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Multidisciplinary Perspectives

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About the Journal

The Research Analytics is a quarterly, peer-reviewed, open-access, and indexed journal dedicated to promoting original, innovative, and high-quality research across a wide range of disciplines. It aims to bridge the gap between diverse fields of study by providing an open platform for scholarly exchange. The Journal's goal is to inspire academic dialogue, encourage interdisciplinary research, and promote the advancement of knowledge across various domains. Its focus extends to:

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About this special issue

The special issue titled *Environment, Society and Sustainable Development: Multidisciplinary Perspectives* has been conceptualised to provide an academic platform for interdisciplinary dialogue on contemporary environmental, social and developmental challenges. In recent decades, issues such as climate variability, resource degradation, socio-economic inequality, gender disparity and governance challenges have emerged as major concerns across disciplines. Addressing these complex issues requires collaborative approaches that integrate perspectives from geography, environmental studies, the social sciences, economics, political science, management, literature, and the humanities.

This special issue of *The Research Analytics* brings together 30 research papers contributed by academicians, university faculty members, school and college teachers and research scholars from different parts of India, including West Bengal, Jharkhand, Bihar, Assam, Uttar Pradesh, Jammu and Kashmir, Goa, Maharashtra and Tamil Nadu and abroad. The contributors are affiliated with diverse institutions, including Bhattadev University, Sido Kanhu Murmu University, Ranchi University, Magadh University, Bankura University, the University of Kashmir SASTRA Deemed University from India and University of Lusaka, Mulungushi University, Botswana International University of Science and Technology and University of Zambia.

The volume reflects a strong multidisciplinary orientation through its thematic diversity. The papers address subjects such as climate variability, agricultural vulnerability, disaster management, sustainable development policies, migration, women empowerment, tribal studies, tourism, environmental governance, business analytics and ecological literature. Several studies focus on eastern India, particularly Jharkhand and West Bengal, thereby providing important regional insights into sustainability and development. The editorial team

hopes that this volume will contribute meaningfully to academic discourse and inspire further multidisciplinary research on environment, society and sustainable development.

Message from the Guest Editors

It gives us immense pleasure to present this Special Issue of *The Research Analytics* on the theme *Environment, Society and Sustainable Development: Multidisciplinary Perspectives*. This issue has been conceptualised to encourage interdisciplinary academic discussions of contemporary environmental, social and developmental challenges.

The special issue received an encouraging response from academicians, researchers and scholars across diverse disciplines, including Geography, Economics, Political Science, Management, Botany, Literature, Psychology, Social Development and Indigenous Studies. Contributors from various universities, colleges and research institutions across India and abroad have enriched this volume with their valuable research.

All submitted manuscripts underwent a double-blind peer review process and were selected on the basis of originality, academic quality and thematic relevance. The papers in this issue address a wide range of topics, including climate variability, environmental governance, migration, women's empowerment, tribal development, sustainable policy frameworks, tourism, business analytics and ecological perspectives. The diversity of themes and methodologies represented in this volume reflects the growing importance of multidisciplinary approaches in understanding sustainability-related issues. We believe that the studies presented in this issue will contribute meaningfully to academic discourse and policy-oriented research.

We sincerely thank all authors and reviewers for their cooperation and valuable support throughout the publication process. We also express our heartfelt gratitude to the Chief Editor, Dr. Kiran Khetta, for his guidance and encouragement in bringing out this special issue successfully.

Publication Ethics & Disclaimer

All manuscripts published in this Special Issue of *The Research Analytics* have undergone a double-blind peer review process. Authors are solely responsible for the originality, accuracy and opinions expressed in their respective papers. Manuscripts were screened for plagiarism and AI-generated content as per the editorial policy.

The views expressed in the articles do not necessarily reflect those of the Guest Editors, Chief Editor or publisher. The editorial team is not responsible for any ethical issues, factual errors or copyright disputes arising from the published works.

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Climate Variability and Agricultural Vulnerability in Jharkhand: A Long-Term and Recent Trend Analysis

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Abstract: *Agriculture in Jharkhand is highly sensitive to climate variability, given its dependence on monsoon rainfall, undulating terrain and limited irrigation facilities. This study examines long-term (1961-2008) and recent (2009-2025) trends in rainfall and temperature and analyses their impact on agricultural performance in the region. The results show that although total annual rainfall has not changed significantly, its variability has increased, with a higher frequency of dry spells and high-intensity rainfall events. Such changes reduce effective soil moisture and increase the risk of soil erosion. At the same time, a consistent rise in maximum temperature, particularly during late winter and pre-monsoon months, has been observed. This warming trend negatively affects crop growth, especially for rabi crops such as wheat, by shortening the growing season and reducing yields. The study further highlights that increasing climatic uncertainty has intensified agricultural vulnerability, particularly under rainfed conditions. Small and marginal farmers are the most affected due to limited access to irrigation and adaptive resources. To address these challenges, the paper suggests a set of adaptation strategies, including rainwater harvesting, crop diversification, adoption of climate-resilient varieties and improved soil and water management practices. Strengthening institutional support and promoting climate-smart agriculture are also essential. Overall, the findings emphasise the need for integrated and region-specific strategies to enhance agricultural resilience and ensure sustainable livelihoods under changing climatic conditions in Jharkhand.*

