significantly higher profit margins compared to conventional crops, driving increased interest among local farmers.

To maximize yields, scientists have introduced innovative farming models, while the government provides institutional training workshops and subsidy programs to support sector growth. Notably, the region's produce has been globally recognized through the "Mithila Makhana" Geographical Indication (GI) tag.

Despite these advancements, market supply falls short of global demand. The sector continues to grapple with critical bottlenecks, including the persistence of traditional farming methods, financial constraints, limited technical know-how, climate change, and environmental degradation.

Makhana cultivation have bright future in the Madhubani district. But it is necessary to provide good quality seed, increase the farm land and ponds, concentration on scientific innovative ideas and focus on technical processing. The unutilized ponds, mauns, ox-bow land, chaurs and wetland should be prepared for foxnut farming. The good strategy and management is required for good production. The storage facility for ready product must be provided. The quality of product should increase that Makhana will compete with other companies in the international market. The support of SHGs, local government and large farmers will prove profitable in the near future.

Nevertheless, Makhana cultivation remains the backbone of the regional economy, offering immense potential for sustainable development.

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ENVIRONMENTAL AND SOCIO-ECONOMIC DIMENSIONS OF PLASTIC WASTE IN PATNA MUNICIPAL CORPORATION AREA OF BIHAR

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ABSTRACT

Rapid urbanization, population growth, and increasing dependence on plastic products have made plastic pollution a major environmental challenge, particularly in developing states such as Bihar, where waste collection, recycling, and disposal systems remain inadequate to manage the rising volume of plastic waste. This study examines the environmental and socio-economic dimensions of plastic waste in the Patna Municipal Corporation Area (PMCA) of Bihar. The study followed a descriptive research design and drew on both primary and secondary sources of data. Primary data were collected through household surveys, field observations, and interviews, while secondary data were obtained from government reports, municipal records, and relevant academic literature. The study is based on responses from 110 participants selected through random and purposive sampling techniques. The findings show that plastic waste forms a significant component of municipal solid waste and is commonly found along roadsides, drainage channels, market areas, and water bodies. Inadequate waste segregation, collection, recycling, and disposal have contributed to environmental degradation, blocked drains, waterlogging, and public health problems. The study also reveals limited public awareness and weaknesses in the implementation of existing plastic waste management regulations. Strengthening waste management infrastructure, promoting segregation of waste at source, improving recycling systems, and encouraging public participation are essential for sustainable plastic waste management and for supporting Patna's transition towards a plastic-smart city.

Keywords: *Plastic Pollution, Municipal Solid Waste, Recycling, Public Awareness, Urban Environment.*

Introduction

Plastic has become an indispensable material in modern society because of its lightweight nature, durability, versatility, and relatively low manufacturing cost. These characteristics have led to its widespread use in domestic, commercial, industrial, and agricultural activities. However, the continuous increase in plastic consumption, particularly of disposable and single-use products, has resulted in generation of enormous quantities of waste that remain in the environment for long periods due to their slow rate of natural decomposition.

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Plastic pollution is now recognized as a major environmental issue affecting terrestrial, freshwater, and marine ecosystems across the world. Improperly managed plastic waste often accumulates in open spaces, drainage channels, rivers, and other water bodies, where it disrupts ecosystem functions and contributes to environmental degradation. The fragmentation of plastic waste into microplastics has further intensified concerns regarding biodiversity loss and potential human health risks.

India has experienced a rapid increase in plastic consumption due to urbanization, population growth, economic development, and changing consumer behaviour. As a result, Urban Local Bodies (ULBs) face increasing pressure to manage growing volumes of plastic waste. Although measures such as the Plastic Waste Management Rules and restrictions on selected single-use plastic items have strengthened the policy framework, effective implementation continues to be constrained by inadequate waste segregation, limited recycling facilities, weak enforcement, and insufficient public participation.

Patna, the capital city of Bihar, has experienced rapid urban expansion during the past three decades. The growth of residential areas, increasing use of packaged consumer goods, and limitations in municipal waste management infrastructure have contributed to a rise in plastic waste generation. Plastic litter is frequently observed in drains, along roadsides, around marketplaces, and near water bodies, leading to environmental pollution, drainage congestion, waterlogging, and associated public health problems. In view of these concerns, the present research evaluates the existing status of plastic pollution in the Patna Municipal Corporation Area by examining its sources, environmental and socio-economic impacts, and current management practices. The findings are expected to generate evidence-based recommendations that can support more effective plastic waste management policies and contribute to the development of a cleaner, healthier, and more sustainable urban environment.

Plastic pollution has become one of the most pressing environmental concerns at global, national, and local scales. Existing research identifies it as a multidimensional issue with environmental, economic, social, and public health implications. Several studies have examined the growing scale of plastic pollution worldwide. In *Turning the Tide on Plastic*, Lucy Siegle (2018) discussed the environmental consequences of increasing dependence on disposable plastics and pointed to weaknesses in existing waste governance systems. Krantzberg et al. (2020) emphasized the importance of effective governance, public participation, and nature-based solutions in reducing plastic pollution.

Researchers have also examined the social and health dimensions of plastic pollution. Caren Irr (2021) linked consumer culture with rising plastic dependency and waste generation. Romer (2021) highlighted the importance of recycling and proper waste segregation in

minimizing the impacts of plastic pollution. Matt Simon (2023) reported the widespread presence of microplastics in the environment and human tissues, highlighting potential long-term health concerns.

Goel and Tripathi (2024), Brears (2024), and Kapoor, Treichel, and Zdarta (2026) discussed sustainable alternatives, recycling technologies, circular economy approaches, and policy measures. Their studies emphasize that technological solutions must be supported by effective governance and public participation.

In India, rapid urbanization and changing consumption patterns have significantly increased plastic waste generation. Although initiatives such as the Plastic Waste Management Rules (2016) and subsequent amendments, the Swachh Bharat Mission, and restrictions on selected single-use plastics have strengthened the policy framework, implementation remains constrained by inadequate infrastructure, weak enforcement, and limited public awareness. Research from Patna and other Ganga basin cities identifies inadequate segregation, limited recycling, and improper disposal as major causes of plastic accumulation in drains, roadsides, and water bodies. Despite municipal initiatives such as door-to-door waste collection and awareness programmes, effective plastic waste management continues to be a challenge. Existing research on the environmental and socio-economic dimensions of plastic pollution in Patna Municipal Corporation Area is limited compared with global and national studies.

Study Area

The study was conducted within the jurisdiction of Patna Municipal Corporation Area (PMCA), located in Patna, the capital city of Bihar. As one of eastern India's fastest-growing metropolitan centres, Patna plays a significant role as the state's administrative, commercial, educational, and cultural centre. Geographically, Patna lies between 25°36′ N latitude and 85°08′ E longitude. It is bordered by the Ganga River in the north, the Punpun River in the south, Fatuha in the east, and Danapur in the west. The city lies in the fertile alluvial plains of the Ganga basin and experiences a subtropical climate with distinct summer, monsoon, and winter seasons.

Patna Municipal Corporation Area comprises 75 municipal wards and faces growing solid waste management challenges due to rapid urbanization, population growth, and changing consumption patterns. Increasing plastic use, inadequate waste segregation and collection, improper disposal, and limited recycling facilities have resulted in plastic accumulation in public spaces, drains, and water bodies. These problems contribute to environmental degradation, drainage congestion, urban flooding, and public health risks. Despite existing regulations and municipal initiatives, weak enforcement and limited public awareness hinder

effective plastic waste management. Considering its rapid demographic expansion, increasing commercial activities, and location along the Ganga River, Patna provides an appropriate setting for examining the environmental and socio-economic dimensions of plastic pollution and identifying measures for sustainable urban waste management.

Objectives

The main objective of this research is to examine the environmental and socio-economic dimensions of plastic waste pollution within the Patna Municipal Corporation Area. The specific objectives are:

1. To analyze the pattern and magnitude of plastic consumption in the Patna Municipal Corporation Area.
2. To identify the principal sources of plastic waste generation.
3. To evaluate the environmental, health, and socio-economic impacts associated with plastic pollution.
4. To assess the effectiveness of existing plastic waste management system, including waste collection, segregation, recycling and disposal practices.
5. To analyse the level of public awareness regarding plastic pollution, its environmental consequences, and the need for sustainable waste management practices.

Methodology

This paper is mainly based on information obtained from primary data and follows a descriptive research design to study the status, causes, impacts, and management of plastic waste pollution in the Patna Municipal Corporation Area (PMCA). Primary data were collected through structured questionnaires, interviews, and field surveys (direct observations) to get information on plastic use, waste disposal practices, public awareness, and the environmental impacts of plastic waste. As the data were collected during a specific period, the study adopts a cross-sectional approach.

Both random and purposive sampling techniques were used to collect data from 110 respondents from different wards and locations where plastic pollution was more evident. The respondents were from different age groups, genders, occupations, and socio-economic backgrounds. Secondary information was obtained from government publications, municipal records, and other relevant published sources. The use of both primary and secondary data, along with qualitative and quantitative methods, provides a reliable assessment of plastic pollution and waste management practices in the Patna Municipal Corporation Area.

Discussion and Results

Comparison of Waste Quantification and reported Waste Generation

"Waste generation denotes the quantity of solid waste produced by a specified source per unit time and is commonly expressed as kg capita^{-1} day^{-1} or kg day^{-1} for institutional and municipal systems." Waste quantification involves collecting, measuring, and categorizing waste data through methods such as direct weighing, waste-composition analysis, hauler records, surveys, and diaries.

Table 1 compares assessed and reported municipal solid waste generation across major ULBs. Patna shows the largest discrepancy, with an estimated 1,250 TPD (tonnes per day) against reported quantities of 850 TPD in 2021 and 1,000 TPD in 2022 (CAG, Government of India, 2022). While Muzaffarpur, Munger, and Chhapra reported relatively consistent figures, Darbhanga showed a notable disparity. These differences highlight the need for reliable waste estimation, monitoring, and reporting to support effective waste management planning.

Table 1 : Comparison of Waste Assessment in Major ULBs of Bihar

(Quantity in Tonnes per day)

Sl. No.	ULB	Waste as per Quantification Study	Reported Waste 2021	Reported Waste 2022
1	**Patna**	1,250	850	1,000
2	**Muzaffarpur**	182	NA	180
3	**Darbhanga**	201	120	120
4	**Munger**	89	65	88*
5	**Chhapra**	87 - 92	NA	87.5*

Data Source: *Compiled from Audit Report (Local Government), CAG, Government of India (2022). Pp. 33–34. (Based on information furnished by ULBs during the audit.)*

A primary survey of 110 respondents in the Patna Municipal Corporation Area (PMCA) examined plastic consumption, awareness, disposal practices, and perceptions of plastic pollution. The findings, presented through tables and charts, provide an empirical basis for the study's conclusions and policy recommendations.

Socio-Economic Profile of Respondents

The survey included 110 respondents, comprising 62 males (56.4%) and 48 females (43.6%), indicating relatively balanced gender representation. The largest age group was 26–40 years (N=42; 38.2%), followed by 18–25 years (N=30; 27.3%) and 41–60 years (N=25; 22.7%).

Occupationally, students constituted the largest group (N=28; 25.5%), followed by private sector employees (N=20; 18.2%) and homemakers (N=18; 16.4%). Government employees, businesspersons, and respondents from other occupational categories also represented a substantial proportion of the sample. This diversity in age and occupation provides varied perspectives on plastic consumption and waste management practices in the Patna Municipal Corporation Area.

Extent of Plastic Bag Usage

India is among the highest consumers in absolute terms, with estimates of 160 billion plastic bags used annually and daily figures often cited around 10–12 billion bags. Plastic bags form a significant share of urban litter and drain-clogging waste in Indian cities, contributing to flooding and public-health risks, which is why many municipalities emphasize both enforcement and behavioural campaigns. A majority of respondents (N=60; 54.5%) reported using plastic bags regularly, while 35 (31.8%) used them occasionally and only 15 (13.7%) reported never using plastic bags (refer to Figure 1). This indicates that plastic bags have become an integral part of everyday activities because of their convenience, affordability, and widespread availability.



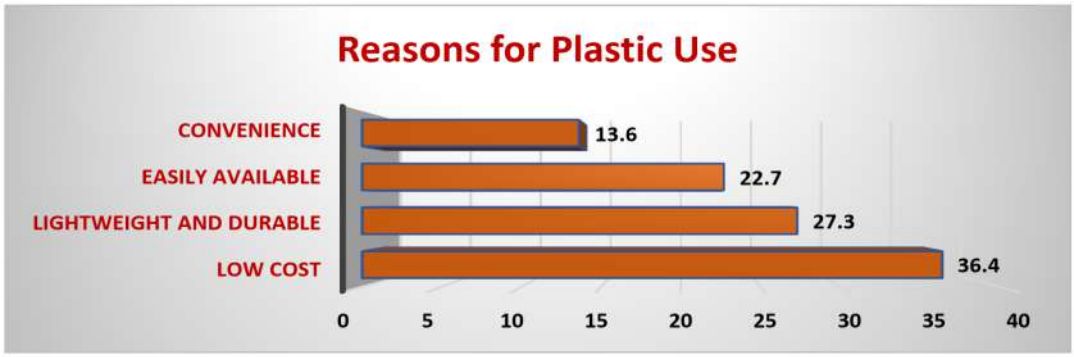
Source: *Field survey (2026), N=110.*

Figure 1 : Prevalence of Plastic Bag Usage

Reasons for Plastic Use

The persistence of plastic bag use is driven primarily by their low production cost, light weight, and functional advantages such as water resistance and durability, which align with the operational needs of both retailers and consumers. The primary reason for plastic use reported by respondents was its low cost (N=40; 36.4%), followed by its lightweight and durable nature

(N=30; 27.3%), easy availability (N=25; 22.7%), and convenience (N=15; 13.6%) (refer to Figure 2). These findings suggest that economic and convenience-related factors are the primary drivers of plastic consumption.

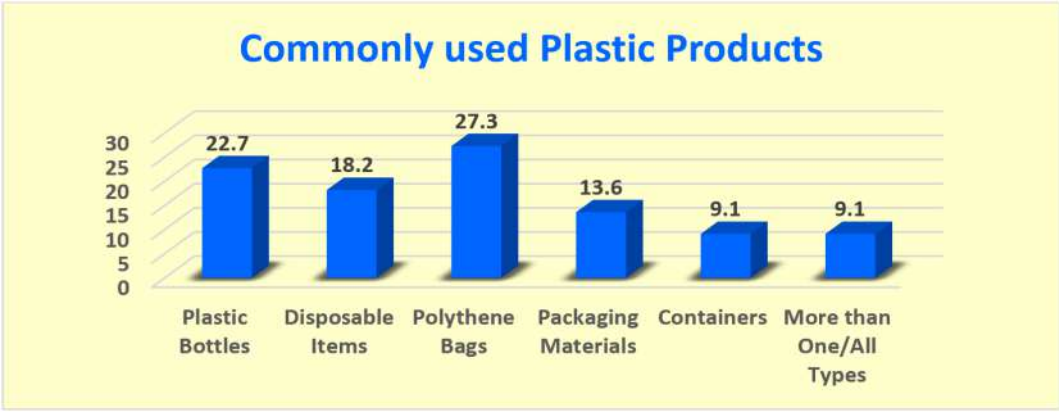


Source: *Field survey (2026), N=110.*

Figure 2 : Reasons for Plastic Use

Commonly Used Plastic Products

Among the plastic products used by respondents, polythene bags were the most commonly used (N=30; 27.3%), followed by plastic bottles (N=25; 22.7%), disposable items (N=20; 18.2%), and packaging materials (N=15; 13.6%) (refer to Figure 3). This highlights the growing problem of single-use plastics. Packaging materials and disposable products such as cups and plates constitute a significant portion of urban waste, placing additional pressure on solid waste management systems.

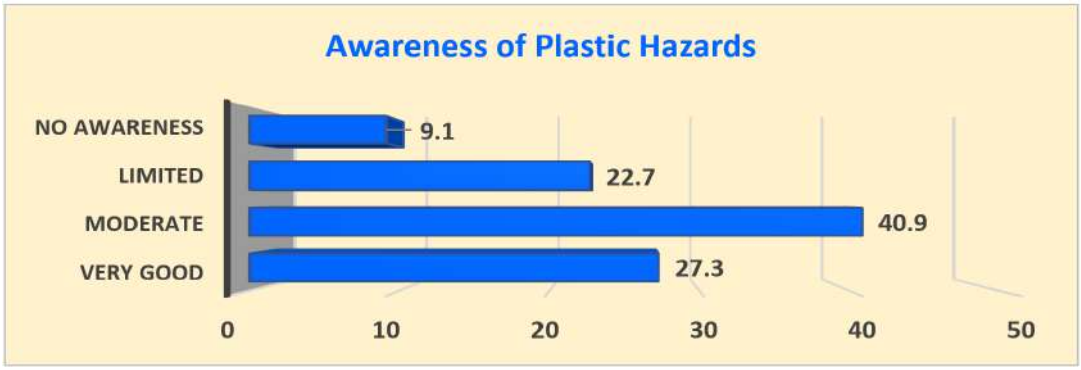


Source: *Field survey (2026), N=110.*

Figure 3 : Commonly used Plastic Products

Level of Awareness of Plastic Pollution

The survey indicates that 45 (40.9%) respondents had a moderate level of awareness of the environmental hazards associated with plastic pollution, while 30 (27.3%) (refer to Figure 4) respondents reported a high level of awareness. Although awareness is relatively widespread, it does not consistently result in environmentally responsible practices.

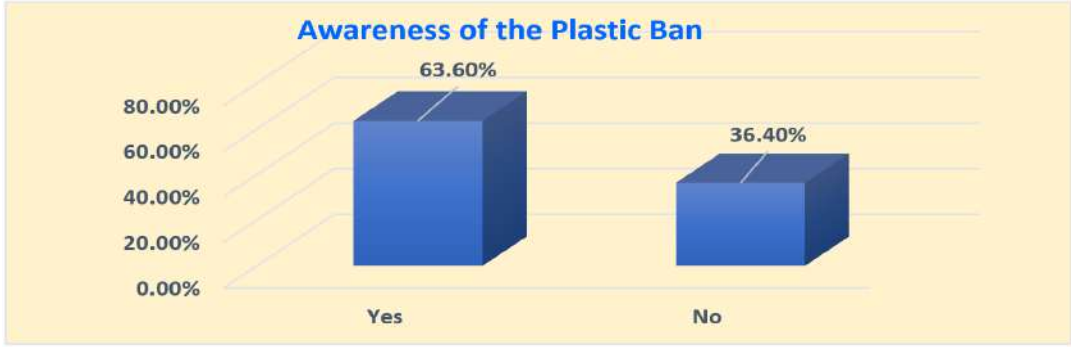


Source: *Field survey (2026), N=110.*

Figure 4 : Awareness of Plastic Hazards

Awareness of the Plastic Ban

Despite high awareness, an awareness–behaviour gap persists, as continued availability of banned items and perceived weak enforcement sustain their use in everyday transactions. Approximately 70 (63.6%) respondents were aware of the plastic ban, whereas 40 (36.4%) were unaware (refer to Figure 5). Although awareness levels are relatively high, plastic consumption remains widespread, indicating a significant awareness–action gap. Knowledge of environmental consequences does not necessarily translate into environmentally responsible behaviour.

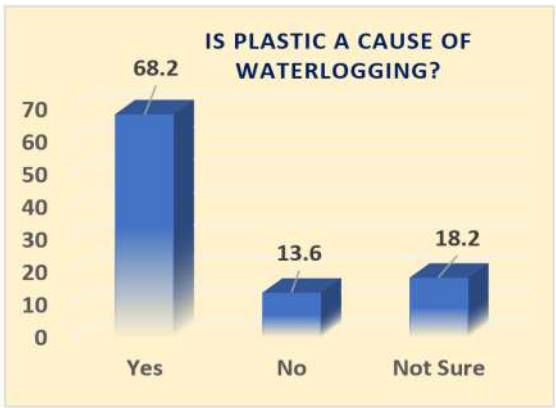


Source: *Field survey (2026), N=110.*

Figure 5 : Awareness of the Plastic Ban

Plastic-Induced Waterlogging

The study reveals that 75 (68.2%) respondents identified plastic waste as a major cause of waterlogging, whereas 15 (13.6%) disagreed and 20 (18.2%) were uncertain (refer to Figure 6). The findings indicate that most respondents recognize the role of plastic waste in clogging drainage systems and increasing the occurrence of urban flooding, although a section of the population still lacks complete awareness of this issue.





Plastic Waste in Water Bodies

Plastic waste, ranging from macro-debris to microplastics, now accumulates ubiquitously in freshwater ecosystems, where it degrades water quality, disrupts food webs, and poses chronic risks to aquatic biodiversity and human health. Figure 7 indicates that 70 (63.6%) respondents had observed plastic waste accumulation in water bodies, whereas 20 (18.2%) had not, and 20 (18.2%) reported observing it occasionally. This highlights the seriousness of water pollution caused by plastic waste. Plastic accumulation in rivers, ponds, and drains degrades water quality and threatens aquatic life.



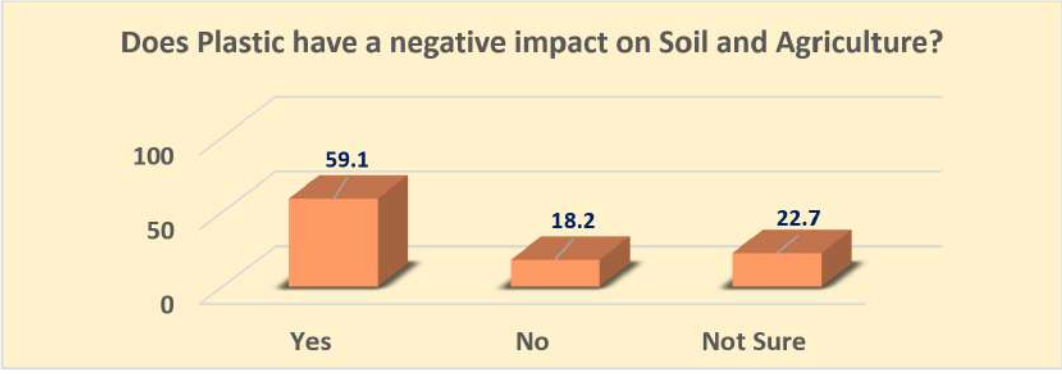


Source: Field survey (2026), N=110. Image Source: Photograph taken by the author (2026).

Figure 7 : Have you observed Plastic Waste in water sources?

Impact on Soil and Agriculture

A majority of respondents, i.e. 65 (59.1%), believed that plastic waste adversely affects soil quality and agricultural crops, whereas 20 (18.2%) disagreed and 25 (22.7%) were uncertain (Figure 8). The accumulation of plastic waste in soil can restrict water infiltration, reduce soil aeration, and gradually lower soil fertility. In addition, the presence of microplastics in agricultural land may enter the food chain, posing long-term environmental and public health concerns.



Source: *Field survey (2026), N=110.*

Figure 8 : Does Plastic have a negative impact on Soil and Agriculture?

Major Environmental Consequences

The survey and field observations identify the following major environmental consequences of plastic pollution:

- Blockage of drainage systems leading to urban flooding.
- Contamination of rivers, ponds, and other water bodies.
- Declining soil quality and reduced agricultural productivity.
- Adverse effects on biodiversity and natural ecosystems.
- Accumulation of plastic waste in open areas, resulting in environmental degradation.

Health Risks Associated with Plastic Pollution

The survey findings indicate that 80 (72.7%) respondents believed that plastic pollution adversely affects human health, whereas 15 (13.6%) disagreed, and an equal proportion (N=15; 13.6%) were uncertain (Figure 9). This suggests a high level of public awareness regarding the health hazards associated with plastic pollution. Toxic gases released from burning plastic, such as dioxins, can cause respiratory diseases, allergies, and other serious health issues.



Data Source: *Field survey (2026), N=110.* ***Image Source:*** *Photograph taken by the author (2026).*

Figure 9 : Does Plastic Pollution increase Health Problems?

Perceived Severity of Smoke from Plastic Burning

The survey findings indicate that 40 (36.4%) respondents rated the smoke generated from the open burning of plastic waste as "Serious," while 25 (22.7%) rated it as "Very Serious." These findings demonstrate that a majority of respondents regard emissions from burning plastic as a significant threat to public health.

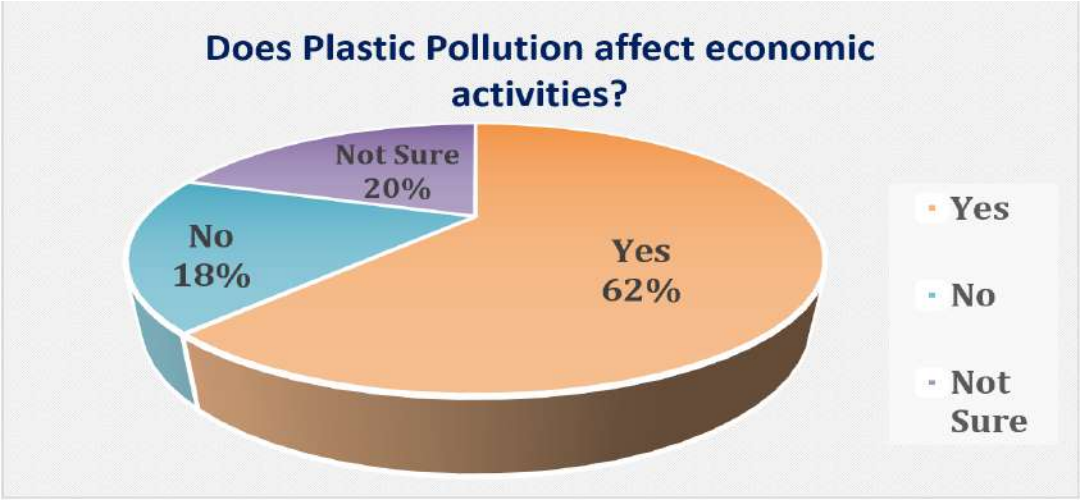
Table 2 : Severity of Smoke from Open Plastic Burning (Scale 1–5)

Scale	Description	Number	Percentage
1	Very Low	5	4.5
2	Low	10	9.1
3	Moderate	30	27.3
4	Serious	40	36.4
5	Very Serious	25	22.7
Total		**110**	**100.0**

Data Source: *Field survey (2026), N=110.*

Economic Impacts

Figure 10 shows that 68 (61.8%) respondents believed that plastic pollution adversely affects economic activities, whereas 20 (18.2%) disagreed and 22 (20.0%) were uncertain. Plastic pollution increases municipal cleaning costs, places additional burdens on healthcare services, and disrupts transportation and commercial activities due to waterlogging.

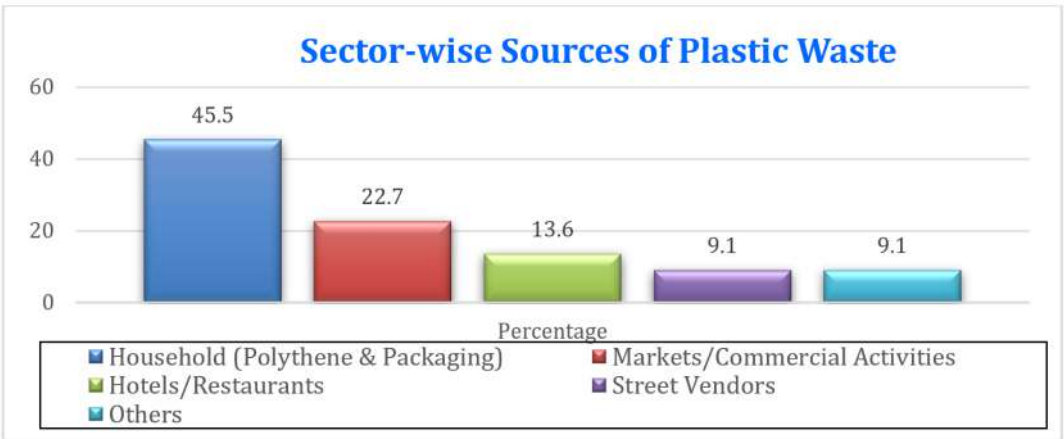


Data Source: *Field survey (2026), N=110.*

Figure 10 : Does Plastic Pollution affect economic activities?

Major Sources and Quantity of Plastic Waste in Patna

Figure 11 shows that households were identified as the largest source of plastic waste by 50 (45.5%) respondents, followed by markets and commercial activities (N=25; 22.7%), hotels and restaurants (N=15; 13.6%), street vendors (N=10; 9.1%), and other sources (N=10; 9.1%). The results indicate that plastic waste generation is widespread across different sectors of society, with household consumption being the dominant contributor.

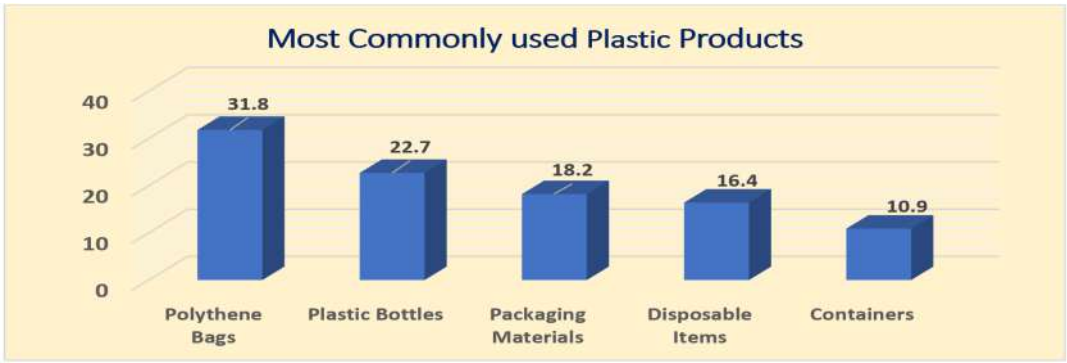


Data Source: *Field survey (2026), N=110.*

Figure 11 : Sources of Plastic Waste Generation in Patna

Most Common Plastic Products

As illustrated in Figure 12, polythene bags were identified as the most widely used plastic products by 35 (31.8%) respondents, followed by plastic bottles (N=25; 22.7%), packaging materials (N=20; 18.2%), disposable items (N=18; 16.4%), and plastic containers (N=12; 10.9%). The predominance of polythene bags reflects the continued dependence on single-use plastics within urban households.



Data Source: *Field survey (2026), N=110.*

Figure 12 : Most Commonly Used Plastic Products

Plastic Waste Disposal Methods

Figure 13 shows that 50 (45.5%) respondents disposed of plastic waste through municipal collection services. However, 30 (27.3%) reported discarding plastic waste in open areas, 20 (18.2%) practiced open burning, and only 10 (9.1%) reported reusing or recycling plastic materials. The findings reveal that environmentally harmful disposal practices remain common, while recycling rates are very low.



Data Source: *Field survey (2026), N=110.*

Figure 13 : Household Plastic Waste Disposal Practices

Estimation of Household Plastic Waste Generation

Half of the respondents (N=55; 50.0%) reported high household plastic waste generation (more than 3 kg/week), while 35 respondents (31.8%) reported moderate generation (1-2 kg/week) and 20 respondents (18.2%) reported low generation (less than 1 kg/week). The results indicate that plastic waste generation is substantial and continuously increasing. Household consumption patterns, extensive use of polythene bags, and inadequate recycling infrastructure are major contributors to the problem.



Data Source: *Field survey (2026), N=110.*

Figure 14 : Estimated Quantity of Plastic Waste at Household Level

Government Measures for Plastic Waste Management and Recycling in Patna

The *Integrated Plastic Waste Management Initiative*, implemented by the United Nations Development Programme (UNDP) in collaboration with Hindustan Coca-Cola Beverages Private Limited (HCCBPL), addresses plastic pollution through systematic collection, segregation, processing, and recycling, promoting resource recovery and a circular economy (UNDP, 2021). The initiative aligns with the Swachh Bharat Mission, Plastic Waste Management Rules, 2016, and Sustainable Development Goals (SDGs), while supporting the social inclusion and livelihood improvement of waste pickers (Safai Sathis) through their integration into formal waste management systems (UNDP India, n.d.; Patna Municipal Corporation, 2026).

To support these objectives, *Plastic Material Recovery Facility (PMRF)/Swachhta Kendras* have been established to strengthen plastic waste management in Patna through collection, segregation, processing, and recycling. These centres receive waste from municipal sources, bulk waste generators, and waste pickers, including low-grade plastics, multilayered plastics, and thin plastic carry bags. Each facility processes approximately 4–5 tonnes of plastic waste daily through sorting, shredding, and baling before transferring the recovered materials to authorized recyclers (Patna Municipal Corporation, 2026; UNDP, n.d.).

Plastic waste is classified into seven categories: PET, PE, HDPE, LDPE, PVC, PS, and PP. The recovered materials are recycled or reused in road construction, plastic lumber manufacturing, Refuse-Derived Fuel (RDF) production, and cement industries. By promoting coordination among municipal authorities, communities, recyclers, and informal waste workers, PMRFs improve resource recovery and recycling efficiency, support waste pickers' livelihoods, and reduce plastic pollution through a circular economy approach. Suitable infrastructure and digital monitoring can further strengthen their effectiveness (Patna Municipal Corporation, 2026; CPCB, 2019).

What is needed for effective Plastic Waste Management in Patna

Despite government regulations and municipal initiatives, plastic pollution remains a major challenge in Patna due to poor waste segregation, irregular collection, limited recycling facilities, weak enforcement, low public awareness, and rising plastic consumption. Rapid urbanization and inadequate stakeholder coordination further hinder effective management. Lessons from Sikkim's plastic restrictions, Indore's door-to-door collection and source segregation, and San Francisco's restrictions on selected single-use plastics offer useful strategies for Patna.

An integrated strategy should prioritise source segregation, ward-level plastic collection and recovery centres, improved recycling, responsible disposal, and the use of cloth and jute bags and reusable alternatives. Regular cleaning of drains and the Ganga riverfront should complement preventive measures against plastic littering. Effective implementation requires coordinated participation by Patna Municipal Corporation, households, educational institutions, market associations, vendors, resident associations, and waste pickers. Stronger enforcement, ward-level monitoring, public awareness campaigns, incentives, and periodic progress reports can improve accountability, reduce plastic waste accumulation and drain blockages, and support a cleaner and more sustainable Patna.

Conclusion

Plastic waste has emerged as a significant environmental and socio-economic challenge in the Patna Municipal Corporation Area of Bihar. Rapid urbanisation, changing consumption

patterns, and the widespread use of single-use plastics have increased pressure on the city's waste management systems. Improper disposal, inadequate segregation, and limited recycling facilities contribute to land and water pollution, drainage congestion, and urban flooding. Beyond environmental degradation, plastic waste management also affects public health, municipal expenditure, commercial activities, and the livelihoods of waste workers. Thus, plastic pollution represents an interconnected urban sustainability challenge rather than merely a waste disposal problem.

The study highlights the need to strengthen municipal waste collection, source segregation, recycling infrastructure, and enforcement of existing regulations. Promoting reusable alternatives, encouraging responsible consumption, and adopting the principles of Reduce, Reuse, and Recycle (3Rs) are essential for reducing plastic waste at its source. Public awareness must be supported by practical opportunities for responsible disposal and greater coordination among Patna Municipal Corporation, businesses, educational institutions, communities, and waste pickers. Integrating informal waste workers into formal waste management systems can further support material recovery and sustainable livelihoods.

Ultimately, sustainable plastic waste management in Patna requires an integrated approach that addresses both environmental protection and socio-economic well-being. Effective policies must move beyond regulatory provisions to ensure implementation, institutional accountability, and meaningful public participation. By treating plastic waste as a resource for recovery rather than an unwanted residue, Patna can reduce environmental pressures, protect the Ganga riverfront, improve urban living conditions, and advance towards a cleaner, more inclusive, and sustainable future.

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STUDY OF LANDFORMS OF GRANITIC REGION : A CASE STUDY OF JOYCHANDI PAHAR, PURULIA DISTRICT, WEST BENGAL

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ABSTRACT

Inselbergs are denudational remnants of uplands formed by deep weathering and stable tectonic conditions. They are rocky outcrops forming isolated hills or groups of hills. Joychandi Pahar, which is an eastern extension of the Chhotanagpur Plateau, is distinguished by its unique geophysical features and sub-tropical climate. The Purulia district, situated in West Bengal, faces considerable droughts owing to its location on the eastern fringe of the Plateau. This district experiences a sub-tropical climate characterized by high evaporation rates and low precipitation, with annual rainfall ranging from 1100 to 1420 mm. The region is recognized for its hot summers and cold winters, with summer temperatures soaring up to 52°C and winter temperatures dropping to approximately 7°C. It analyzes geomorphological processes like weathering, erosion, and tectonics. Data collection includes photographs, field notes, GPS coordinates, and secondary data such as elevation models, topographic maps, satellite imagery, and roughness maps.All features, including Sugarloaf (288 m), Bornhardt (272 m), Tors (285 m), Castle copies (294 m), Nubbin (215 m), Mesa (255 m), and Butte (222 m), ascend above this level, exhibiting different levels of residual height. The tallest feature, Castle copies (294 m), is approximately 99 m above the pond level, implying significant resistance to erosion. In contrast, the lowest feature, Nubbin (215 m), only rises 20 m, suggesting a higher degree of weathering or advanced denudation.

Keywords: *Inselbergs, Chhotanagpur Plateau, Bornhardt, Weathering, DEM*

Introduction

Inselbergs are often interpreted as denudational remnants of formerly more extensive uplands which have formed as a result of deep weathering and stable tectonic conditions followed by tectonic uplift(Römer, 2005). Inselbergs are rocky outcrops standing out from surrounding plains, shaping more or less isolated hills or groups of hills. Environmental conditions on inselbergs can be extremely harsh for plant life(Mignaut et al., 2010). “Inselberg” is a German word which may be directly translated to mean “island-mountain”. In its classical, conventional and most-widely used sense, it refers to an isolated hill standing on or surrounded by a relatively level land(Umeuduji, 2017).Weathering processes contribute significantly to

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the distinctive geomorphology found in tropical and subtropical regions. Common features of tropical weathering include resilient landforms like inselbergs, intense solution processes such as silica karst, and deep weathering profiles that yield end-stage products like laterite and kaolin(Pope, 2013b). A warm climate translates to sustained high temperatures, influencing chemical reaction rates (Pope, 2013b). Hillslopes exhibit linear erosional scours reaching depths of up to 20 meters, originating beneath the hillcrest and concluding above a significant basal break of slope, where they gradually become shallower and transition into small fans (Cawthorn et al., 2015). Measuring denudation rates in orogenic systems is essential for comprehending the interaction between tectonics and climate in the formation of topography (Nóbile et al., 2017).

The weathering state and weatherability of rocks are crucial for engineering geology projects and their application in construction. The physical and chemical processes resulting from weathering can be indicated by variations in index properties, including dry density, void ratio, clay content, and seismic velocity (Ceryan, 2012). Domes and tors, which stand as monolithic structures and attain heights of several hundred meters, are characteristic features of granitic landscapes. Additionally, granitic landscapes are adorned with castellated domes and boulders dispersed throughout, while tors are spheroidally eroded boulders that are firmly anchored in the bedrock (Sayan, 2016). Inselbergs are rocky formations typically made up of a granitic or gneiss matrix, characterized by their monolithic proportions and significant levels of biodiversity and endemism across various climatic regions (da Silveira et al., 2022).

Study Area

Joychandi Pahar is located latitude between23°31`44N - 23°31`13N and longitude between 86°40`15E- 86°39'22E. Perimeter- 4.03 km and Area- 49.8 ha or 498,000 m² or 0.498 km². Regionally, this area represents an eastern extension of the peninsular landmass known as the Chhotanagpur Plateau. It has experienced several phases of peneplanation and uplift, which have culminated in a physiography characterized by superposed plateaus featuring various planation surfaces(Nag, 2005). The Purulia district, situated in West Bengal, frequently experiences significant droughts as a result of its position on the eastern edge of the Chotanagpur Plateau, characterized by unique geophysical attributes (Mandal et al., 2025). The Purulia district has a sub-tropical climate marked by elevated evaporation rates and minimal precipitation, with annual rainfall averaging between 1100 and 1420 mm and district is known for its intensely hot summers and extremely cold winters. During the summer, temperatures can reach as high as approximately 52 °C, whereas winter averages are around 7°C (Mandal et al., 2025). The Mesoarchaean nucleus of the Singhbhum Granite Complex (SBG) within the Eastern Indian Craton is bordered to the north by highly deformed and metamorphosed Palaeoproterozoic volcano-sedimentary formations arranged in an E-W

trending arcuate belt, referred to as NSFB (Dwivedi et al., 2011). The Purulia district exhibits significant lithological diversity. The CGC is primarily composed of various forms of granite gneisses. The predominant mineral composition in this region includes phyllite and mica schists that are part of the Singbhum orogenic belt (Nayak et al., 2020). The district contains a variety of rock formations from different geological periods, including the Chhotanagpur gneissic complex, the meta-sedimentary rocks of the Singhbhum group, intrusive granites, volcanic rocks from the Dalma group, as well as sediments from the Gondwana and Quaternary periods (Geological Survey of India, 2001)(Das et al., 2019).

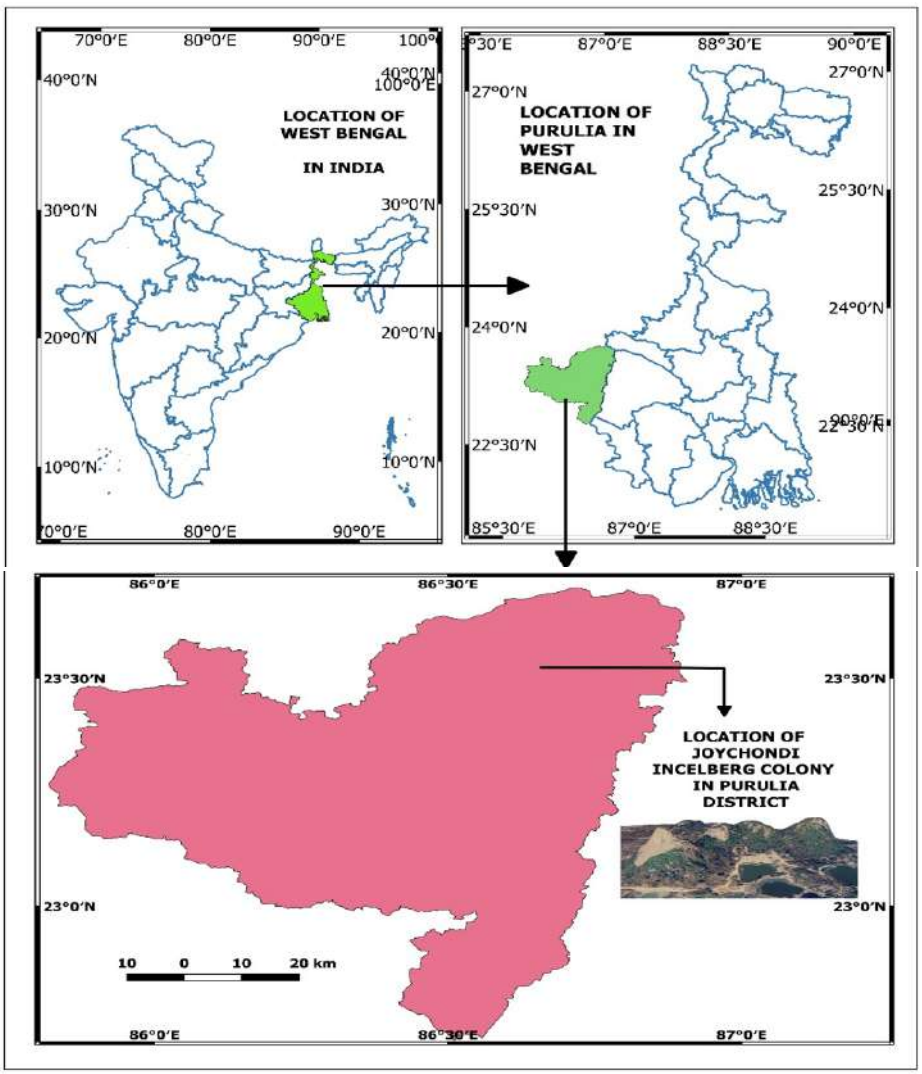


Figure 1 : Location Map of Study Area

Methodology: At the petrographic level, various field runs facilitated an examination of distinct petrographic types ranging from outcrop scale to sample scale. Following the description of plutons, samples of different rocks were gathered, described, and labeled. A Garmin GPS device was utilized to pinpoint various samples, which were then marked with a permanent marker and placed in suitable bags. The selection of geomorphosites was conducted based on criteria emphasized by certain researchers (Zangmo Tefogoum et al., 2022). We have collected samples from bald-headed domes and tors and flat-topped peneplaned exposures (Roy et al., 2021). Field work The field survey was based on a detailed observation and description of micro-morphological features and physical nature of the profiles. Some geomorphological and geological techniques were integrated to analyze and understand the weathering processes operating in three sample sites in the study region (Dolui et al., 2016).