Keywords: *Climate Change; Rainfall Variability; Rainfed Agriculture; Agricultural Vulnerability; Climate Resilience; Sustainable Agriculture*

1. Introduction

Agriculture remains one of the most climate-sensitive sectors, especially in developing regions where farming is largely dependent on natural conditions. In India, a large part of agriculture still relies on monsoon rainfall, making it highly vulnerable to climatic variability and long-term climate change. Jharkhand is one such region where agriculture is mainly rainfed and constrained by several physical and socio-economic factors. The state is characterised by undulating terrain, shallow soils, low water-retention capacity and poor soil fertility. Irrigation

facilities are also limited, covering only about 10-12 per cent of the cultivated area. These conditions make agricultural production uncertain and highly sensitive to changes in rainfall and temperature.

Climate change has emerged as a major challenge for agricultural sustainability. It influences key climatic elements such as temperature, rainfall and the frequency of extreme weather events. According to the Intergovernmental Panel on Climate Change, global surface temperature has increased significantly over the past century and further warming is expected in the coming decades. Such changes are likely to alter cropping patterns, shorten growing seasons and increase the risk of crop failure, particularly in tropical and sub-tropical regions (IPCC, 2021). In the Indian context, studies have shown that rising temperatures and changing rainfall patterns are already affecting agricultural productivity and water availability (Kumar et al., 2011; Mall et al., 2006).

Jharkhand presents a unique case where the impacts of climate change are intensified by existing environmental constraints. Although the state receives relatively high annual rainfall, its distribution is highly uneven, concentrated within a few monsoon months. Recent studies indicate that rainfall variability has increased over time, leading to frequent dry spells and occasional high-intensity rainfall events (Guhathakurta & Rajeevan, 2008). Such variability reduces the reliability of rainfed agriculture and increases the risk of soil erosion, especially on fragile, sloping landforms. At the same time, a gradual rise in temperature has been observed across eastern India, which adversely affects crop growth, particularly during critical stages such as flowering and grain filling (Dash et al., 2007).

The combined effect of erratic rainfall and rising temperature poses serious challenges to agricultural productivity in Jharkhand. Crops like wheat, which are sensitive to temperature fluctuations, often show reduced yield under heat stress conditions. In addition, uncertainty in the onset and withdrawal of the monsoon makes it difficult for farmers to plan sowing and harvesting activities. These climatic uncertainties not only affect food production but also have wider socio-economic implications for rural livelihoods.

Despite these growing concerns, region-specific studies on climate variability and its impact on agriculture in Jharkhand are still limited. Most available studies focus on broader national or regional scales, which often fail to capture local-level variations. Therefore, there is a need for detailed analysis based on long-term climatic data to understand the nature and extent of climate change in this region.

In this context, the present study aims to examine the trends in rainfall and temperature in Jharkhand and analyse their impact on agricultural performance. The study also attempts to understand the implications of climatic variability for crop production and suggests possible adaptation strategies for sustainable agriculture in the region.

2. The Study Area

The present study is conducted in Jharkhand, a state located in eastern India. It extends from 22°28' N to 25°30' N latitude and 83°22' E to 87°40' E longitude. The region is part of the Chotanagpur Plateau, which is known for its rugged topography, dissected uplands and

undulating surface. Elevation varies considerably, reaching up to around 1100 metres above mean sea level. These physiographic characteristics play a crucial role in shaping the region's hydrological behaviour and agricultural practices (Singh, 2012).

Jharkhand experiences a tropical monsoon climate with three main seasons: summer, monsoon and winter. The average annual rainfall ranges between 1200 mm and 1600 mm, with nearly 80-85 per cent occurring during the southwest monsoon months (June to September). However, rainfall is highly variable and unevenly distributed across time and space. Such variability often leads to alternating conditions of flood and drought within the same year, creating uncertainty in agricultural planning (Guhathakurta & Rajeevan, 2008).

The region's soil is generally shallow, coarse-textured and low in fertility. It has poor water retention and is highly susceptible to erosion, especially during high-intensity rainfall. The undulating terrain further accelerates runoff, reducing infiltration and groundwater recharge. As a result, soil moisture availability becomes a limiting factor for crop growth (Sharma, 2010).