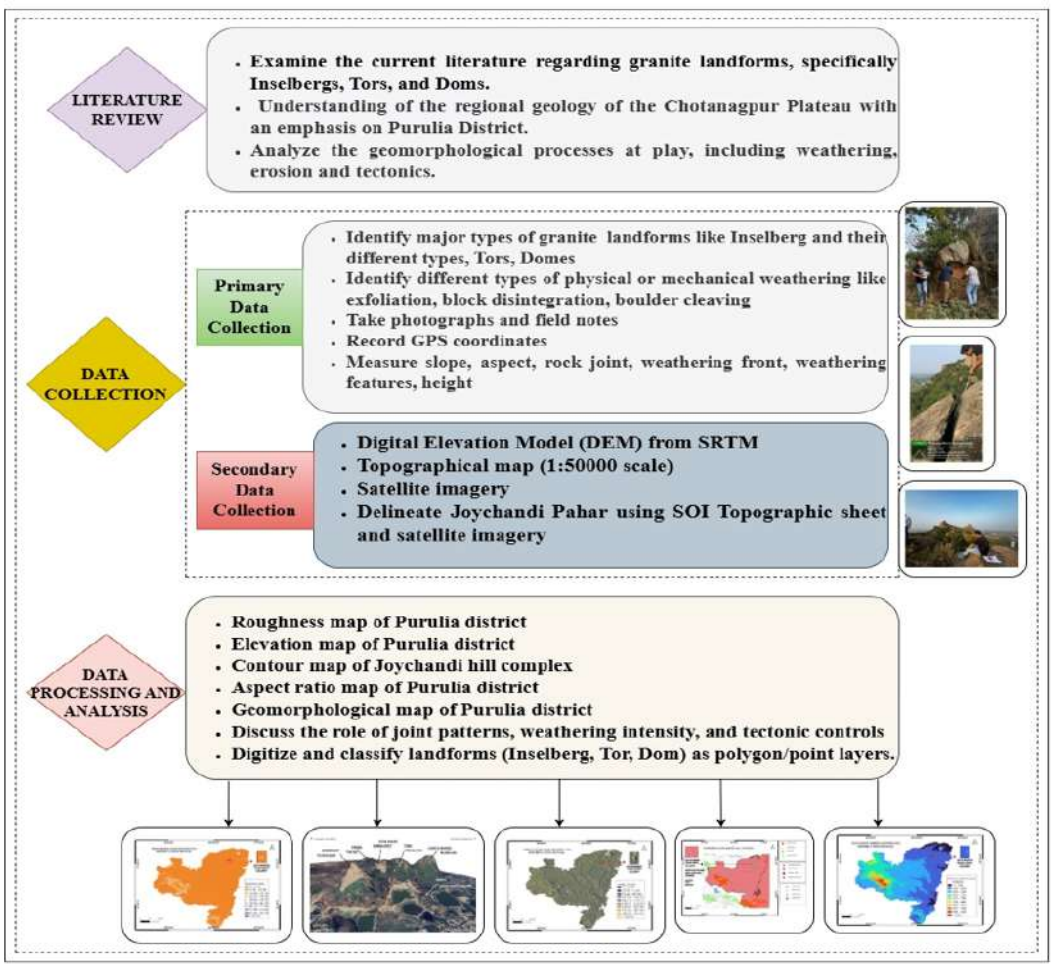


Figure 2 : Methodology flowchart of the study

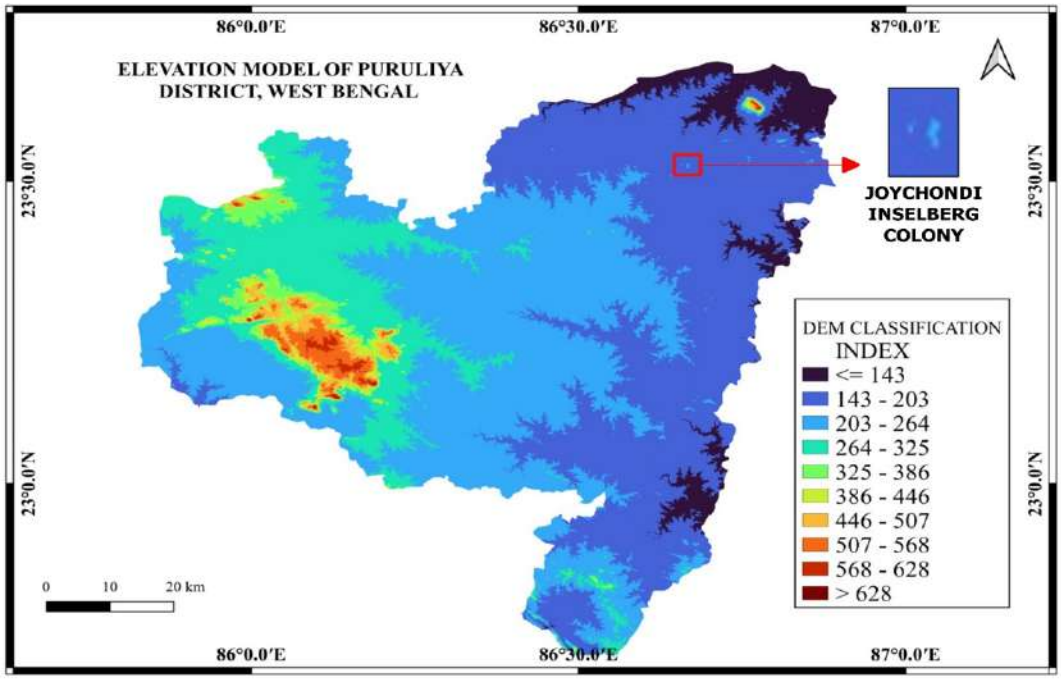


Figure 3 : Digital Elevation Model (DEM) of Purulia District

Major Findings

The Digital Elevation Model (DEM): The Digital Elevation Model (DEM), due to advancements in computer and satellite technology, has contributed significantly to the accuracy of most hydrological models (Tran et al., 2023). Digital Elevation Model (DEM) is a generic term for digital topographic and/or bathymetric data, in all its forms. There is some confusion in the use of the terms DEM (Digital Elevation Model), DTM (Digital Terrain Model), and DSM (Digital Surface Model) (Mesa-Mingorance & Ariza-López, 2020). To obtain the DEM, varieties of the satellite images are available at different spectral, radiometric, spatial and temporal resolutions. An advantage of the DEM development using satellite images is that it reduces collecting the DEM for larger areas with respect to time, costs, and effort, and updated information (Lakshmi & Yarrakula, 2018).The Joychondi hill complex rises prominently above the surrounding terrain, with a highest contour of 270 m and a slope of 16.5°, indicating moderately steep relief. The surrounding area, ranging 143–203 m, forms gentler plains around the hill. The DEM isopleth shading clearly highlights this elevation gradient, showing steep slopes near the hill core and smooth transitions toward the periphery. This pattern reflects the inselberg nature of Joychondi, where resistant granite protrudes above eroded land, influencing local runoff, drainage, and micro-relief variations (Figure 3).

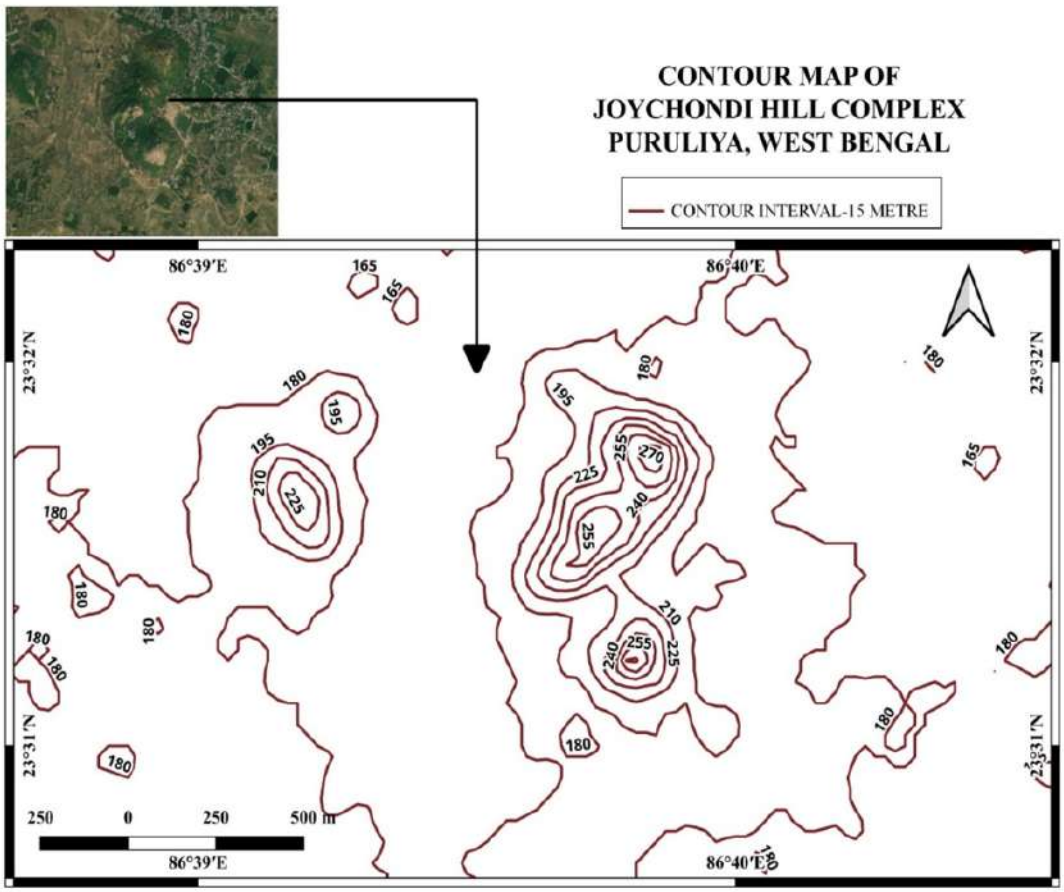


Figure 4 : Contour map of Joychandi hill complex, Purulia District

A contour line joins all the points of subsurface strata height/elevation of equal value on the map. The base level contour line on the map is sea level. A numbers of contour lines are drawn on the map, each line showing a particular height. Any point on the contour line is above sea level. The difference in elevation between two adjacent contour lines is called the 'contour interval (Abdul Quddus, n.d.).The map has a contour interval of 15m, with the inselberg complex rising from its base at about 180 m above sea level and peaking at 270 m, thus rising 90m above the surrounding landscape. It represents a pediment with granitic inselberg structure, which are prominently visible rising sharply with a steep slope of 30% or 16.5^0. The complex is aligned in North-South direction, perpendicular to the great circle of Tropic of Cancer which passes in its vicinity. The contour map of the Joychandi Hills Complex of Purulia district is illustrated in Figure 4 below. This contour map features contour intervals of 15 m with an altitude ranging from the base, where the height above sea level is about 180 m, to

270 m. It therefore stands 90 m above its surroundings. This is a sediment of granitic composition. The orientation of the complex is north to south with respect to the great circle of the Tropic of Cancer that passes through it.

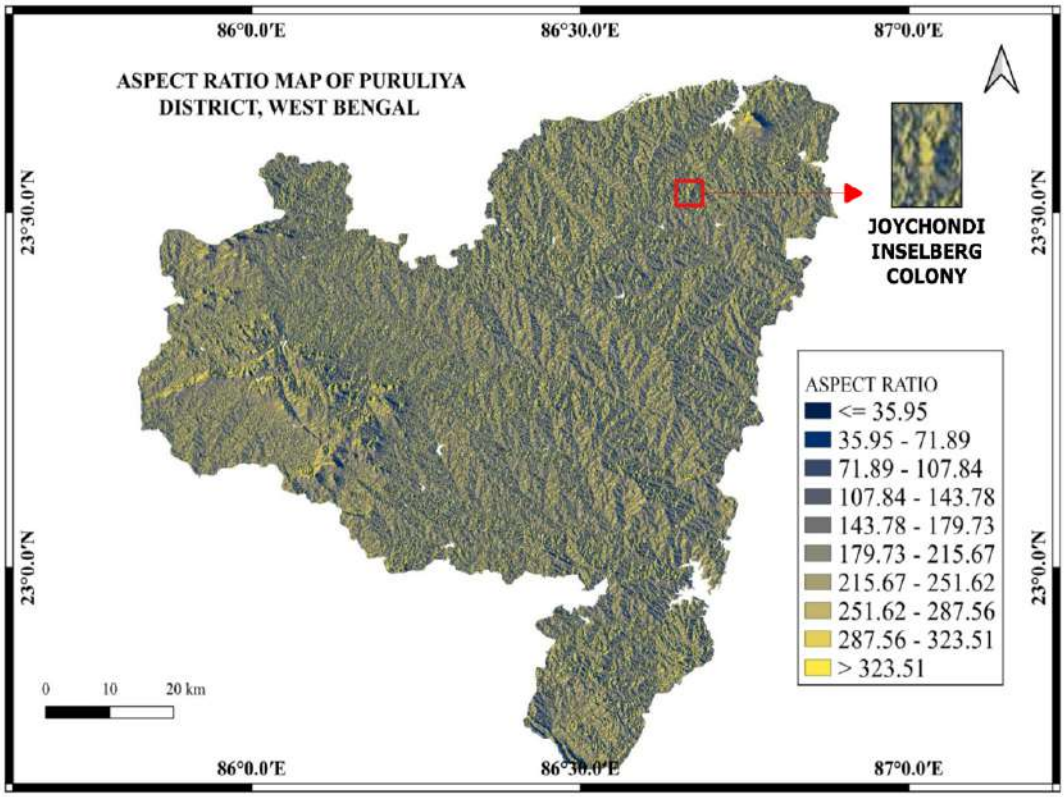


Figure 5 : Aspect ratio map of Purulia District

The aspect ratio values (100–280) for Joychondi inselberg complex , within an approximately 1 km area show that the hills are not round but stretched or elongated in shape. This shape suggests that the hills are controlled by the rock structure below.Because of this structural influence, the slopes of the hills are uneven that is one flank is steeper (scarp face) and the other side is gentler (dip slope). Such landforms are common in areas of old, eroded plateaus where rocks have been shaped by both structure and erosion over a long time (Figure 5).

A geomorphological map is important because it helps understand landform evolution, surface processes, and resource management; according to NRSC Bhuvan and CGWB, Joychondi is classified as a denudational and aeolian geomorphological feature, reflecting both erosion-driven and wind-influenced landform processes.

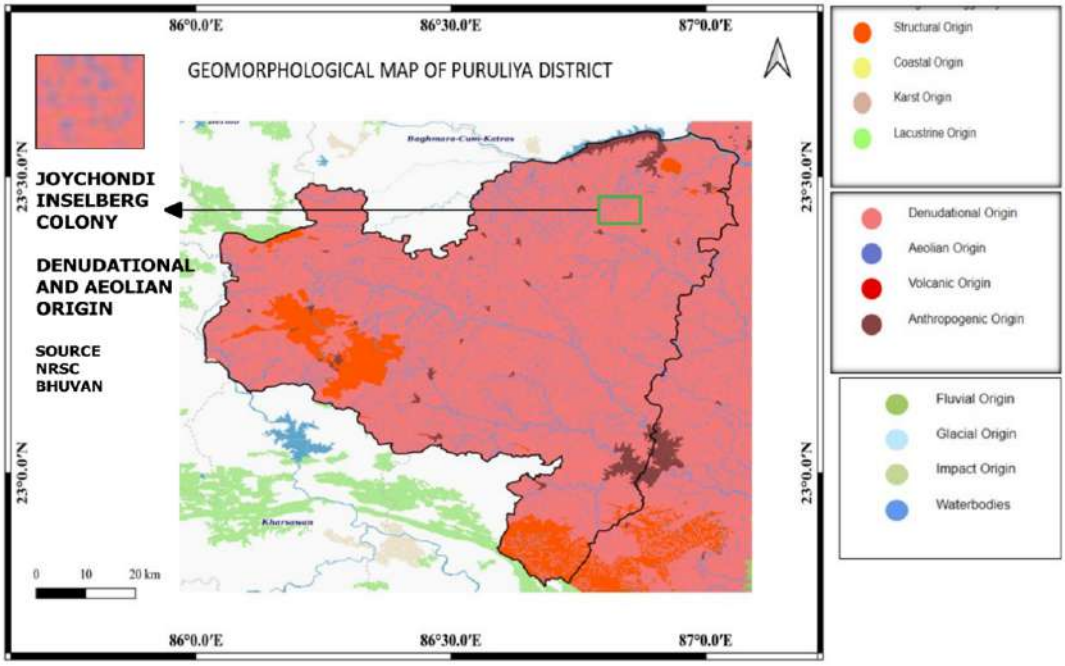


Figure 6 : Geomorphological map of Purulia District

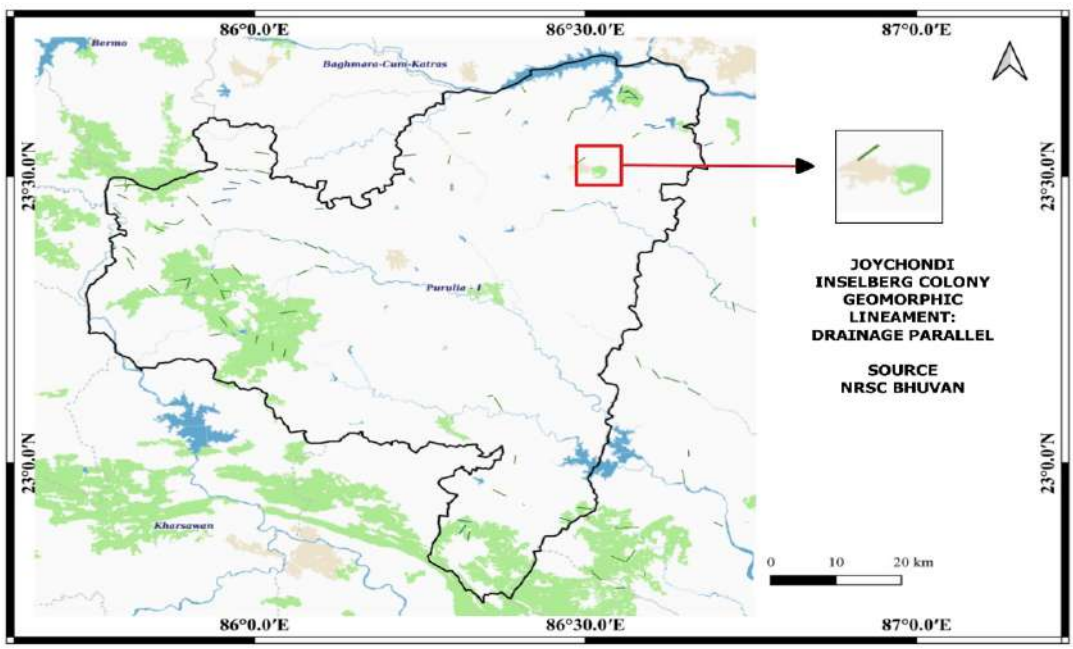


Figure 7 : Lineament map of Purulia district

Lineament: The lineaments are patterns characterized by linear or curvilinear features and are essential, especially in geomorphic and structural analysis. Lineaments such as joints and fractures, which typically arise from tectonic stress and strain, offer significant insights into surface features. They also facilitate the infiltration of surface runoff into the subsurface and contribute to the movement and storage of groundwater (Nag, 2005). Lineaments are flat formations on the earth's surface that indicate an underlying geological structure. These may include fractures, cleavages, faults, and other surfaces of discontinuity, which are characterized by rectilinear or slightly curvilinear linear features, as observed through satellite imagery (Bhattacharya et al., 2021). Lineament density was determined by the count of intersections among lineaments, the total number of lineaments, and the cumulative length of lineaments within each grid (with a grid size of 1km × 1km)(Haeruddin & Irawan, 2020). The density map illustrating the structure of lineaments offers insights into the concentration of lineaments per unit area. The lineament density maps are generated using optical and radar data to examine the distribution of the lineaments(Sichugova L.V et al., 2020). Lineament density is elevated (>0.3 km/km2) in the western and central regions, while it is moderate (0.15–0.3 km/km2) in certain areas across the district (Das et al., 2019). The lineaments are features that can be either linear or curvilinear, and they are essential, especially in the analysis of geomorphology and structure. Photo-lineaments typically indicate the surface manifestations of fractures in bedrock, which are projected, to varying degrees, vertically upward to the erosion surface through different mechanisms (Acharya, 2013).(Fig-8)

Granite: Granite magmas are intruded as dense fluids through the lithosphere stopping when the magma cooling and loss of volatiles increase their viscosity over the flow threshold (Romaní, 2008). The Purulia district in West Bengal is primarily characterized by Proterozoic hard granite gneiss formations, along with softer phyllite and mica schist from the Singhbhum group, which is a component of the Chotanagpur plateau (Dolui et al., 2016). PENINSULAR SHIELD From a geological perspective, the northern Singbhum craton constitutes a segment of the Chhota Nagpur gneissic complex (CGC), which fundamentally represents the eastern Indian peninsular shield (Dunn, 1942). This area is primarily composed of Pre-Cambrian metamorphic rocks, with Gondwana sediments located in the northeastern part (Bera et al., 2021). Bornhardts are consistently linked to sheet structure; however, the question of whether these arcuate fractures lead to the domed shape or are a result of it remains a topic of debate. Over the last 150 years, two completely opposing perspectives regarding the connection between the land surface's form and the geometry of sheeting joints have developed (Ramon Vidal-Romani & Twidale, 2005). The arfvedsonite granite pluton is situated along the North Purulia Shear Zone of the CGC, which is part of the ENE-WSW oriented Satpura Orogenic Belt that extends for 1500 km. This belt developed during the Grenvillian period approximately 900–1000 million years ago. The CGC encompasses an area of roughly 100,000 square kilometers within the eastern Indian shield(Goswami et al., 2024).

Four dome-shaped formations containing a continuous intrusive granitic (GRm) body from the late Proterozoic era are prominently located over the North Puruliya Shear Zone (NPSZ), referred to as Jaichandi Hill. This hill is a renowned religious site for Hindus, situated near the town of Raghunathpur in the Puruliya district. From a geological perspective, this massive porphyritic granitoid batholith is created through the amalgamation of mantle-derived mafic magma and crustal melts in settings characterized by continent-continent collisions (A. Ghosh et al., 2021). The basin margin zone, defined by the shallow depths of Archean and Gondwana rocks, along with the western shelf zone, which is characterized by a gentle gradient slope of the basement (specifically the Rajmahal Basalt Traps) extending towards the east and southeast, exhibits the characteristics of a tropical strong wet-dry morphogenetic landform, namely lateritic terrain interspersed with Paleogene sediments (S. Ghosh et al., 2015). The Purulia district is located in the eastern section of the Chhota Nagpur plateau. Geologically, this region holds considerable importance. It is an essential component of India's peninsular shield (Sarkar, 2025). Various approaches to classify granite landscapes can be found in literature ,but it seems that the proposal of the present author is the most elaborate and accounts for the global diversity. Accordingly, the following types of relief are recognized: Plains; Plains with residual hills; Multi-convex topography; Multi-concave topography; Plateaus; Dissected plateaus; Undulating hilly lands; Joint-valley topography; All-slopes relief; Stepped relief (Migoń, 2021)

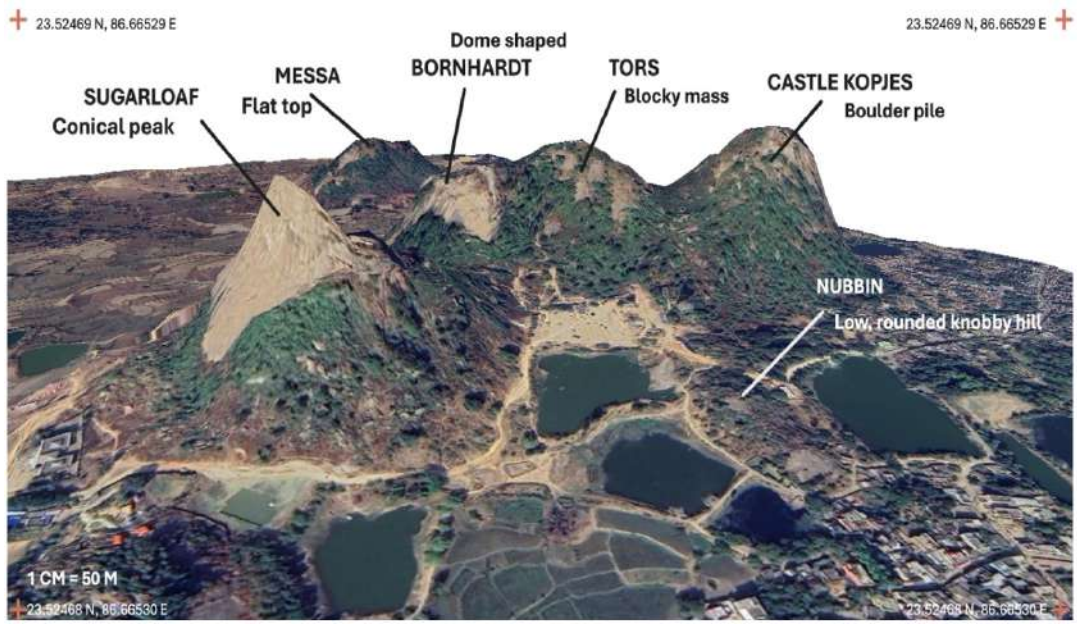


Figure 8 : Different types of geomorphic features of Joychandi hill complex

The elevations of the various landforms at Joychondi Hill Complex above mean sea level (MSL) indicate that the surrounding pond surface lies at 195 m, forming the local base level of erosion. All the features such as Sugarloaf (288 m), Bornhardt (272 m), Tors (285 m), Castle copies (294 m), Nubbin (215 m), Mesa (255 m), and Butte (222 m)—rise above this level, showing varying degrees of residual height. The highest feature, Castle copies (294 m), stands about 99 m above the pond level, suggesting strong resistance to erosion, while the lowest, Nubbin (215 m), rises only 20 m, indicating greater weathering or advanced denudation. Overall, the elevation differences reflect a landscape of uneven denudation, where resistant rock masses stand as remaining isolated residual hills above a gently lowered erosion surface.

Many tropical basement terrains are characterized by undulating plains dotted by inselbergs of various shapes and sizes (Afolabi et al., 2018).

Mesa: An inselberg typically derived from horizontally bedded rock (often but not necessarily of sedimentary origin) with a hard resistant top layer above softer, more rapidly eroding, rock resulting in the formation of outcrops with a relatively flat summit and steep sides. Also sometimes referred to as a table mountain (Vanschoenwinkel et al., 2025a)

Tor: Small residual rock mass usually <10 m height , isolated by freefaces on all sides (Vanschoenwinkel et al., 2025a)

Nubbin: Small conical hills composed of large blocks and boulders

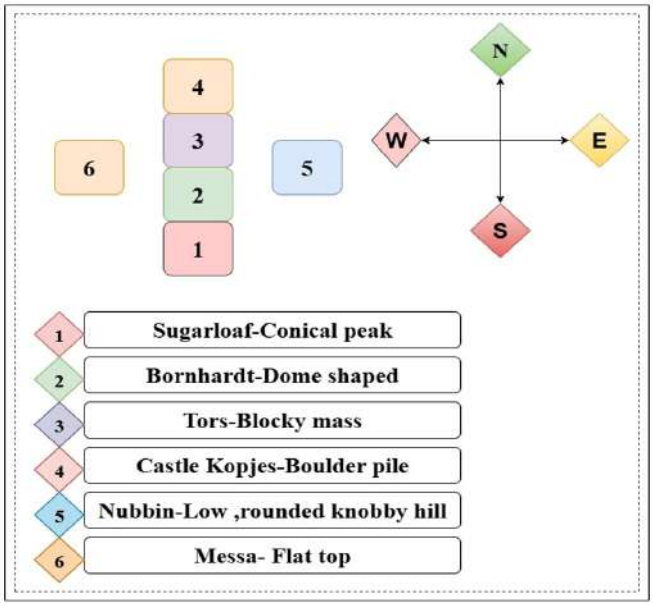


Figure 9 : Different types of geomorphic features located

Inselbergs are ancient landscape features, likely colonized since the Cenozoic period,providing refuges for xerophytic and hydrophilic species during periods of climatic change (Cordeiro et al., 2025).

Inselbergs (from German Insel = island and Berg = mountain) (Vanschoenwinkel et al., 2025).

Domed Inselbergs (Bornhardts): These formations are typically composed of bare rock and feature steep sides. They can be found not only in a domed shape but also as elongated whale-backs or ridges. Domed inselbergs differ in size and may appear either in isolation or in clusters(Musarurwa, n.d.). The interaction of internal and external geological processes has contributed to transform the latter into inselbergs, whose geotouristic values are yet to be studied (Zangmo Tefogoum et al., 2022). Etymologically, the term "bornhardt" has been commonly adopted by geomorphologists obviously as a mark of credit to W. Bornhardt due to his pioneering and extensive study of this class of hills (Bornhardt, 1900). King (1948) noted that since after the description of these granite-gneiss inselbergs by Bornhardt himself, explanations of their form and occurrence have attracted many geomorphologists, Characteristically, bornhardts are monolithic, domed inselbergs which greatly vary in size, with some being up to 300m in height (Umeuduji, 2017). A dome-shaped inselberg named after the German explorer Wilhelm Bornhardt (Willis, 1934), typically composed of igneous or metamorphic rocks such as granites and gneiss. The term "sugarloaf", in reference to the famous Sugarloaf Mountain in Brazil, is considered a synonym (Vanschoenwinkel et al., 2025a) An isolated, steep-sided, dome-shaped hill that rises sharply from the surrounding etch plain. It features a distinct convex summit. This hill can attain a height of 300 meters and exhibits relatively few joints, apart from some curvilinear sheet joints and radial joints that occur as a result of pressure release.

Dom shaped: Dome-shaped formations are linked to igneous and metamorphic substrates (such as granite and gneiss), typically resulting in rounded mountains that often feature boulders. In this paper, the term 'inselberg' is used to describe both categories of landforms (Burke, 2003). Domed Inselbergs (Bornhardts) are typically composed of exposed rock and feature steep inclines.

Castellated Inselbergs (Castle Koppies): Castle koppies, also known as Kopjes, are formations of crystalline boulders that resemble castles. The word koppie is an Afrikaans term that translates to hill. Castle koppies are characteristic of savanna areas, although they bear resemblance to tors found in temperate climates(Musarurwa, n.d.).

Causes of formation Tor and domes:

Differential weathering and erosion: resilient rock formations such as tors and inselbergs persist, while the surrounding softer or more fractured rock is worn away. Subsurface

(chemical) weathering occurs along joints, leading to the formation of corestones that eventually become exposed as tors when the overlying material is eroded away.

Formation of domes: potential causes include uplift, magma intrusion, or structural doming; subsequent erosion reveals the dome's underlying structure.

Climatic influences: Arid versus humid conditions, as well as freeze-thaw cycles, impact the processes of weathering. In Purulia, the climate leans towards tropical/subtropical, resulting in a predominance of chemical weathering along joints, coupled with monsoonal rainfall. The presence of vegetation can either shield or enhance weathering in various locations.

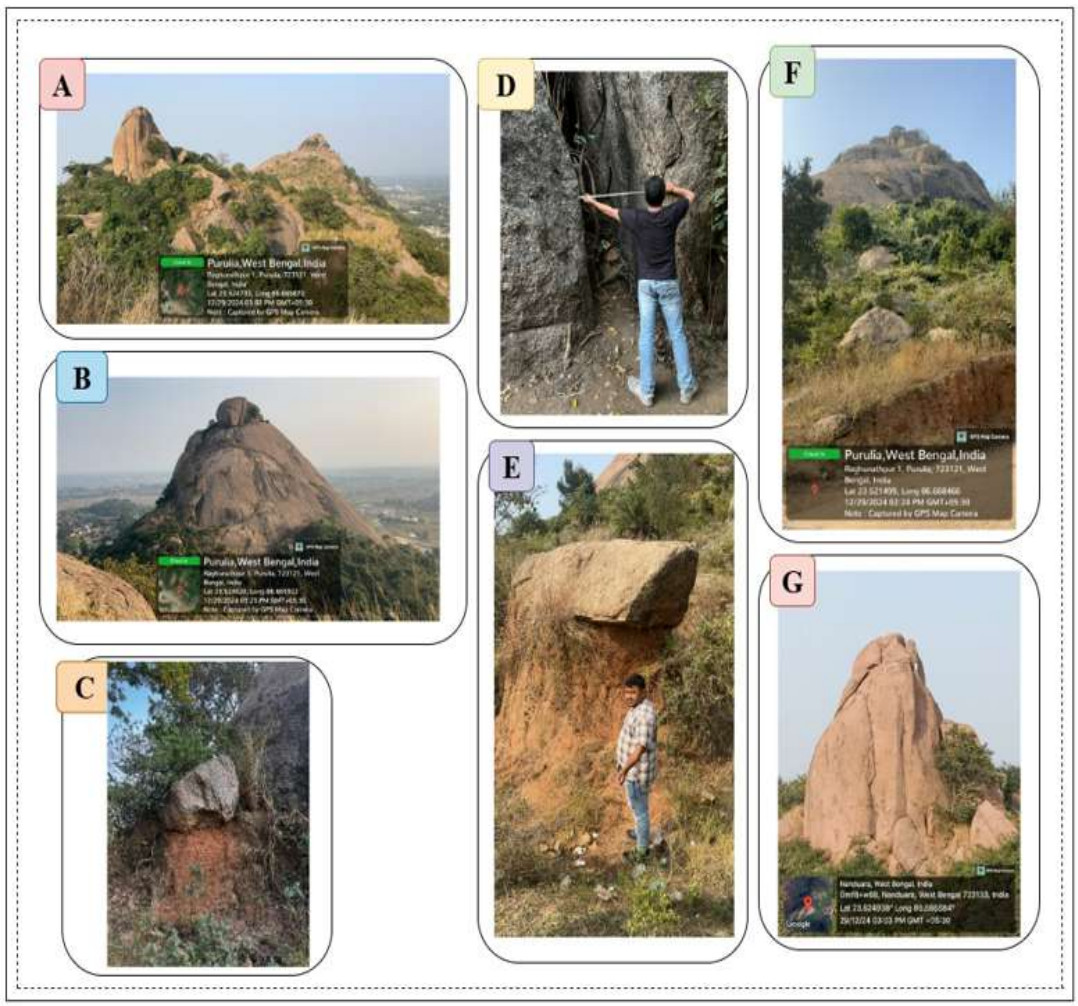


Figure 10 : Castellated Inselbergs (Castle Koppies)

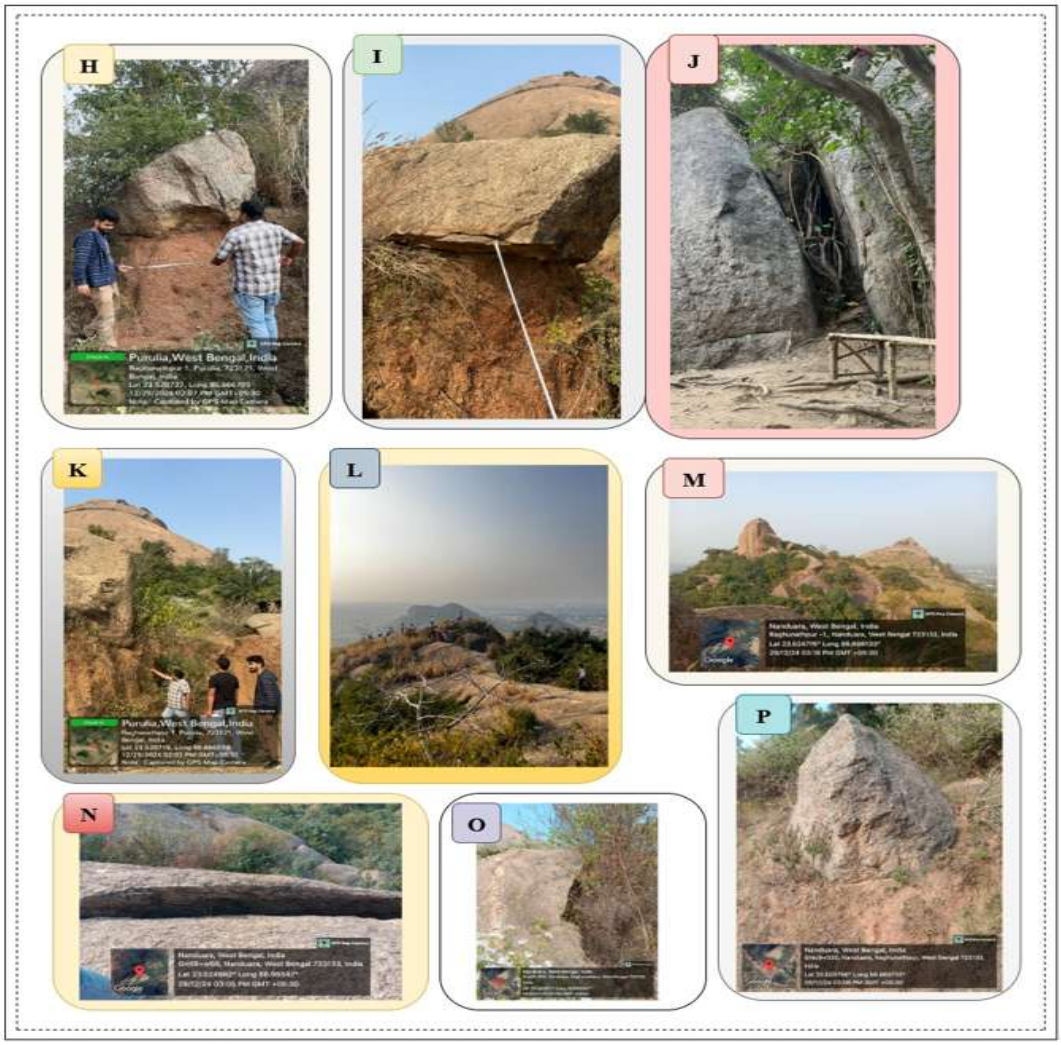


Figure 11 : Geomorphic features location in the study area

Summary

In this work, the Joychandi Pahar inselberg complex has been studied in great detail using the geomorphological approach. Some of the important conclusions drawn from this study include:

A. Diversity of Landforms: There are many different landforms of granite formation found in the area of this complex (0.498 km²). These are Sugarloaf (288 m), Bornhardt (272 m), Tors (285 m), Castle Kopjes (294 m), Nubbin (215 m), Mesa (255 m), and Butte (222 m).

B. Elevation and Relief: The elevation range of this inselberg complex lies between 180 m and 270 m with a residual relief of 90 m. The local base level of erosion here is 195 m (pond surface).

C. Structural Influence: The orientation of this complex in the north-south direction (perpendicular to the Tropic of Cancer) and the aspect ratio of 100–280 clearly show the structural control.

D. Differential Weathering: The differences in height for the different geomorphologic structures are attributed to differential weathering and erosion, where the resistant rock masses form higher structures while the weathered rock masses form lower structures (Castle Kopjes, 294 m and Nubbin, 215 m).

E. Weathering Processes: Field observations of the weathering fronts and rock cracks give physical evidence of chemical weathering within the joint and fracture zones. This is shown by the weathering front dimension (6.8 ft × 36.8 ft) and rock crack dimension (20.1 ft × 2.2 ft × 24.1 ft).

F. Lithology and Tectonics: The presence of the drainage-parallel lineaments from the lineament analysis indicates that the structure influences the drainage patterns, while the granite gneisses of the Chhotanagpur Gneissic Complex provide the lithology.

G. Geomorphological Classification: The Joychandi area can be classified as a denudation and aeolian geomorphological structure.

Conclusion

The landforms of the Joychandi Pahar inselberg complex form a classic case of the evolution of granite landforms in a tropical/subtropical environment in the eastern extension of the Chhotanagpur plateau region. It is shown in this paper that the formation of this diverse set of landforms has been a function of the interaction of various controlling factors such as lithology, structure, and climate, which operate on a geological time scale under a stable tectonic regime.The important findings of this study are-The differential weathering and erosion form the dominant processes for creating the inselberg complex. The resistant nature of the granitic rocks resisted the erosion, whereas softer rocks were removed.The role of structure can be seen in the orientation and shape of the landforms, which have an alignment in the north-south direction with a high aspect ratio. Climate is an important factor influencing the weathering process, as the tropical/subtropical climate of Purulia encourages chemical weathering processes of the rock massif along joint lines and faults. The winters that are characterized by dryness and high evaporation rates could also have an effect on aeolian

weathering processes.The great geomorphological diversity of the Joychandi complex with its set of bornhardts, tors, castle kopjes, mesas, buttes, sugarloaves, and nubbins makes the area an important object for geoconservation and geotourism. The description of the area and the description of its geotopes are the bases for further studies.The research adds to the knowledge about the inselbergs' development process in the Indian case, especially on the Chhotanagpur Plateau, and offers a methodology for such studies.For future research, the quantification of the landform age, the petrographical study of granitic rocks, and the assessment of the geotourism potential of the Joychandi inselberg complex can be mentioned. The application of geospatial techniques, such as LiDAR and DEM, would help better understand the micro-morphology of the landform development process.

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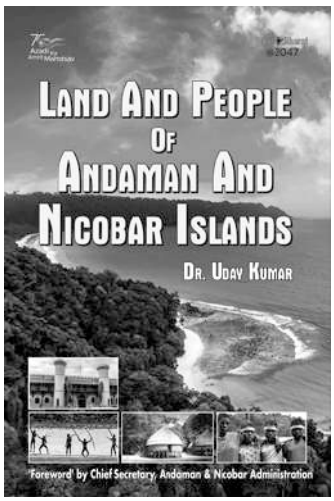
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BOOK REVIEW



Title of the Book	Land and People of Andaman and Nicobar Islands
Name of the Author	DR. UDAY KUMAR
No. of Chapters	13
No. of Pages	222
ISBN	978-8198837660
Publisher	Rajesh Publications, Ansari Road, Darya Ganj, New Delhi-110002
Year of Publication	2025
Price	795/- (Hardcover)
Online link	*www.amazon.in/dp/B0FR217BTQ*

Introduction

The book "Land and People of Andaman and Nicobar Islands", authored by Dr. Uday Kumar, Assistant Regional Director, IGNOU, Regional Centre, Port Blair, is a comprehensive work focussing on the geographical, historical, social, cultural, demographic, administrative and developmental dimensions of the Andaman and Nicobar Islands. Published by Rajesh Publications, New Delhi in 2025, the book provides a structured account of these unique islands and their people. The Chief Secretary of Andaman and Nicobar Administration Dr. Chandra Bhushan Kumar, IAS has written the 'foreword' for this book.

The book is broadly organised around two interconnected themes- 'Land' and 'People'. The first theme examines the physical and geographical characteristics of the islands, while the second focuses on their inhabitants, society, culture, administration, economy and development.

Contents and Coverage

The book contains thirteen principal chapters, followed by appendices and a bibliography. It begins with an introduction and a discussion of the geography of the Andaman and Nicobar Islands, followed by their history and the peoples of the islands. The geographical section covers important aspects such as geological formation, physiography, climate, drainage, soils, natural vegetation and natural resources.

The middle section on people gives particular attention to the aboriginal tribes of the islands and their socio-cultural characteristics. It also examines the demographic profile of the islands

and provides discussions on administration and governance, urbanisation and urban life. The later chapters broaden the scope of the book by examining trade and transportation, tourism, the strategic significance of the islands, and the problems and prospects of development. The inclusion of a chapter titled 'Andaman and Nicobar Islands: At a Glance', together with appendices and a bibliography, further enhance the reference value of the book.

This sequence gives the work a clear progression from setting and history to people, institutions, economic activity, strategic importance and development. The range of subjects indicated in the contents makes the book relevant to readers seeking an organized understanding of the region and its people.

History and People

The inclusion of history followed by chapters on the peoples of the islands gives the work a useful temporal and human context. Particular attention is given to the aboriginal or primitive tribes and to their socio-cultural features. This is an important area of the contents because the distinctive communities of the islands cannot be understood adequately through demographic statistics alone. At the same time, the subject requires careful, respectful and contemporary treatment, especially when discussing indigenous communities; the book's stated emphasis makes this a significant area for academic scrutiny.

Demography, Administration and Urbanisation

The chapters on demographic profile, administration and governance, and urbanisation and urban life shift the analysis from description of place and people toward institutional and social change. Together they help connect population characteristics with administrative structures and patterns of urban development. This sequence is particularly useful for understanding how settlement and governance interact in an island territory.

Trade, Transportation and Tourism

The treatment of trade and transportation is important because connectivity is central to island development. The tourism chapter complements this discussion by addressing one of the most visible economic and public-facing dimensions of the islands. Critically, these subjects are best understood in relation to environmental limits, local communities and infrastructure. The book's combined treatment creates an appropriate basis for examining the opportunities and constraints associated with development.

Strategic Significance

The separate chapter on the strategic significance of the Andaman and Nicobar Islands expands the book beyond conventional regional geography. It recognises the island's importance in relation to their location and wider national interests. Including this theme alongside

geography, society, transportation and development gives the book a broader contemporary relevance.

Problem and Prospects of Development

The concluding chapter on problem and prospects provides an important analytical direction. Rather than ending with description alone, the contents move toward questions of development and future possibilities. This makes the book more useful for policy-oriented discussion. A strong critical reading, however, should examine how competing objectives-economic development, environmental conservation, social well-being, indigenous interests, connectivity and strategic requirements are balanced in the discussion.

Overall Strengths of the Contents

The principal strength of the contents is their interdisciplinary character. Geography, history, anthropology, demography, administration, urban studies, transport, tourism and development are brought together in one volume. The chapter sequence is accessible, and the inclusion of appendices and bibliography increases the book's reference value. The 'At a Glance' section is also potentially useful for readers who need a concise factual overview. According to the supplied book description, the work is intended for students, researchers, academics, tourists and others interested in the islands, and the breadth of the contents supports that wide intended readership.

Areas for Critical Consideration

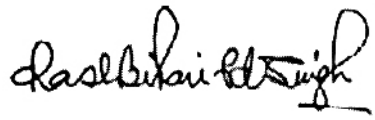
The wide range of subjects is both an advantage and a limitation. Covering many fields in a single volume can reduce the space available for deep analysis of individual themes. The contents also invite readers to consider whether physical geography, indigenous society, demographic change, governance, tourism, strategic interests and development are sufficiently integrated rather than treated as separate topics. In particular, a critical reader should look for the extent to which environmental sustainability and the interests of indigenous communities are connected with discussions of tourism, infrastructure and development. These are questions for close reading of the full chapters; the supplied contents information alone does not provide enough evidence to judge the depth or quality of the treatment in each chapter.

Conclusion

In conclusion, the book "Land and People of Andaman and Nicobar Islands" is a comprehensive study of one of India's distinctive island regions. The most appreciating part of the book is a balanced coverage of topics belonging to both land and people. By combining geographical, historical and human dimensions, the book provides a holistic framework for

understanding the Land and People of Andaman and Nicobar Islands. The work can be understood as a broad, multidisciplinary reference intended to introduce readers to the distinctive land, people and contemporary issues of the Andaman and Nicobar Islands.

The young and promising author, Dr. Uday Kumar has done wonderful work in presenting this book before us. He himself has written that this is his maiden effort. I am sure that he will bring necessary improvements if needed in the next edition of the book. The book is written in a very simple but lucid manner. It is designed in such a way that students, researchers and academics will immensely be benefited. The book will also be helpful to tourists having interest in Andaman and Nicobar Islands. The author of the book definitely commands our appreciation and good wishes with a hope that his pen will not stop here. I hope that readers will like to look into his new creative writings based on critical thinking about different geographical regions.



(Prof. Rash Bihari Pd. Singh)
Professor of Geography,
Former Vice Chancellor
Nalanda Open University &
Patna University, Patna (Bihar)

GENERAL SECRETARY REPORT

On the Auspicious Occasion of the XXVII Annual Conference and National Seminar of The Association of Geographers, Bihar and Jharkhand 31 October - 01 November, 2026 Department of Geography, L.N. Mithila University, Darbhanga

Hon'ble Chief Guest and Guest of Honour of today's inaugural session of 27th Annual Conference cum National Seminar, Chief Patron, Patron, President, Past Presidents, President Elect of the AGBJ, Convener, other dignitaries on the dais, fellow delegates, Life Members & Annual Members of the Association, Invited Guests, Students, Media Persons, Ladies and Gentlemen.

I am standing before you to present my fifth General Secretary report of the overall activities of the association. It is a matter of great privilege and honour for me to present this report on the occasion of the 27th Annual Conference cum National Seminar under the auspices of the Association of Geographers, Bihar and Jharkhand, which is being attended by a large number of distinguished scholars and researchers, not only from different parts of the states of Bihar and Jharkhand but also from other Indian states and again not only from geography but also from several other branches of knowledge.

Friends! Our association has now become more than twenty seven years old. During these years the Association has strengthened, united and organized the geographers of Bihar and Jharkhand. The association itself has been strengthened in respect of life members, financial position and infrastructural facilities. These have been possible due to the active participation by the P.G. Departments and College Departments of Geography of different universities to give an active support in the functioning of the association. The number of life members of our association has been increased up to 1600 approximately.

I am happy to inform the AGBJ family that our financial position is also considerably sound. This financial year also the statement of account of the Association has been certified by the Chartered Accountant and the treasurer will present the balance sheet in the Annual General Body Meeting to be held tomorrow.

The infrastructural facilities of the Association has also improved much during the last few years. Website has been launched and email address created. We are communicating well with such a large number of members through the website of the association. All relevant informations are now available on the website and one can click www.agbj.in for getting any information. You may interact with the association office bearers through the email-agbj2003@gmail.com and WhatsApp social media. Besides that, you may also interact with the Editor-in-Chief or Managing Editor regarding journal of the association through the email geographicalperspectiveagbj@gmail.com.

Dear Friends! Various Departments of Geography of the Universities of Bihar and Jharkhand are promoting the subject by organising Seminars, Symposium, Workshop, Invited Lectures and other academic activities throughout the year. Department of Geography, Patna University, has unveiled a landmark peer-reviewed, open-access biannual online journal "Geographical Studies and Development" bearing the e-ISSN 3140-0612 which is now available at www.geographicalstudies.com. Two special invited lectures were organized by the department during last one year. Prof. R.B.P. Singh, senior teacher and renowned scholar, delivered a special lecture on "World population Growth: Disaster Vs Disastrous" on the occasion of 'World Population Day' on 11 July, 2026. The inauguration of Herbal Park and unveiling the statue of Bhoogol Ratna Prof. P. Dayal in the premise of Department of Geography, Patna University on 26th September, 2025 by the Hon'ble Minister of Education, Govt. of Bihar, Shri Sunil Kumar. A book entitled "Climate Change and Agricultural Practices in India" edited by Prof. Md. Nazim, Dr. Debjani Sarkar Ghosh and Prof. M.K. Sinha was also released by the Hon'ble Minister on this special occasion. Prof. Md. Nazim, former Head of the Department, presented a paper on "Urban Growth and Air Quality in Patna Municipal Corporation Area: A Geographical Analysis" in the 18th International Asian Urbanisation Conference (IUAC) organised by Sindhu Central University, Ladakh from August 4-8, 2026. Dr. Pramod Kumar Pandey successfully completed 55 days ISRO-sponsored NNRMS Faculty Development Programme on Remote Sensing & GIS Technology and Applications organized by IIRS, Dehradun from 18th May to 11th July, 2026.

The Department of Geography, Patliputra University, Patna has organised a special invited lecture on the topic "Geospatial Technology for Climate Action and Sustainability" delivered by Mr. Shashi Shekhar, Consultant, Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India, New Delhi on 12th September, 2026. Dr. Gaurav Sikka, Assistant Professor of Geography of A.N. College, Patna has been appointed as Officer on Special Duty (Academic) in Bihar Lok Bhawan with additional charge. Department of Geography, College of Commerce, Arts and Science is empanelled as a knowledge partner for Urban Biodiversity Studies and City Biodiversity Index in Biological Sciences for bio-diversity related studies. A special invited lecture was delivered by Shri Rajesh Ranjan, Mindfulness Coach and Corporate leader on the topic "Conscious Connected Breathwork" organised by the Department. Dr. Vidya Yadav edited a book entitled "The Built Environment and Public Health in India: Opportunities, Challenges and Future Pathways" in Springer Nature, Singapore.

The Department of Geography, LNMU, Darbhanga has organized 27th Foundation Day Lecture of the Association of Geographers, Bihar and Jharkhand on 9th May, 2026. Prof. Ratnesh Kumar Jha, Sr. Scientist, Dr. Rajendra Prasad Agriculture University, Pusa, Samastipur has delivered a invited lecture on the topic "Strengthening India's Food Systems and Rejuvenating agriculture through climate smart practices in special context of Bihar" on

this occasion. A large number of extra-curricular academic activities have been organised by the Department during last one year.

Twelve episodes of Prof. S.K. Sinha Memorial Online Lecture Series has been conducted in the Department of Geography, V.K.S.U., Ara. An ICSSR funded Major Research Project has been awarded to Dr. Kumar Nirbhay, Assistant Professor of Geography, H.D. Jain College, Ara as Project Director. Prof. Sanjay Kumar, Head of the Department of Geography, V.K.S.U. Ara received recognition from the London Book of World Records on 28 January, 2026 for 'Educationist with most verified works and Professor with most diversified work'.

The Department of Geography, Magadh University, Bodh Gaya has conducted five special lectures as a part of Prof. R.P. Singh Memorial Lecture Series during last one year. Dr. Maushami, Sr. Assistant Professor has successfully completed ISRO sponsored NNRMS Faculty Development Programme on Remote Sensing & GIS Applications in Urban and Regional Studies organised by IIRS, Dehradun.

The Department of Geography, Vinoba Bhave University, Hazaribag has successfully organised the 26th Annual Conference cum two days National Seminar of AGBJ on 11-12 October, 2025 under the Convenership of Dr. Saroj Kumar Singh, Head of the Department.

Department of Geography, M.J.K. College, Bettiah and P.G. Department of Geography, B.R.A. Bihar University, Muzaffarpur have jointly organised a 'Seven Days Lecture Series' from September 3 to 10, 2026.

Dr. Shailesh Kumar, Sr. Assistant Professor of Geography, Y.N. College, Dighwara edited two books entitled "The Tribes of India" and "Major Tribes of India" as associate editor, and co-authored two books entitled "Environmental Geography" and "Regional Planning and Development". An ICSSR-funded Major Research Project has been awarded to Dr. Ramanuj Kaushik, Assistant Professor of Geography, D.A.V. P.G. College, Siwan, as Project Co-ordinator with Co-Project Director Dr. Prabhakar Nishad and Dr. Anupam Kumar Singh. Another ICSSR funded Major Research Project has been awarded to Dr. Visha Sharma, Assistant Professor of Geography, D.A.V. P.G. College, Siwan.

An ICSSR funded Minor Research Project titled "Socio-economic and Health Assessment of the JJM in Rural Bihar: An Empirical Study of Samastipur District" has been awarded to Dr. Amit Kumar, Assistant Professor cum Head, Department of Geography, Munger University as a Co-Principal Co-ordinator in collaboration with Department of Geography, V.K.S.U., Ara.

Friends! It is our pleasure to inform you that Prof. V.N.P. Sinha, Emeritus Fellow, Former Head of the Department of Geography, Patna University and former President of AGBJ has edited three exclusive books titled "The Tribes of India", "Major Tribes of India" and "A Comprehensive Geography of Bihar" during last one year at the age of eighty seven years.

During these 27 years of journey of AGBJ, twenty annual conferences cum National Seminar have been organised in the Department of Geography of different universities of Bihar and Jharkhand and seven annual conferences cum National Seminar have been organized in the colleges of different universities of Bihar and Jharkhand like Rajendra College, Chapra; MJK College, Bettiah; Nirmala College, Ranchi; Kisan College, Biharsharif; A.N. College, Patna; Chas College, Chas, Bokaro; and S.B. College, Ara.

Since our last annual conference held in October, 2025, geography departments of different universities of Bihar and Jharkhand have organised several academic activities both offline as well as online. A large number of Assistant Professors including guest faculties of Geography have joined in different Universities of Bihar and Jharkhand during the last two years. We seize this occasion to congratulate them and also request them to associate themselves with the Association to carry it forward and to make it an association of new generation geographers. Your association will give a new generational move to enhance your academic future. I am sorry to state that due to shortage of time achievements of several geographers of Bihar and Jharkhand in the fields of book writing, receiving awards, attending National and International Seminars, Symposium and Workshops getting promotion, etc., I am not in a position to mention respective names, but I, on behalf of the Association congratulate them and wish to have a bright future.

At the end I once again express my sincere thanks to all of you for your kind co-operation and support in running the Association. I am sure that our bond to work together will promote the cause of geography and succeed in establishing geography as an indispensable subject in coming years. We need to work academically on challenging issues in a systematic and scientific way so that stake holders in the field of planning and management may not be able to ignore the importance of Geography.

I hope that your two-days stay at this historical and pious land of Jagat Janini Mata Sita will be academically very fruitful. At last, I owe deep sense of gratitude to the convener, Co-convener, organising secretary and members of the organising committee of this Conference cum two days National Seminar who have provided all kinds of facilities directly or indirectly, students, staff and media persons who supported directly or indirectly satisfactorily.

Thanking you all once again.

Jai Bhoogol ! Jai AGBJ !! Jai Mithila !!!



(Dr. Manoj Kumar Sinha)
General Secretary, AGBJ
email: agbj2003@gmail.com

THE ASSOCIATION OF GEOGRAPHERS BIHAR & JHARKHAND

DEPARTMENTAL NEWS

PATNA UNIVERSITY, PATNA

1. Joining/Appointement of New Faculty Members:

Prof. Manoj Kumar Sinha joined Department of Geography, Patna University as Head of the department on 29th January, 2026.

2. Activities held in the Department:

I. Launch of an online Journal

The Department of Geography, Patna University, has unveiled "Geographical Studies and Development"—a landmark peer-reviewed, open-access, online biannual journal bearing the e-ISSN 3140-0612, Vol-1, Issue-1 (July-December-2026) is available at www.geographicalstudies.com.

II. Inauguration of Herbal Park and Unveiling the Statue of Bhoogol Ratna Prof. P. Dayal

The inauguration of "Herbal Park and Unveiling of the Statue of 'Bhoogol Ratna' Professor Parmeshwar Dayal" in the Department of Geography, Patna University was held on 26th September, 2025 by the Hon'ble Minister of Education, Government of Bihar, Shri Sunil Kumar. The programme organised under the aegis of P. Dayal Foundation and was presided over by the Vice Chancellor, Patna University, Prof. Ajay Kumar Singh. The book titled "Climate Change and Agricultural Practices in India" was also released on this special occasion.

III. A written Quiz Competition and a Poster Presentation on the theme **"Ozone for Life"** was organized by the department on the occasion of World Ozone Day-2025.

IV. International Day for Peace, 2025 was observed on 20th September, 2025. The programme was supported by Prem Rawat Fundation of Peace. Videos and lectures were dislayed in this context.

V. A poster presentation competition on the occasion of World Earth Day -2026 was held on 22.04.2026 in the Department of Geography on the focal theme **"Our Power, Our planet."**

VI. The Department of Geography organised a **"Plantation Drive"** on 05.06.2026 in the campus.

VII. **Prof. (Dr.) R.B.P Singh**, Former Head, Department of Geography, P.U. and Ex- Vice Chancellor, Patna University & Nalanda Open University delivered a special lecture on **"World Population Growth: Disaster vs Disastrous (**जनसंख्या वृद्धि**:** विनाशकारी बनाम अनर्थकारी**)"** on 11.07.2026 on the occasion of 'World Population Day'.

VIII. A special lecture was organized on 15.09.2026 on the occasion of Hindi Diwas in the Department of Geography Patna University. The Lecture was delivered by Prof. Tarun Kumar Former Head Department of Hindi Patna College and Principal Patna College on the topic **"**आज का दौर और हिंदी**".**

Conference, Seminar, Training Programmes and Workshop organised/ participated:

I. One-Day Training Programme on the topic: **"Ground Water Development and Management"** by the **Ministry of Jal Shakti, Government of India, Central Ground Water Board, MER, Patna** in collaboration with Department of Geography, Patna University was held on **23rd September, 2025**. The programme was inaugurated by **Shri Rajiv Ranjan Shukla**, Regional Director, Shri David Kumar Chaturvedi, Joint Director, Jal Jeevan Mission & Superintending Engineer, PHED Bihar.

II. **Prof. Md. Nazim** participated in the 18th International Asian Urbanisation Conference (IAUC), 2026 on "Resilient Futures: Urbanisation, Climate Change, and Sustainable Development Policy in a Changing World" and presented paper on "Urban Growth and Air Quality in Patna Municipal Corporation Area: A Geographical Analysis", organised by Sindhu Central University, Ladakh from August 4-8, 2026.

III. **Dr. Pramod Kumar Pandey** attended ISRO Sponsored NNRMS Faculty Development Programme on Remote Sensing & GIS Technology and Applications organized by Indian Institute of Remote Sensing (IIRS), Dehradun from 18-05-2026 to 11-07-2026.

IV. **Dr. Sudha Shree** participated in the 9th International Conference on "Sustainable Future Earth: Emerging Issues and Challenges in Resource Utilisation and Management," organized by the University Department of Geography at Ranchi University, Jharkhand, India, from October 07–09, 2025. Under the National Association of Geographers, India (NAGI), presented a research paper titled "Climate Change impacts on biodiversity and natural resources (An Indian Perspective)."

V. **Dr. Meera Thakur** presented a Paper titled "Balancing Economic Growth with Environmental Conservation in Jharkhand" in 9th International Conference On Sustainable Future Earth, Emerging Issues And Challenges In Resource Utilisation and Management Organized by National Association of Geographers, India (NAGI) and University Department of Geography, Ranchi University, Ranchi, Jharkhand on 07-09 October 2025.

VI. **Dr. Anil Kumar** presented a paper titled "An assessment of environmental problems and sustainable development in Rohtas district Bihar" at the PM-USHA International conference Jnanasetu: The Bridge of Knowledge, held on 19 September 2026, organized by the Department of Environmental Science at Atal Kalam, Gujarat University.

Publications

Prof. Md. Nazim, Dr. Debjani Sarkar Ghose and Prof. Manoj Kumar Sinha edited a book **"Climate Change and Agricultural Practices in India"**, ISBN: 978-81-9883760-8, Rajesh Publications, New Delhi, 2025.

Publications in Journals

I. **Nazim, M.** (2026), Geographical Indication Tag for Mithila Makhana and Its Prospects for Development in North Bihar, India, Geographical Studies and Development, 1(1), 23-40. ISSN (online) – 3140 – 0612, https://geographicalstudies.com/articles/GSD110006.

II. **Nazim, M.** (2026), Labour Migration from Kosi Seemanchal Region of Bihar Trends and Patterns (2000 – 2025) , Geographical Studies and Development, 1(1), 91- 111. ISSN (online) – 3140 – 0612, https://geographicalstudies.com/articles/GSD110006.

III. **Akanksha, Sarkar Ghose, D.** (2026), Quality of Life of Working Women in the Unorganized Sectors in Patna Urban Agglomeration, Bihar, India, Indian Journal of Spatial Science, 17(2), pp. 78-85, ISSN 2249-3921, EISSN 2249-4316.

IV. **Padmja Prakash, Sarkar Ghose, D.** (2026), A Spatial Analysis of the Medical and Healthcare Services in the Patna Municipal Corporation, Bihar, Indian Journal of Spatial Science 17(1), pp. 87-96, ISSN 2249-3921, EISSN 2249-4316.

V. **Kumari Tulika, Sarkar Ghose, D.** (2025), 'Socio-Economic Challenges faced by Working Women in Saharsa, Bihar, India', Indian Journal of Spatial Science, 16(4), pp 71-76, ISSN 2249-3921, EISSN 2249-4316.

VI. **Sikka, Gaurav, Bharti, Prerna** (2025), 'Nagar Van Yojna, A Beacon of Hope for Urban Biodiversity in Bihar' Anugrah Jyoti, pp 100- 107, ISSN: 2454- 1133.

VII. **Ashraf, M., & Anjum, Z.** (2026). Pre-Monsoon Water Quality Degradation Along the Punpun River from Pali to Fatuha Blocks, Patna District: Implications for Aquatic Habitat Suitability. Geographical Studies and Development, 1(1), 77-90. ISSN (online) - 3140-0612, https://geographicalstudies.com/articles/GSD110006

VIII. **Thakur, Meera** (2026)," Tribes of Dadra, Nagar Haveli, Daman and Diu", in Prof. (Dr.) V.N.P. Sinha & Prof. (Dr.) Ram Pravesh Yadav (ed) 'The Tribes of INDIA, Rajesh Publications, New Delhi, pp-96-107, ISBN:978-81-99889-63-7.

Others

I. **Prof. Md. Nazim** Participated in the 1st User Awareness Programme on "ONOS and INFLIBNET Services" organised by Higher Education Department, Govt. of Bihar on 18th Dec, 2025.

II. **Prof. Md. Nazim** Participated as an expert in the committee for preparation of Uniform Syllabus of Sem-III and IV of the 2-year Postgraduate Programme in Geography, organised by Bihar Lok Bhavan, Patna, from 01.09.2026 to 07.09.2026. Participated as an expert in the Committee for preparation of Uniform Syllabus of Sem-III and IV of the 2-year Postgraduate Programme in Geography, organised by Bihar Lok Bhavan, Patna, from 01.09.2026 to 07.09.2026.

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PATLIPUTRA UNIVERSITY, PATNA

Joining/ Appointment :

I. **Dr. Shashi Bhushan**, Assistant Professor of Geography, R.L.S.Y. College, Bakhtiyarpur, joined in the Department of Geography, Patliputra University, Patna on 12th May, 2026.

II. **Dr. Bhawana Nigam** joined as Head of the Department of Geography, A.N. College in November, 2025.

III. **Dr. Gaurav Sikka** appointed as OSD (Academic) Bihar Lok Bhavan on Additional Charge and leading initiatives on E- Library, Capacity building programmes, SAMARTH, Curriculum Reforms and Research.

Departmental Activities and Achievements :

I. **Mr. Shashi Shekhar**, Consultant, MoEFCC, New Delhi delivered a special lecture on the topic "Geographical Technology for Climate Action and Sustainability" on 12/09/2026.

II. Department of Geography, College of Commerce, Arts & Science is empanelled as a knowledge partners for Urban Biodiversity Studies and City Biodiversity Index in Biological Sciences for biodiversity-related studies by Bihar State Biodiversity Board (BSBB), 2026.

III. **Dr. P.K. Agarwal**, Ex-HOD, PMCH & Dr. Rakesh Singh, Department of Geography, A. N. Sinha Institute, Patna delivered special lecture on the occasion of World Population Day on 11th July, 2026 at Department of Geography, College of Commerce, Arts & Science, Patna.

IV. **Shri Rajesh Ranjan**, Mindfulness Coach and Corporate Leader delivered a special lecture on Conscious Connected Breathwork on 11th November, 2025 in the Department of Geography, College of Commerce, Arts & Science, Patna.

Publications:

Dr. Bhawna Nigam, Assistant Professor cum Head, A.N. College, Patna

I. Book Chapter-Recreational Facilities and Safety in Urban Public Green Open Spaces, Parks, and Playgrounds in Patna Municipal Corporation of Bihar. Springer Nature, Pg 83-105, 02 January 2026. New Frontiers in Regional Science: Asian Perspectives eBook ISBN-978-981-95-1865-4, Print ISBN-978-981-95-1864-7. Vol.85 https://link.springer.com/book/10.1007/978-981-95-1865-4

II. Research Article- Land Degradation and climate change: A case study of Agricultural Vulnerability and adaptation in Patna District, Bihar, India. Indian Journal Spatial Sciences –Peer-reviewed / Referred Journal pg.. 87-96, IJSS VOL-17 NO.1 Spring Issue 2026, EISSN: 2249-4316, ISSN: 2249-3921, IF: 2.080.

III. Keynote address delivered on the topic: Adaptation to climate change and sustainability: a case study of women in Agriculture in Bihar. Multidisciplinary International Seminar (MIS-SSC-2026) on "Beyond Boundaries: Multidisciplinary Education and Research for a Rapidly Transforming Scientific World", S. S. College, Jehanabad. Magadh University, Bihar. 19 – 21 February 2026.

Dr Vinita Prasad, Associate Professor, A. N. College, Patna

I. Published research paper titled "**Traditional Groundwater Recharge Techniques in India", published** in Hydrosystem Restoration Handbook: Groundwater Artificial Recharge with Conventional Water, Vol.3, edited by Saeid Eslamian and Faezeh Eslamian, Elsevier Publication, ISBN 978-0-443-29104-3, October'2025, Ch. 7, p.p. 133-152.

II. Published research paper titled "**Farmland Drainage Water and Suitability Assessment for Groundwater Artificial Recharge with Unconventional Water (GARU)" published** in Hydro-system Restoration Handbook: Groundwater Artificial Recharge with Conventional Water, Vol.4, edited by Saeid Eslamian and Faezeh Eslamian, Elsevier Publication, ISBN 978-0-443-29104-0, March'2026, Ch. 11.

III. Presented research paper titled 'Climate Change and Climate Smart Agriculture: Way Forward' at the National Conference on 'Community based Approach towards Sustainable Environment and Society: Viksit Bharat @2024, jointly organized by Patna Women's College, and St. Philomena College, Mysuru, on 24-25, March,2026.

IV. Delivered Guest Lecture on the topic "E-waste: Issues and Challenges" on the occasion of World Ozone Day 16.09.2026, at Patna Women's College, Patna.

Dr. Gaurav Sikka, Assistant Professor, A.N. College, Patna

I. Yiwei Wang, Yuping Bai, Xiangzheng Deng, **Gaurav Sikka,** Yecui Hu, Yangfan Chen, Guofeng Wang (2025) Exploring Dietary Transition and its Environmental Mitigation Effects in China, Sustainable Production and Consumption, *Online ISSN: 2352-5509* https://doi.org/10.1016/j.spc.2025.10.006 Elsevier, Volume 61, December 2025, Pages 37-47 (Impact Factor 9.6, Cite Score 22.5)

II. Jyoti P., Abhay R.K., **Gaurav Sikka (2025)** Bibliometric review of literature on sustainable, smart, and green cities, *Romanian Journal of Geography*, Romanian Academy, Vol.69(2)201–215 ISSN Online: 2285-9675

III. Sinenhlanhla Memela, **Gaurav Sikka** (2025) From Kutcha to Pucca houses: the impacts of architectural transformation on the Madhubani paintings of Bihar (India) *Romanian Journal of Geography,* Vol.69(2) 289–303 ISSN Online: 2285-9675

IV. Xin Chen, Yuping Bai, Yecui Hu, Xin Xuan, Gaurav Sikka, Keyi Lyu, Guofeng Wang (2026) Assessing the equity and efficiency of crop and livestock-related agricultural greenhouse gas emissions contributes to achieving regionally differentiated emission mitigation, *Physics and Chemistry of the Earth, Parts A/B/C*, Elsevier, 104417, ISSN 1474-7065, https://doi.org/10.1016/j.pce.2026.104417 (Impact Factor 4.6, Cite Score 6.0)

V. Satellite and Atmospheric Models based Quantification of Crop Burning Contributions on Air Quality in parts of the Indo-Gangetic Plain, *Environ Dev Sustainability*. (2026) https://doi.org/10.1007/s10668-026-07726-2 (Impact Factor 4.9)

VI. Household deprivation in India's aspirational districts in 2019-21: Comparing EAG and non-EAG states, *SN Social Science,* 6, 367 (2026). https://doi.org/10.1007/s43545-026-01645-9 (Q2 journal)

Dr Deepak Kumar, Assistant Professor, A.N. College, Patna

I. Published research paper titled **Seasonal Migration in South Bihar in the Aftermath of the COVID-19 Pandemic: Patterns, Impact, and Policy Response"** Published in "Research Vidyapith International Multidisciplinary Journal" (International Open Access, Peer-reviewed & Refereed Journal) (Multidisciplinary, Monthly, Multilanguage), Vol-3, Issue-3, March 2026 www.researchvidyapith.com ISSN (Online): 3048-7331

Dr Amar Kumar, Assistant Professor, A.N. College, Patna

I. Published research paper titled "**Social Status of the Elderly Population in Sitamarhi District of Bihar: A Geographical Analysis" in** peer-reviewed journal अनुग्रह ज्योति, ISSN: 2454 1133, अंक 16 जून 2026.

Dr. Vidya Yadav, Asst. Professor cum Head, College of Commerce, Arts and Science, Patna

I. **Kumari, S. and Yadav, V.** (2025). "**Mate Selection, Caste Norms, and Female Decision-Making in Indian Marital Systems: A Systematic Review**". Asian Journal of Advanced Research and Reports, 19 (7): pp-176-93. https://doi.org/10.9734/ajarr/2025/v19i71090.

II. **Yadav, V.** (2025). "**Linkages between Built Environment, Lifestyle, and Physical Activity: A Study of Selected Localities in Greater Mumbai City"**. In: Yadav, V., Mishra, M., Gavasker, K.K. (eds) The Built Environment and Public Health in India. New Frontiers in Regional Science: Asian Perspectives, vol 85. Springer, Singapore. https://doi.org/10.1007/978-981-95-1865-4_7

III. **Dr. Vidya Yadav,** an editor for the book entitled "**The Built Environment and Public Health in India - Opportunities, Challenges, and Future Pathways**" in the book series "New Frontiers in Regional Science: Asian Perspectives" in Springer Nature Singapore Pte Ltd., ISBN: 978-981-95-1865-4; Due: 1st January 2026.DOI https://doi.org/10.1007/978-981-95-1865-4.

IV. **Dr. Vidya Yadav presented a paper** in the **National Conference on Gender Equity in Urban India: Bridging Gaps through Policy Planning & Public Finance** on **Deprivation of Basic Livelihood: A reality for Urban Homeless in Bihar** during 17th -18Th March, 2026 at Osmania University, Hyderabad.

Dr. Rashmi Ranjana, Asst. Professor, College of Commerce, Arts and Science, Patna

I. **Ranjana, R.** (2026), Temporal Trends and Changes in Literacy Rates in Begusarai District: A Geographical Analysis. Journal of Advance and Future Research. ISSN: 2984-889X. VOLUME 4, ISSUE 2, February 2026. JAAFR.ORG.

II. **Ranjana, R.** (2026), Socio-Economic Impacts of Education in Begusarai District, Bihar: A Gender-Based Geographical Analysis. International Journal of Versatile Research and Analysis (IJVRA) 2026. Volume 4, Issue 2, February 2026. ISSN: 2984-8903. IJVRA.ORG.

Dr. Monika Kumari, Asst. Professor, College of Commerce, Arts and Science, Patna

I. **Dr. Kumari, M.** (2025) "Khond Tribes of India" in Sinha. V.N.P, Yadav, P. Ram(eds) Major Tribes of India. Culture, Heritage, Traditions, Identity, Vol-I 2026, Rajesh Pubs., New Delhi- 110002, www.rajeshpublications.com, www.geographybooks.co.in, ISBN: 978-81-68799-03-5, Page no. 128-138.

II. **Dr. Monika Kumari** presented a paper in the "**Socio-Economic Dimension and Tribal community in Paschim Champaran" at National Association of Geographers, India (NAGI) 9TH International conference held on Oct 7th – 9th, 2025** organised by University Department of Geography, Ranchi University, Ranchi.

Dr. Anita Singh, Asst. Professor, College of Commerce, Arts and Science, Patna

I. **Dr. Anita Singh** attended **multidisciplinary international seminar on "Environment, Health, Climate Change and Society**" and presented research paper on the topic of revising the issue of climate change, agriculture practices and food security in Bihar, which is conducted on 21st and 22nd January 2026, conducted by Mahila College, Dalmianagar, Rohtas (a constituent unit of Veer Kunwar Singh University, Ara, Bihar).

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LALIT NARAYAN MITHILA UNIVERSITY, DARBHANGA

Joining/ Appintment of new faculty:

I. **Dr. Rani Singh** joined as Assistant professor of Geography in the Department of Geography on 07th October, 2025.

Departmental Events:

I. **Dr. Anuranjan**, Head, Dept. of Geography, LNMU, Darbhanga delivered a special lecture on the occasion of **World Food Day** in collaboration with Dr. Prabhat Das Foundation, Darbhanga.

II. **Dr. Sandeep Kumar Jha** delivered special lecture on the topic **"Geo generalist era where spatial meets everything"** on the occasion of **GIS Day** on 19 November, 2025.

III. **Md. Zahid Hussain** delivered a Invited Lecture on **"Human trafficking in India and Bihar : Awareness, Prevention and Intervention"** on 13th December, 2025.

IV. A Seminar in joint collaboration with Dr. Prabhat Das Foundation, Darbhanga on the topic **"Aravali under Siege : Balancing between development and conservation**" held on 24 December, 2025.

V. **Dr. Pankaj Kumar**, Dept. of Foreign language, Manipur University delivered an invited lecture on the topic "**Understanding Japan : A Cultural Geographical Perspective**" on 13.01.2026.

VI. **Prof. Vidya Nath Jha**, Ex. Principal, MLSM College, Darbhanga delivered a special lecture on the topic **"Wetlands and traditional knowledge: Celebrating Cultural Heritage in Mithila Region "** on the occasion of Science Day (28.02.2026) in joint collaboration with **"Talab Bachao Abhiyan"**.

VII. **Dr. Sharda Nand Choudhary**, Retd. Head, MK College, Laheriasarai delivered a special lecture on "**World Water Day**" on 23.03.2026.

VIII. **Dr. Sonu Ram Shankar & Dr. S. N. Choudhary** delivered invited lecture on the topic "**Indo-China Hydropower Projects in the Himalkayan Region: Issues and Challenges**" on 19 February 2025.

IX. **Prof. S. N. Jha**, Ex. Vice-Chancellor, LNMU, Darbhanga & Prof. Nehal Ahmad, Ex Head, Univ. Dept. of Zoology, LNMU, Darbhanga delivered special lecture on the occasion of Earth Day on 22.04.2026.

X. **Prof. Ratnesh Kumar Jha**, Senior Scientist, Dr. Rajendra Prasad Agricultural University Pusa, Samastipur delivered 27th Foundation Day Lecture of AGBJ on the topic "Strengthening India's food systems and rejuvenating agriculture through climate smart practices in special context to Bihar on 09.05.2026.

XI. **Dr. Anuranjan**, Head of the Department delivered a special lecture on the topic "Antar-rashtriya Jaiv Vividhta Diwas" on 22.05.2026 in joint collaboration with Dr. Prabhas Das Foundation, Darbhanga.

XII. World Environment Day on 05.06.2026, World Ocean Day on 08.06.2026, World Population Day on 11.07.2026, World Resource Day on 24.07.2026, World Agricultural Day on 09.09.2026 and International Ozone Day on 16.09.2026 were celebrated in the department.

Conference/Seminars/Workshops Organised/Attended:

I. **Dr Rani Singh**, Assistant Professor, presented a research paper entitled "Climatic–Topographic Control on Tropospheric Pollutants over the Uttarakhand Himalaya: Multi-Year Sentinel-5P TROPOMI Analysis" at the 47th Indian Geography Congress, (NAGI) under the theme "Geo Vision for Viksit Bharat @ 2047: Strategic Planning for Climate Resilience & Sustainable Future," at the Department of Geography, University of Rajasthan, Jaipur, during 13–15 November 2025.

II. **Dr Rani Singh**, Assistant Professor, presented a research paper entitled "Assessing the Environmental and Health Implications of Marble Slurry Generation and Disposal in Kishangarh, Ajmer District, Rajasthan" at the 47th Indian Geography Congress, (NAGI) under the theme "Geo Vision for Viksit Bharat @ 2047: Strategic Planning for Climate Resilience & Sustainable Future," at the Department of Geography, University of Rajasthan, Jaipur, during 13–15 November 2025.

III. **Dr Rani Singh**, Assistant Professor, presented a research paper entitled "Linkage of Education with Democracy and Its Anticipated Impact on the Young Generation in India" at the ICSSR-Sponsored National Seminar organized by the Department of Political Science, JMDPL Mahila College, Madhubani, on 27 January 2026.

IV. **Dr Rani Singh**, Assistant Professor, delivered two academic sessions as an Expert Resource Person on "GIS and Remote. Sensing Applications in Water Resource Studies" at a Two-Day Workshop organized by the Department of Geography, Doon University, Dehradun, Uttarakhand, on 19–20 December 2025.

List of Publications:

Dr Anuranjan

I. Urban Flood Resilient: A study of flood 2019 in the city Patna, published in Annals of the Bhandarkar Oriental Research Institute, Vol C1 Issue 11,2025 with ISSN-0378-1143, IF- 6.5, UGC care listed Group 1.

II. Assessment of Urban Resilience: A study of Patna City, published in Annals of the Bhandarkar Oriental Research Institute, Vol C1 Issue 12, 2025 with ISSN- 0378-1143, IF- 6.5, UGC care listed Group 1.

Dr Manu Raj Sharma

I. **Sharma, M.R.**, Das, S.K. 2026. Integrated eco-hydrological and vegetation productivity analysis of wetland landscapes in Madhubani, Bihar (2002–2024). Scientific Reports. https://doi.org/10.1038/s41598-026-60072-1. ISSN (Online): 2045-2322.

II. **Sharma, M.R.**, Das, S.K., Shankar, A., Chandel, V.B.S. 2026. Climate Change and Sustainable Adaptation: An Analysis of the Effects of Rainfall Variability on Wetland Ecosystems in Madhubani, Bihar, India. In: Khanam, Z., Jamal, S., Siddiqui, A.R. (eds.), Climate Change, Resilience and Ecosystem Services. Sustainable Development Goals Series. Springer, Cham. Pp. 33-50. ISBN: 978-3-031-96976-8. https://doi.org/10.1007/978-3-031-96977-5_3

Dr Sunil Kumar Singh A.

I. **Tyagi, S., Singh, A.S.K.** (2026). Linking Vegetation Health and Water Risk of Wetlands in Vaishali District Through NDVI, SAVI, MNDWI, and WRI (2014 - 2024). International Journal of Social Science and Humanity Research. 14, (2): 17-26. ISSN 2348- 3164. **DOI:** https://doi.org/10.5281/zenodo.19417214

Dr. Rashmi Shikha

I. **Kumari P. and Shikha, R. 2025**. "ग्रामीण हाट और आर्थिक विकास : पंडौल प्रखंड के सन्दर्भ में", 'JOURNAL OF THE ASIATIC SOCIETYOF MUMBAI' ISSN-0972-0677 . UGC-CARE List Group-I, pp-146 to 156.

II. **Kumari K. J. and Shikha R.** "दरभंगा जिला के बहादुरपुर प्रखंड में महिला शिक्षा का कृषि, आय एवं आजीविका के विविधीकरण पर प्रभाव : एक भौगोलिक अध्ययन"'**Madhy-Bharti-Humanities and Social Sciences', ISSN 0974-0066,** UGC-CARE List Group-I, pp-84 to 90.

VEER KUNWAR SINGH UNIVERSITY, ARA

Joining/ Appointment/ Superannuation:

I. **Prof. Sanjay Kumar** joined as Head of the Department of Geography, VKSU, Ara**,** on 13 June 2026**.**

II. **Dr. Dweepika Shekhar Singh** joined as Head, P.G. Department of Geography, Maharaja College, Ara.

III. **Dr. Nirbhay Kumar** joined as Head, P.G. Department of Geography, H.D. Jain College, Ara.

Publications:

I. **Prof. Sanjay Kumar**, Professor & Head, Department of Geography has published the book entitled **"Sugam Samajik Vigyan-1"**, by Bharti Bhawan (P&D), with ISBN-13: **9788199871076**, in **2026**.

Conference, Seminar, Training Programmes and Workshop organised/ participated:

I. **Prof. Sanjay Kumar**, Professor & Head, P.G. Department of Geography, Veer Kunwar Singh University, Ara, organised a symposium on **"Tree Conservation – Development without Destruction: Innovative Pathways for Tree Conservation"**.

II. Prof. S. K. Sinha Memorial Online Lecture Series (Episodes 18 to 29) were conducted under the convenorship of Prof. (Dr.) Sanjay Kumar, Head, P.G. Department of Geography, Veer Kunwar Singh University, Ara, Bihar.

- **Dr. Akhilendra Nath Tiwary, Senior Assistant Professor, Department of Geography, Sardar Vallabhbhai Patel College, Bhabua, Kaimur, Bihar**, served as **Co-Convener** of the ICSSR-sponsored two-day National Seminar on **"The Concept of Water-Forest-Land and Indigenous Knowledge: Integration within the Indian Knowledge Tradition and Its Contemporary Relevance,"** jointly organised by Sardar Vallabhbhai Patel College, Bhabua, and Vanvasi Seva Kendra, Adhaura, Kaimur, held on **9–10 October 2026**.

- **Dr. Akhilendra Nath Tiwary, Senior Assistant Professor, Department of Geography, Sardar Vallabhbhai Patel College, Bhabua, Kaimur** served as **Convener** of the **Financial Literacy Programme**, jointly organised with the Association of Mutual Funds in India (AMFI), Mumbai, in association with IQAC, Sardar Vallabhbhai Patel College, Bhabua, on **8 July 2026**.
- **Dr. Akhilendra Nath Tiwary, Senior Assistant Professor, Department of Geography, Sardar Vallabhbhai Patel College, Bhabua, Kaimur** served as **Convener** of the **Cyber Awareness Programme**, organised on **3 July 2026** in collaboration with the Cyber Police Station, Kaimur (Bhabua), and IQAC, Sardar Vallabhbhai Patel College, Bhabua, with the objective of creating awareness among teachers and staff about the growing menace of **cyber fraud and cybercrime**.
- **Dr. Akhilendra Nath Tiwary, Senior Assistant Professor, Department of Geography, Sardar Vallabhbhai Patel College, Bhabua, Kaimur, Bihar**, served as **Co-Convener** of the ICHR-sponsored two-day National Seminar on **"Sardar Vallabhbhai Patel's Nation-Building Trinity: Integration, Good Governance, and Moral Economy,"** jointly organised by the **Indian Council of Historical Research (ICHR), New Delhi, R.K. Institute of Education, Jaddupur, and Sardar Vallabhbhai Patel College, Bhabua, Kaimur**, held on **14–15 May 2026**.
- **Dr. Akhilendra Nath Tiwary, Senior Assistant Professor, Department of Geography, Sardar Vallabhbhai Patel College, Bhabua, Kaimur, Bihar**, served as **Co-Convener** of the ICSSR-sponsored two-day International Seminar on **"From Vedic Revival to Cultural Empowerment: The Contribution of Arya Samaj to Indian Indentured Labourers,"** jointly organised by **Sardar Vallabhbhai Patel Mahavidyalaya, Bhabua**, and sponsored by the **Indian Council of Social Science Research (ICSSR), New Delhi**, held on **25–26 September 2025**.

Any other achievements:

- **Prof. Sanjay Kumar**, Professor & Head, P.G. Department of Geography, Maharaja College, Ara, received recognition from the London Book of World Records on 28 January 2026 for "**Educationist with Most Verified Works and Professor with Most Diversified Work."** He received also a **Letter of Appreciation from SCERT, Mahendru, Patna, Education Department, Government of Bihar**, dated **12 February 2026**.

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MAGADH UNIVERSITY, BODH GAYA

Joining/ Appointment/ Superannuation:

I. **Prof. Upendra Kumar** superannuated as the Head, P.G. Department of Geography, Magadh University, Bodh Gaya on 31st January 2026.

II. **Prof. Basudeo Prasad** joined as the Head, P.G. Department of Geography, Magadh University, Bodh Gaya on 1st February 2026.

III. **Prof. Basudeo Prasad**, Head, P.G. Department of Geography appointed as the Inspector of Colleges, Science, member of Academic Council and the Senate, Magadh University.

IV. **Dr. Awnish Kumar and Dr. Himanshu Rajak** joined the P.G. Department of Geography, Magadh University, Bodh Gaya as Guest Faculty in September 2026.

V. **Dr. Pintu Kumar**, Senior Assistant Professor has been nominated as a State Convenor, Bihar Chapter of Indian National Cartographic Association, Ref. No. 39/(BRANCH)/INCA/2025-26.

Special Lectures:

I. The Inaugural Lecture of Prof. R.P. Singh Lecture Series was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC, Magadh University, Bodh Gaya on the topic "Application of Geographic Information System" on 19th September 2025. The Guest Speaker was Prof. Lubna Siddiqui, Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi.

II. A Special Lecture as a part of Prof. R.P. Singh Memorial Lecture Series was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC Magadh University, Bodh Gaya on the topic "Aquatic Bio Resource as the Source of Livelihood: A Case Study of Darbhanga District in Bihar" on 8th of November 2026. The Guest Speaker was Prof. (Dr.) Anuranjan, Head, University Department of Geography, L.N. Mithila University, Darbhanga.

III. A Special Lecture as a part of Prof. R.P. Singh Memorial Lecture Series was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC Magadh University, Bodh Gaya on the topic "Prof. R.P.Singh: Founder of the Geomorphological Researches in the Indian Subcontinent". The Guest Speaker was Prof. (Dr.) D.P. Singh, Former Head, Department of Geography, A.N. College, Patna.

IV. Dr. Bhuvaneshwar Prasad Memorial Lecture was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC, Magadh University, Bodh Gaya on 20th January, 2026. The topic of the Lecture was "Sacred Places and Landscape Geometry: Uprooting the IKS (Indian Knowledge System)". The Guest Speaker was Prof. Rana P.B. Singh, Professor & Head (Ex), Department of Geography, B.H.U., Varanasi, Visiting Professor, CSAS Gifu Women's University, Japan

V. A Special Lecture as a part of Prof. R.P. Singh Memorial Lecture Series was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC Magadh University, Bodh Gaya on the topic "Community Participation in Disaster Risk Management in India" on 19th February 2026. The Guest Speaker was Prof. Bupinder Zutshi, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi.

VI. A Special Lecture was organised by the Department of Geography, Magadh University, Bodh Gaya under the aegis of IQAC, Magadh University, Bodh Gaya on 4th April 2026. The topic of the lecture was "Socio-economic Survey: An Introduction". Dr. Sanjay Kumar, Assistant Professor, MMV, Banaras Hindu University was the resource person.

VII. A Special Lecture was organised by the P.G. Department of Geography, Magadh University, Bodh Gaya as a part of Prof. R.P. Singh Memorial Lecture Series under the aegis of IQAC, Magadh University, Bodh Gaya on 7th August 2026. Topic of the Lecture was "Population Dynamics & Sustainable Resource Management". Prof. R.B.P. Singh, Ex-Vice Chancellor, Patna University, Patna was the Guest Speaker.

Other Activities:

I. A socio-economic survey of Rampur village was conducted by the students of Semester IV, Session- 2024-2026 on 18th March 2026 under the supervision and guidance of Dr. Basudeo Prasad, Head, Department of Geography and the faculty members – Dr. Meenakshi Prasad, Dr. Pintu Kumar, Dr. Maushami, Mr. Rakesh Kumar, Dr. Lakhbhadra Singh Naruka, Dr. Niraj Kumar Singh, Dr. Awinish & Dr. Himanshu Rajak.

Academic Activities of Faculty Members:

I. **Dr. Maushami**, Senior Assistant Professor participated in the ISRO-sponsored NNRMS Faculty Development Programme on Remote Sensing & GIS

Applications in Urban & Regional Studies organised by IIRS, Dehradun from May 18 to July 10, 2026 and successfully completed it.

II. **Dr. Maushami**, Senior Assistant Professor, co-authored a research article titled 'A Review on Exploring the Interplay of Urban Heat Island Effects and Groundwater Recharge Through a Bibliometric Perspective from 2000-2024 in International Journal of Geology, Earth & Environmental Sciences ISSN: 2277-2081An Open Access, Online International Journal Available http://www.cibtech.org/jgee.html, 2025 Vol. 15, pp. 118-131

III. **Dr. Pintu Kumar**, Senior Assistant Professor authored a research paper titled 'An Assessment of the Tourist Facilities and Changing Scenario in the Buddhist Circuit in Bihar' in Geographical Perspective, October 2025, Vol.-XX-VI (ISSN: 0970-809X)

IV. **Dr. Pintu Kumar**, Senior Assistant Professor authored a book chapter titled 'Understanding Buddhist Sacred Landscape and Service Centre in Bodh Gaya, Bihar' in an edited Book on 'Climate Change and Agricultural Practices in India' by Nazim, Debjani Sarkar Ghosh and M.K. Sinha and published by Rajesh Publication, New Delhi, ISBN: 9788 1988 37608

V. **Dr. Pintu Kumar**, Senior Assistant Professor participated in the ICSSR Sponsored Two-Week Capacity Building Programme on 'Methodological Innovation, Cultural Studies and Epistemic Justice in Social Science Research' organized by Centre for West Asian Studies and Nelson Mandela Centre for Peace and Conflict Resolution, Jamia Millia Islamia, New Delhi from 06-18 October 2025.

VI. **Dr. Niraj Kumar Singh**, Senior Assistant Professor authored a research paper titled 'Cultural Continuity and Social Transformation among the Tharu Tribes of Uttar Pradesh' in International Journal of Geography, Geology and Environment, 7(12), 91–94. ISSN:2706-7491.

VII. **Dr. Niraj Kumar Singh**, Senior Assistant Professor authored a research paper titled 'State Capital Region—Uttar Pradesh: A Geographical Analysis of Regional Development' in International Journal of Advanced Academic Studies, 8(5), 235–242. P-ISSN: 2706-8919; E-ISSN: 2706-8927.

VIII. **Dr. Niraj Kumar Singh**, Senior Assistant Professor authored a paper titled 'Urban Expansion and Land-Use Change in Lucknow during 2015–2025: A Geographical Perspective' in International Journal of Applied Research, 12(5), 248–253. ISSN (Print): 2394-7500; ISSN (Online): 2394-5869.

IX. **Dr. Niraj Kumar Singh**, Senior Assistant Professor authored a paper titled 'Geopolitics of the Indian Ocean: Energy Crisis and Choke Points' in International Journal of Applied Social Science (IJASS), 13(3–4), 395–399.

X. **Dr. Niraj Kumar Singh**, Senior Assistant Professor presented a paper titled "Livelihood Vulnerability of Marginalized Communities: A Comparative Study of Schedule Castes and Scheduled Tribes in Jharkhand" in 9th NAGI International Conference on October 7-9, 2025 organised by University Department of Geography, Ranchi University.

XI. **Dr. Niraj Kumar Singh**, Senior Assistant Professor presented a paper on the topic "The Tharu Tribes of Uttar Pradesh: Historical Roots, Cultural Heritage, and Pathways of Transformation" in Two days, International Seminar on Tharu Tribes challenges and Solutions organized by Department of Geography, Kisan P.G College Baharaich, Uttar Pradesh (Maa Pateshwari University, Balrampur, U.P, India) on October 24-25, 2025.

XII. **Dr. Meenakshi Prasad**, Senior Assistant Professor co-authored a research paper titled Studying the Conservation Status of "Vedis"- The Cultural Heritage of the Holy City of Gaya, Bihar in ANNALS of the National Association of Geographers India, Volume 45(2) 2025, pp. 250-268

XIII. **Dr. Meenakshi Prasad**, Senior Assistant Professor jointly presented a research paper titled 'Assessing Urban Heat Island Intensity 7 Green Space Distribution Using GIS: A Study of Patna Municipal Corporation Area. At the National Conference on "Community Based Approach Towards Sustainable Environment and Society: Viksit Bharat @2047" held on 24th and 25th March 2026, organized by the Department of Geography, Patna Women's College in collaboration with the Department of Chemistry, St. Philomena College (Autonomous), Mysuru, Karnataka

XIV. **Dr. Meenakshi Prasad**, Senior Assistant Professor participated in the ISRO-sponsored NNRMS Faculty Development Programme on Remote Sensing & GIS Applications in Urban & Regional Studies organised by IIRS, Dehradun from May 18 to July 10, 2026 and successfully completed it.

XV. **Dr. Meenakshi Prasad**, Senior Assistant Professor co-authored a book chapter titled ' Covid-19 Vulnerability: A Societal Implication and Community Response in edited book "Socio-Ecological Crisis of Development" https://www.springerprofessional.de/en/socio-ecological-crisis-of-development/52451780#TOC

XVI. **Mr. Rakesh Kumar**, Senior Assistant Professor co-authored a research paper titled "Dynamic Causality between CO2 Emissions, Urbanization and Economic Growth in India and South Africa" published in International Journal of Energy Economics and Policy; Year: 2026, Volume: 16 (1), 276-285. (Scopus Indexed Journal), DOI: https://share.google/bIsuOFL8Zx9JGTtqI

XVII. **Mr. Rakesh Kumar**, Senior Assistant Professor co-authored a research paper titled "Socioeconomic Determinants of Child Undernutrition in Bihar: Evidence from NFHS-5" published in Archives of Current Research International; Year: 2026, Volume 26, Issue 8, Page 601-615, 2026,ISSN: 2454-7077, DOI: https://doi.org/10.9734/acri/2026/v26i82082

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VINOBA BHAVE UNIVERSITY, HAZARIBAG

I. The Department of Geography, Vinoba Bhave University, Hazaribag, successfully organized the 26th AGBJ Annual Conference and National Seminar 2025 on 11–12 October 2025, followed by a field excursion on 13 October 2025. The conference was successfully organized under the convenership of Dr. Saroj Kumar Singh, Head, Department of Geography, Vinoba Bhave University, Hazaribag. The event was centred on the theme "Sustainable Utilisation of Resources of Bihar and Jharkhand @ Viksit Bharat 2047", emphasizing the importance of sustainable resource management in achieving the vision of a developed India.

II. The Department of Geography, Vinoba Bhave University, Hazaribag, organized educational tours to **Kolkata-Sundarban (11–12 March 2026)** for postgraduate students as part of its experiential learning programme.

III. **Shri Surendra Prasad Singh**, environmental activist has shared his experiences in forest protection, biodiversity conservation and community participation on the occasion of Earth Day organized by Department of Geography, Vinoba Bhave University, Hazaribag on 22 April 2026.

A memorable slogan from the programme captured the essence of human-nature coexistence:

"Hiran, Bagh, Bhalu, Haathi- Manav Ke The Saathi,
Haathi Ko Chheda, Ghar Tumhara Toda."

IV. **Sri S. K. Pandey**, Retired General Manager, CCL delivered a lecture on the theme "Environmental Degradation due to Mining Activities in Jharkhand and Its Remedial Measures" on the occasion of World Environment Day on 5th June 2026. Dr. Kamla Prasad, Former Head, Department of Geography has elaborated on the mining scenario across Jharkhand and its environmental implications. A plantation drive in the university campus was also organized on this occasion.

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B.R.A. BIHAR UNIVERSITY, MUZAFFARPUR

Joining/ Appointment/ Superannuation:

I. **Dr. Mamta Roy** joined the University Department of Geography on 27.09.2025.

II. **Dr. Indrani Roy** joined the University Department of Geography on 27.09.2025.

Publications:

I. **Dr. Ida Ella Seema Kerketta**, Associate Professor published a paper titled "The Socio-Economic Condition of Women: A Geographical Study of Vaishali District - Glimpses" in ISSN 2250-0561, Dec-2025, Vol-15, No.1.

II. **Dr. Ida Ella Seema Kerketta**, Associate Professor published a paper titled ""जमुई जिले में सतत कृषि पद्धतियों तथा भूमि उपयोग में हो रहे परिवर्तनों का भौगोलिक विश्लेषण" Volume – 8, Page No. – 63-67, Year 2026."

III. **Dr. Ida Ella Seema Kerketta**, Associate Professor published a paper entitled "जमुई जिले में जलवायु परिवर्तन के कारण भूमि उपयोग में हो रहे परिवर्तनों का भौगोलिक अध्ययन" in "Quest Journal of Research in Environmental and Earth Sciences", ISSN (Online): 2348-2532, Volume-11 ~ Issue 12 (December 2025) pp: 143-154. Article is available online at http://www.questjournals.org/jrees/archive.html

IV. **Dr. Shirin Hayat**, Sr. Assistant professor published a book chapter Chakma Tribes in Major Tribes of India.

V. **Dr. Shirin Hayat**, Sr. Assistant professor published a paper titled "पूर्वी चंपारण जिला में आर्थिक गतिविधियों में महिलाओं को भागीदारी: एक स्थानिक विश्लेषण" ,The Eternity, Volume XVII, January-March-2026.

VI. **Dr. Shirin Hayat**, Sr. Assistant professor participated in the 9th NAGI International Conference, Ranchi University Ranchi-7-9 October-2025.

VII. **Dr. Tripti Kumari**, Sr. Assistant Professor, M.J.K. College, Bettiah, W. Champaran published a research paper entitled "Socio-Economic Vulnerabilities and Livelihood Dynamics of Tailoring Communities: A Case Study of Bettiah City" published by Social Science Journal for Advanced Research, Volume-6, Issue-4: July 2026 ISSN 2583-0074, doi: https://doi.org/10.54741/SSJAR/6.4.2026.385

VIII. **Dr. Barkha Chaplot**, Sr. Assistant Professor, M.J.K. College, Bettiah. W. Champara published a research paper titled Global Flood awareness system (glofas): from global hydrological forecasting to operational flood-risk early warning chaplot B. published by Larhyss Journal, ISSN 1112-3680, n°67, Sept 2026, pp. 177-194 © 2026 All rights reserved, Legal Deposit 1266-2002

IX. **Dr. Yogendra Samyak**, Sr. Assistant Professor, M.J.K. College, Bettiah. W. Champaran published a research paper entitled "Science as a social institution: a review of sociological theories explaining its role in modernity and globalization" published by Scientific Culture, Vol. 12, No. 2.1, (2026), pp. 3171-3180 DOI: 10.5281/zenodo.122.126245

Conferences, Seminars, Training Programmes and Workshops Organised/ Participated

I. University Dept. of Geography organized a Seminar on "Ozone Layer Depletion: A Multidimensional Threat to Life & Environment" on 16th September 2026. On the occasion, the students of semester IV, session 2024-26, also undertook a plantation drive in the Department premises.

Other activities:

II. Department of Geography, M.J.K. College, Bettiah and University Dept. of Geography, B.R.A. Bihar University, Muzaffarpur jointly organized a "Seven Day Lecture Series" from 3rd to 10th September 2026.

III. Department organized a Geographical Tour from 4th to 6th August for the Session 2024-26 to Rohtas & Kaimur.

IV. Department organized a Cultural Programme on 09.09.2026.

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MUNGER UNIVERSITY, MUNGER

Joining/Appointment:

I. **Dr. Amit Kumar**, Assistant Professor of Geography, joined as Head of the Department of Geography, Munger University, Munger on 17/03/2026 (Second term).

II. **Dr. Sanjeev Kumar**, Assistant Professor of Geography, joined PG Department of Geography, Munger University, Munger on 18/03/2026.

Publications :

I. **Dr. Amit Kumar (2025)** "Understanding the Dynamics of Asian Migration in India: Exploring Trends, Patterns, Causes and Duration of Stay Periods" Annals of the National Association of Geographers, India, Vol-05 & Isuue.01, PP-191-199.

II. **Dr. Amit Kumar (2026)** "Bridging the Rural Water Divide through Jal Jeevan Mission in Bihar: Household Determinants of Functional Tap Water Access" Environmental Science Archives, Vol-05 & Isuue.01, PP-191-199.

III. **Dr. Amit Kumar (2026)** "Maternal Employment and Child Nutrition: A Systematic Review of Evidence and Policy Perspectives" International Journal for Multidisciplinary Research (IJFMR), Vol-08 & Isuue.04, PP-01-16.

IV. **Dr. Amit Kumar (2026)** "Maternal Employment and Child Nutrition: A Systematic Review of Evidence and Policy Perspectives" International Journal for Multidisciplinary Research (IJFMR), Vol-08 & Isuue.04, PP-01-16.

V. **डॉ अमित कुमार** (2026) "ग्रामीण बिहार में पुरुष प्रवासन और महिला सशक्तिकरण के बीच सबंध (सिवान जिला के संदर्भ में)" वेदांजली Vol-25 & Isuue.02, PP-103-106.

VI. **डॉ अमित कुमार** (2026) "बिहार के ग्रामीण परिवारों के सामाजिक-आर्थिक विकास में प्रवासन एवं प्रेषण राशि की भूमिका: सिवान जिला का अध्ययन" **International Journal of Creative Research Thoughts (IJCRT)** Vol-14 & Isuue.07, PP-412-421.

Book :

I. **Dr. Amit Kumar (2026)** "Maping Maternal and Child Nutritional Health in South Bihar" Lambert Academic Publishing GmbH & Co.KG, Germany, ISBN- 978-620-9-44098-4, PP-01-201.

Research Projects :

I. **Dr. Amit Kumar** (2025) as a co-principal Co-Ordinator funded by ICSSR minor project titled "Socio-Economic and Health Assessment of The JJM in Rural Bihar: An Empirical Study of Samastipur District" Dept. of Geography Munger University collaboration with Dept of Geography, VKS University Ara.

Conference, Seminar, Training Programmes and Workshop :

I. **Dr. Amit Kumar (2025)** paper presented title "Out-migration and social transformation in Rural Bihar" 47th Indian Geography Congress, to be held at Department of Geography, University of Rajasthan, Jaipur, Rajasthan November 13-15, 2025.

II. **Dr. Ravin Kumar (2025)** paper presented title "Environmental impact of mining activities: A case study of Alwar district Rajasthan" 47th Indian Geography Congress, to be held at Department of Geography, University of Rajasthan, Jaipur, Rajasthan November 13-15, 2025.

III. **Dr. Sanjeev Kumar (2026)** paper presented titled **"Spatial Pattern of Social Well-Being in Bihar: Population and Health Dimension."** in national conference "Community Based Approach towards Sustainable Environment and Society: Viksit Bharat @2047" organized by the Department of Geography, Patna Women's College held on 24th and 25th March 2026.

IV. **Manish Kumar Madhukar (2025)** paper presented titled "**The role of women working status on child nutrition in India**" 47th Indian Geography Congress, to be held at Department of Geography, University of Rajasthan, Jaipur, Rajasthan November 13-15, 2025.

V. **Nitu Kumari (2025)** paper presented titled "**Effect of male out-migration on women empowerment in rural Bihar**" 47th Indian Geography Congress, to be held at Department of Geography, University of Rajasthan, Jaipur, Rajasthan November 13-15, 2025.

VI. **Manish Kumar Madhukar (2025)** participated National Conference on "New Educational Policy 2020: Challenges & Possibilities" KSS College, Lakhisarai December 07, 2025.

VII. **Nitu Kumari (2025)** participated National Conference on "New Educational Policy 2020: Challenges & Possibilities" KSS College, Lakhisarai December 07, 2025.

VIII. **Manish Kumar Madhukar (2026)** paper presented titled "**Indigenous Food Systems and Child Nutritional Status in India: A Secondary Data Analysis of Regional Variation and Dietary Practices** "The Concept of water-forest-land and indigenous knowledge integration within the Indian Knowledge tradition and its contemporary relevance, to be held at SVP College & Vanvas Seva Kender, Bhabua, October 09-10, 2026.

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JAI PRAKASH UNIVERSITY, CHAPRA

Joining/ Appointment/ Superannuation:

I. **Prof. (Dr.) Shree Kamaljee** joined as Head in the Department of Geography, J.P.U., Chapra.

Publications:

I. **Dr**. **Tapasya** published a paper entitled "जल संरक्षण में आर्द्र भूमि की भूमिका: सारण जिला का भौगोलिक अध्ययन" in "Research Journal of Arts, Management and Social Sciences".

II. **Neha Kumari Pandey** published research paper entitled 'Indian Knowledge Systems and Environmental Conservation: Integrating Traditional Ecological Wisdom to Address Modern Ecological Challenges', Volume 8, Issue 4, July-August 2026.

III. **Neha Kumari Pandey** published research paper entitled "Socio-Economic Profile of Working Women in Ranchi City: A Review of Secondary Evidence"

IV. **Dr. Alpna Jyoti** published research paper entitled 'Geomorphic Features of Pat Region in Palamu and Latehar Districts, Jharkhand' in Research Today, An International Peer Reviewed Journal of Humanities & Social Sciences Journal of The Society for Education & Social Welfare Varanasi - 221005 (INDIA).

V. **Dr. Alpna Jyoti** authored a chapter entitled "Tribes of Assam" in edited book "TheTribes of India" published by Rajesh Publications, New Delhi 2026. Dr. Jyoti is associate editor also of the book "The Tribes of India".

VI. **Dr. Shailesh Kumar** is co-author in chapter entitled "Tribes of Bihar" of the edited book "The Tribes of India" published by Rajesh Publications, New Delhi 2026. Dr. Kumar is associate editor also of the book "The Tribes of India".

VII. **Dr. Ramanuj Kaushik** author a chapter entitled "Tharu Tribe in India" in Major Tribes of India (Tribes of India Series) ; Rajesh Publications , New Delhi 2026.

VIII. **Dr. Ramanuj Kaushik** author a chapter entitled 'Geography of Disaster, Coordination for Relief and Conflict Resolution: A Case of Kashmir Earthquake 2005' in Book "The Solidarity Approach in Geography" published in Springer Nature.

Research Projects, Grants and Academic Collaborations etc.:

I. A Major Research Project etitled 'An Exploratory Study on Livelihood and Occupational Diversification Strategy of Rural Household in Bihar' funded by Indian Council of Social Science Research (ICSSR), New Delhi has been awarded to Department of Geography, D.A.V. Post Graduate College, Siwan. Dr. Ramanuj Kaushik is Coordinator, Dr. Prabhakar Nishad, Dr. Nasim Ansari, Dr. Anupam Kumar Singh and Dr. Ashutosh Sharan are Project Director.

II. **Dr. Visha Sharma**, DAV Post Graduate College Siwan worked as Co-Principal Investigator (Co-PI) in the research project titled "Integration of Socially Inclusive Interventions for Psychological Well-being of Adolescents in Urban and Rural Health Infrastructure of Uttar Pradesh and Bihar" under the thematic area "Health, Well-being and Gender-Sensitive Health Care System."

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NILAMBER-PITAMBER UNIVERSITY, PALAMU

I. **Dr. Kundan Kumar**, Assistant Professor, Department of Geography, N.P. University, Palamu has participated in Two-day National Seminar Organized by NPU & Bhartiye Bhasha Samiti on Bhartiye Bhasha Pariwar: Unity Among Indian languages held on February 10-11, 2026.

II. **Dr. Kundan Kumar**, Assistant Professor, Department of Geography, N.P. University, Palamu has participated in Two-day workshop on Gender Sensitization and Inclusion Organized by Department of Higher and Technical Education & Jharkhand State Faculty Development Academy at Ranchi held on March 18-19, 2026.

III. **Dr. Kundan Kumar**, Assistant Professor, Department of Geography, N.P. University, Palamu has participated in National Level Two-day Workshop on Digital Repository using Open Source Software (OSS) – Dspace at IIT ISM, Dhanbad held on April 27-28, 2026.

IV. **Dr. Kundan Kumar**, Assistant Professor, Department of Geography, N.P. University, Palamu has participated in Two-day Multidisciplinary National Seminar – "Where Culture meets Nutrition-Jharkhand's Local Food for a Sustainable tomorrow" at Medininagar held on May 8-9, 2026.

V. **Mr. Jay Kumar Honhaga**, Assistant Professor, Department of Geography, N.P. University, Palamu has participated in Two-day Multidisciplinary National Seminar – "Where Culture meets Nutrition-Jharkhand's Local Food for a Sustainable tomorrow" at Medininagar held on May 8-9, 2026.

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Ph.D. Degree Awarded

The list of Ph. D. Degree Awardees will not be published in this journal from this volume. It is resolved due to the uploading of each Ph. D. degree awardee thesis and the details on the 'Shodhganga' platform as well as on the websites of respective universities.

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TRIBUTE



Prof. Ganga Prasad Jha

Prof. Ganga Prasad Jha was born in the year **1939**, 17th November in a small village named **Patania**, under Biraul Block in the district of **Darbhanga, Bihar**.

His birth coincided with the sacred evening Arghya of the great festival of **Chhath Puja**, a highly auspicious moment in Mithila culture.

Early Education: He received his primary education from the Government School located in the nearby village of Sahasram. He pursued his secondary education at the High School in **Pokhram** village of the same Biraul block, from where he successfully completed his Matriculation.

After Matriculation, he moved to Madhubani to join the prestigious **R. K. College** for his Intermediate studies, which he completed with a First Division. His quest for higher education then took him to Patna.

Higher Education & Academic Career :

At Patna, he was fortunate to secure admission in the renowned **Patna University**. He completed both his Graduation and Post-Graduation in Geography from Patna University securing a meritorious position in the merit list at both levels.

After completing his M.A. in Geography, he briefly served as a faculty member at **Bhagalpur University**. In 1**962**, a significant turning point came in his career when he appeared for a faculty appointment interview at Patna University. The interview board was headed by the then Vice-Chancellor of Patna University, **Prof. George Jacob**.

Prof. Jacob was so deeply impressed by his profound subject knowledge and performance that he verbally directed him to join as a faculty member at Patna University immediately, assuring him that the formal letter of appointment would follow. Thus began his long and illustrious academic journey at Patna University.

Research Contribution :

He completed his **Ph.D. in the year 1972** under the able guidance of **Prof. Adya Saran**, a great and renowned professor of Geography. His doctoral thesis titled **"Kamla Balan River Plain - Land Use and Agricultural Systems"** received wide acclaim and laurels in the field of Agricultural Geography.

This pioneering work established him as **one of the pioneer geographers of Agricultural Geography** in India. His research on the Kamla Balan basin remains a landmark study for understanding the agricultural systems of North Bihar.

As an accomplished researcher and guide, he later **supervised more than a dozen scholars** for the award of Ph.D. degree, thereby nurturing a whole generation of geographers.

Academic Leadership :

Prof. Jha served for 40 years in academics. He also served as Controller of the exams of Patna college, Hostel Superintendent of Jackson , Head of the Geography department and the Senate member. He has been a leading member of various prestigious academic bodies, university boards, and professional platforms. His active participation and leadership in different academic committees have significantly contributed to the development of geographical education in Bihar.

Prof. Jha successfully and actively completed his terms of head of the department of geography of Patna College as well as of Patna University. Under his able guidance a globe was made in the department, now a days, Prof. P. Dayal Herbal Park, a cemented map of India in the front and that of the then Bihar in the rear side of the department were made and Sagwan trees were planted during the period when Prof. L. N. Ram was head of the department. During his tenure as head of the department of geography of Patna University, the Golden Jublee of the P.G. department was celebrated in the year 1999 after completion of 50 years of its establishment. A seminar was organised and a souvenir was published on this occasion. The 'स्वर्ण जयंती द्वार' of the department always commemorates that event and makes it memorable.

Personal Life:

Prof. Jha was married at the age of 18, after his Intermediate results, to **Late Meera Devi**. His father, **Late Ram Govind Jha**, and mother, **Late Gulab Devi**, were immensely proud and happy to witness their son's dedication and excellence in studies.

Values and Philosophy :

Throughout his life, Prof. Jha has been an embodiment of **hard work and simple living**. A man of high stewardship, integrity and compassion, he has always believed in leading a life of contentment, helping the needy, and spreading happiness to those around him.

His life remains an inspiration for generations of students, teachers and geographers of Bihar and beyond. He was known for his fatherly treatment to students during the long study tour and the instrumental survey camp.

We remember his contribution in development of the department and pay him heartfelt tribute.

Sd /-
(Prof. Karyanand Paswan)
Professor (Retd.) and Former Head
Department of Geography, Patna University

TRIBUTE



Dr. Vidya Sagar Yadav

The higher education fraternity in Bihar lost an eminent educationist, visionary administrator and inspiring guide with the passing of Dr. Vidya Sagar Yadav on October 6, 2026 in Patna at the age of 84 years. An esteemed geographer, educator and administrator, Dr. Yadav devoted his entire life to the pursuit of knowledge, academic leadership and public services. His career represents an exemplary model of scholarly discipline, administrative efficiency and committed public services.

Dr. Yadav was born on 8th March, 1942, into a farmer's family in Sanskrit Nirmali village under the Balua Bazar police station in Supaul district of Bihar. His father, Late Khubi Yadav, was a renowned freedom fighter of this region. Remained attached to the native soil, Dr. Yadav displayed exceptional intellectual calibre from an early age. He passed his Matriculation with first division in 1958 and secured the 9th position in the Intermediate (I.A.) examination at Patna University in 1960. In 1962, he graduated from Patna College with a First Class B.A. Honours in Geography and was honoured with the prestigious Principal's Gold Medal. He completed his M.A. in Geography from Patna University in 1964 and Ph.D. from L.N. Mithila University, Darbhanga, establishing himself as an insightful scholar of the discipline. Alongside academic excellence, he was a dynamic youth leader, serving as the Secretary and later on Vice-President of the Patna University Students' Union; Secretary, Patna College Common Room and Central Committee; Secretary, Social Service League; Secretary, Fine Arts and Photographic Society; Secretary, Post Graduate Hostel Union while also excelling in NCC as the best cadet awardee and representing university teams in football and volleyball.

Dr. V. S. Yadav began his professional journey on September 12, 1964 as a Lecturer in Geography at Nalanda College, Biharsharif. In 1965, he joined H.D. Jain College, Ara, where he served until June 14, 1973. Over his 38 years long career, he shifted from a passionate classroom teacher to one of the most respected administrators in the educational landscape of Bihar. His nearly 28 years of administrative service encompassed

a number of significant jobs including Deputy Registrar at Lalit Narayan Mithila University, Darbhanga, Controller of Examinations at Ranchi University, Ranchi and Registrar at both Patna University and Tilka Manjhi Bhagalpur University, Bhagalpur. He served as the Director of Higher Education, Government of Bihar, Patna from November 1994 to May 2001 and performed an important role in strengthening higher educational institution, governance, examination's integrity and statewide academic policy and its implementations.

Throughout his tenure in teaching and governance, Dr. Yadav remained widely respected for his procedural clarity and supportive approach towards students and faculty members alike. To honour his lifelong contribution to the discipline of Geography and to encourage young talents in the field, the Association of Geographers, Bihar & Jharkhand (AGBJ) has started the "DR. VIDYA SAGAR YADAV EMERGING GEOGRAPHER'S AWARD" since 2017. With his sad demise, academic bodies across the state, including the Department of Geography, Patna University and Patna College, H.D. Jain College, Ara etc. convened condolence meetings to pay homage and honour his institutional contributions.

Dr. Yadav leaves a legacy of integrity, scholarship and administrative stewardship that continues to guide the academic fraternity. The entire academic fraternity extends its heartfelt condolences. We remember his contribution to the development of the subject of geography and as well as higher education in Bihar. We pay him our heartfelt tribute.

Sd /-

(Prof. Md. Nazim)

Professor & Former Head

Department of Geography

Patna University

JOURNEY OF THE ASSOCIATION OF GEOGRAPHERS, BIHAR & JHARKHAND

Sl. No.	Venue	President	Presided over	Convener	General Secretary	Treasurer	Date	Remarks
1.	Patna University Patna	Prof. P. Dayal	Prof. P. Dayal	Prof. R. B. P. Singh			25-04-1999	Foundation Meeting
2.	Patna University Patna	Prof. L. N. Ram	Prof. L. N. Ram	Prof. G. P. Jha	Prof. R. B. P. Singh	Prof. D. P. Singh	23-24 Nov., 1999	1st Annual Conference
3.	B. R. A. Bihar Univ. Muzaffarpur	Prof. L.C.C.N. Sahdeo	Prof. L. N. Ram	Prof. B. P. Mishra	Prof. R. B. P. Singh	Prof. D. P. Singh	17-18 March, 2001	2nd Annual Conference
4.	Magadh Univ. Bodh Gaya	Prof. L. N. Ram	Prof. L. N. Ram	Prof. M. Prasad	Prof. R. B. P. Singh	Prof. D. P. Singh	16-17 March, 2002	3rd Annual Conference
5.	Rajendra College, Chapra (J. P. Unit)	Prof. R. N. P. Sinha	Prof. R. N. P. Sinha	Prof. B. L. Sinha	Prof. R. B. P. Singh	Prof. D. P. Singh	4-5 Dec., 2003	4th Annual Conference
6.	T. M. Bhagalpur Univ., Bhagalpur	Prof. V. N. P. Sinha	Prof. V. N. P. Sinha	Prof. R. B. Mandal	Prof. R. B. P. Singh	Prof. D. P. Singh	18-19 Oct., 2004	5th Annual Conference
7.	Vinoba Bhave Univ., Hazaribag	Prof. R. Gauntia	Prof. R. Gauntia	Dr. Kamla Prasad	Prof. R. B. P. Singh	Prof. D. P. Singh	9-10 Oct., 2005	6th Annual Conference
8.	V. K. S. University Ara	Prof. S. N. Prasad	Prof. S. N. Prasad	Prof. B. K. Singh	Prof. K. N. Paswan	Prof. Md. Ataullah	27-28 Dec., 2006	7th Annual Conference

9.	M. J. K. College, Bettiah (BRA Bihar)	Prof. Bahura Ekka	Prof. Rana Pratap	Dr. B. N. Choubey	Prof. K. N. Paswan	Dr. Md. Ataullah	3 - 4 Feb., 2007	8thAnnual Conference
10.	Nalanda Open Univ., Patna	Prof. Rana Pratap	Prof. Rana Pratap	Prof. R. B. P. Singh	Prof. K. N. Paswan	Dr. Md. Ataullah	9 - 10 Dec., 2007	9th Annual Conference
11.	Magadh University Bodh Gaya	Prof. N. Sharma	Prof. N. Sharma	Prof. Rana Pratap	Prof. K. N. Paswan	Dr. Md. Ataullah	6 - 7 Dec., 2008	10th Annual Conference
12.	L. N. Mithila Univ. Darbhanga	Prof. R. B. Mandal	Prof. R. B. Mandal	Prof. M. N. Pandey	Prof. K. N. Paswan	Dr. Md. Ataullah	5 - 6 Dec., 2009	11th Annual Conference
13.	T. M. Bhagalpur Univ., Bhagalpur	Prof. G. N. Singh	Prof. G. N. Singh	Prof. G. N. Singh	Prof. D. P. Singh	Dr. Md. Ataullah	11 -12 Dec., 2010	12th Annual Conference
14.	V. B. University Hazaribag	Prof. R. B. P. Singh	Prof. R. B. P. Singh	Dr. O. P. Mahto	Prof. D. P. Singh	Dr. Md. Ataullah	11 - 12 Feb., 2012	13th Annual Conference
15.	J. P. University Chapra	Prof. G. P. Jha	Prof. G. P. Jha	Dr. C. D. Singh	Prof. D. P. Singh	Dr. Md. Ataullah	9 - 10 Feb., 2013	14th Annual Conference
16.	Nirmala College Ranchi (R. U.)	Prof. U. P. Singh	Prof. U. P. Singh	Dr. Debjani Roy	Prof. D. P. Singh	Prof. M. K. Sinha	1 -2 Dec., 2013	15th Annual Conference
17.	Kolhan University Chaibasa	Prof. Kamla Prasad	Prof. Kamla Prasad	Dr. Susanna Hansdak	Prof. D. P. Singh	Prof. M. K. Sinha	Jan. 31 & Feb. 1 2015	16th Annual Conference
18.	B. N. Manal Univ. Madhepura	Prof. Sudeepta Adhikari	Prof. Sudeepta Adhikari	Dr. Bhagwat Pd. Yadav	Prof. D. P. Singh	Prof. M. K. Sinha	19 -20 Dec. 2015	17th Annual Conference

19.	Kisan College Sohsarai, Nalanda	Md. Ishtiaque	Md. Ishtiaque	Dr. Anoop Kr. Singh	Dr. Md. Ataullah	Dr. M. K. Sinha	22 - 23 Oct., 2016	18thAnnual Conference
20.	A. N. College Patna	Prof. Tuntun Jha 'Achal'	Prof. Tuntun Jha 'Achal'	Prof. Poornima Shekhar Singh	Dr. Md. Ataullah	Dr. M. K. Sinha	08 - 09 Oct., 2017	19th Annual Conference
21.	Chas College Chas, Bokaro	Prof. K. N. Paswan	Prof. K. N. Paswan	Dr. S.K. Sharma	Dr. Md. Ataullah	Dr. M. K. Sinha	01 - 02 Dec., 2018	20th Annual Conference
22.	Magadh University Bodh Gaya	Prof. Shio Muni Yadav	Prof. Shio Muni Yadav	Prof. Vidya Singh	Dr. Md. Ataullah	Dr. M. K. Sinha	12 -13 Oct., 2019	21st Annual Conference
23.	T. M. Bhagalpur Univ. Bhagalpur	Prof. D. P. Singh	Prof. D. P. Singh	Dr. Sanjay Kumar Jha	Dr. Md. Ataullah	Dr. M. K. Sinha	29 - 30 Sept., 2021	22ndAnnual Conference
24.	S. B. College Ara	Prof. S. K. Sharma	Prof. S. K. Sharma	Prof. Navin Kumar	Dr. M. K. Sinha	Dr. Uday Kumar	15 - 16 Oct., 2022	23rd Annual Conference
25.	Ranchi University Ranchi	Prof. Md. Ataullah	Prof. Md. Ataullah	Ms. Mery Shalini P Kerketta	Prof. M. K. Sinha	Dr. Uday Kumar	4- 5 Nov., 2023	24th Annual Conference
26.	Patna University Patna	Prof. S.N. Pandey	Prof. S.N. Pandey	Prof. Md. Nazim	Prof. M. K. Sinha	Dr. Shailesh Kumar	27- 28 Oct., 2024	25th Annual Conference
27.	Vinoba Bhave Univ., Hazaribag	Prof. S.N. Choudhary	Prof. S.N. Choudhary	Dr. Saroj Kr. Singh	Prof. M. K. Sinha	Dr. Shailesh Kumar	11- 12 Oct., 2025	26th Annual Conference

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An examples is given below:

a. Hartshorne, Richards. (1950), 'The Functional Approach in Political Geography'. Annals, Association of American Geographers. Vol-40. pp. 95-130.

b. Honey, R. (1981), 'Alternative Approaches to Local Government Change' in A.D. Burnett and P.J. Taylor (eds) Political Studies from Spatial Perspectives. New York: Wiley. pp. 37-50.

c. Kare, U.et al (2016), 'Urban Sprawl: A Temporal Study of the impact of the IT parks in Pune using Remote Sensing'. Transactions (Journal of the Institute of Indian Geographers). Vol. 38. No.1. pp. 25-38.

d. Patel, S.B. and Singh, S.B. (2016), 'Changing course of river Ganga and its impact on human settlement between Mirzapur and Saidpur', The Geographer. Vol. 63, No.1. pp. 36-43.

e. Taylor, Peter j. (1985), Political Geography: World economy, nation-state and locality, London: Longman. pp. 45-49.

10. Tables and Figures/Maps shall be numbered as Table-1, Table-2 and likewise Figure-1, Figure-2, in the text, and be put at the appropriate place of explanation and discussion.

11. Any word (typical) used in the text must be in italics, and be defined in the same page of the text at the end, where it is used.

Plagiarism Policy :

All the submitted manuscripts for publication are checked for plagiarism after submission and before starting review. The Editorial Board will judge any case of plagiarism on its limits. If more than 10% plagiarism is detected by the editorial board members, reviewers or Editors-in-Chief, in any stage of the articles process-before or after acceptance, during editing or even at the proof stage, the article(s) will be summarily rejected.

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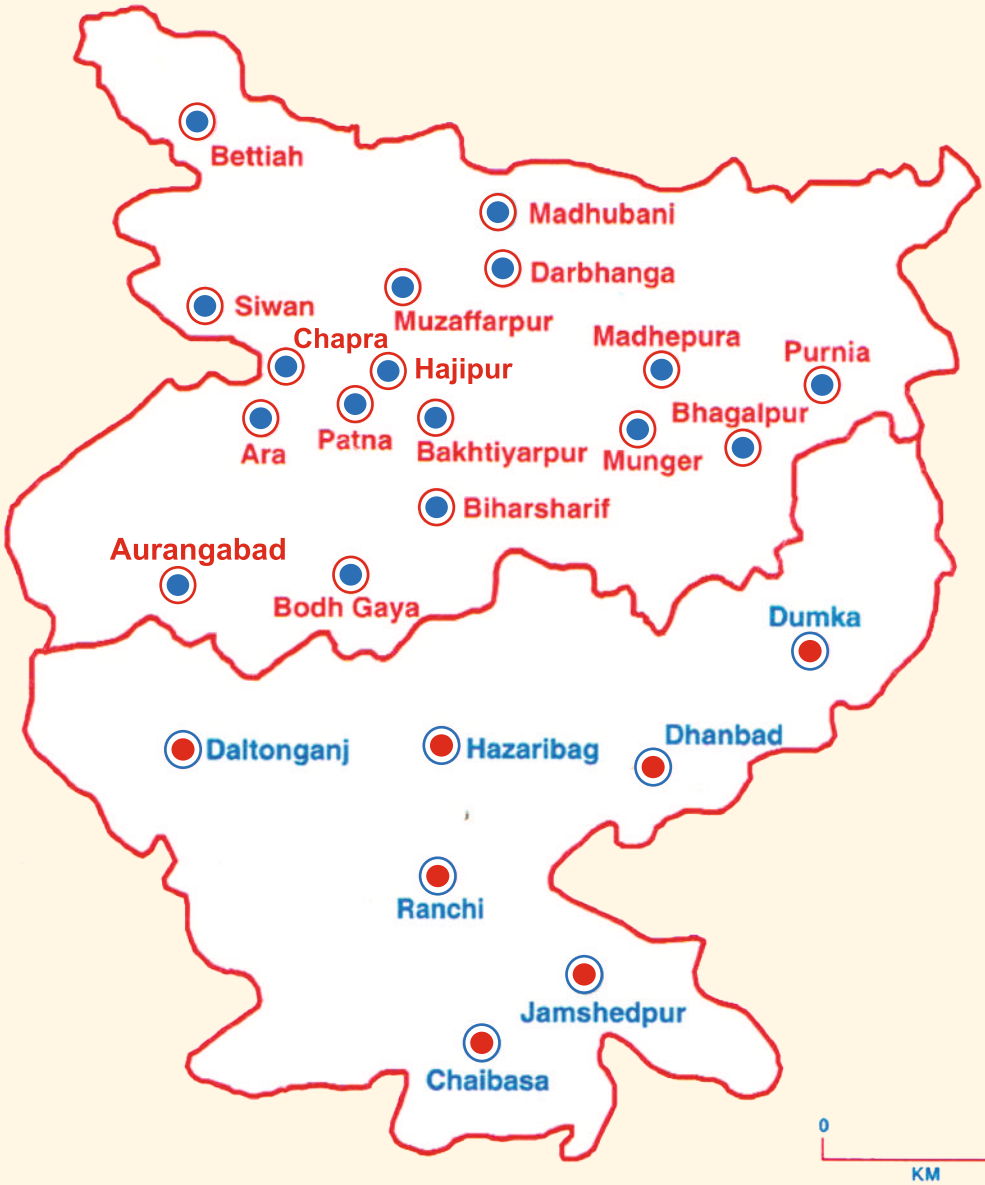
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(B) All Past Presidents of the Association of Geographers, Bihar and Jharkand.

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