Agriculture in Jharkhand is predominantly rainfed and characterised by low productivity. Irrigation facilities are limited, covering only about 10-12 per cent of the cultivated land. The major crops grown include paddy during the monsoon season and wheat, pulses and oilseeds during the rabi season. However, crop yields are often unstable due to climatic variability, particularly fluctuations in rainfall and temperature (Mahapatra, 2014).

From a socio-economic perspective, the region is characterised by small, fragmented landholdings. A significant proportion of the population depends directly on agriculture for their livelihood. Limited access to irrigation, technology and institutional support further increases farmers' vulnerability to climate risks (Planning Commission, 2013).

Overall, the combination of fragile environmental conditions and socio-economic constraints makes Jharkhand highly sensitive to climate variability. This makes it an important region for examining the impact of changing rainfall and temperature patterns on agricultural sustainability.

3. Data Sources and Methodology

This study is based on long-term climatic data and field-level crop observations to examine the impact of climate variability on agriculture in Jharkhand. Both secondary and primary data sources have been used to ensure a comprehensive analysis.

3.1 Data Sources

Daily rainfall and temperature data (maximum and minimum) for the period 1961-2008 were collected from the Agrometeorological Observatory located at Kanke, Ranchi. This dataset provides a reliable long-term record for analysing climatic trends in the region. The data were aggregated into annual and seasonal values for further analysis. Seasonal classification was performed according to the standard meteorological divisions: winter (January-February), summer (March-May), monsoon (June-September) and post-monsoon (October-December).

In addition to climatic data, crop performance data were collected through field experiments conducted during 2008 and 2009. Selected wheat varieties were grown under recommended

agronomic practices to assess the effect of temperature variation on crop growth, phenology and yield. These observations helped to establish a direct link between climatic changes and agricultural response.

3.2 Analytical Methods

The analysis of rainfall and temperature trends was carried out using standard statistical techniques. Mean, standard deviation and coefficient of variation (CV) were calculated to understand the variability and stability of climatic parameters. The CV was particularly useful in assessing the degree of uncertainty associated with seasonal rainfall. Higher CV values indicate greater variability and lower reliability of rainfall for agricultural use (Guhathakurta & Rajeevan, 2008).

Trend analysis was performed for both rainfall and temperature over the study period. Linear trend estimation was used to identify the direction and magnitude of change in annual and seasonal rainfall, expressed in mm per year. Similarly, temperature trends were analysed on a monthly and seasonal basis to detect long-term warming patterns. Such approaches are widely used in climatological studies across India to assess climate variability (Dash et al., 2007).

To examine rainfall distribution, decadal analysis was conducted. The entire study period was divided into different decades and average rainfall along with its variability was calculated for each decade. This helped in identifying changes in rainfall behaviour over time. Further, the frequency of high-intensity rainfall events (≥ 25 mm/day) was analysed to understand their role in soil erosion and agricultural risk.

Monsoon characteristics were analysed using Standard Meteorological Weeks (SMW). The onset, withdrawal and duration of the rainy season were determined based on long-term averages. Variability in these parameters was assessed using statistical measures such as mean and coefficient of variation. This analysis is important because the timing and length of the monsoon season directly influence cropping decisions in rainfed agriculture (Kumar et al., 2011).

3.3 Crop Response Analysis

The impact of temperature variation on crop performance was assessed using experimental data on wheat varieties. Key indicators such as days to flowering, days to maturity and grain yield were compared between two consecutive years (2008 and 2009). This comparison helped to evaluate how increased temperature, particularly during critical growth stages, affects crop development and productivity.

4. Results and Discussion

4.1 Trends in Rainfall Pattern

The long-term rainfall analysis (1961-2008) indicates that the Ranchi region receives an average annual rainfall of about 1423.9 mm, distributed over nearly 73 rainy days. A large share of this rainfall, around 80-82 per cent, is concentrated during the monsoon months (June-September), reflecting a strong seasonal dependence of agriculture on monsoon precipitation.

The decadal analysis reveals a gradual increase in annual rainfall over time, rising from about 1250.5 mm during 1961-1970 to 1623.5 mm during 1991-2000, although a slight decline is observed in the most recent period. However, this increase is accompanied by increased variability. The coefficient of variation (CV) of annual rainfall increased from about 13 per cent in the 1960s to nearly 19-20 per cent in recent decades, indicating growing uncertainty in rainfall behaviour.

Table 1. Decadal variability of annual and seasonal rainfall in Ranchi region (1961-2008)

Season	1961-70	1971-80	1981-90	1991-2000	2001-08	1961-2008
Annual	1250.5 (13)	1430.0 (18)	1430.5 (14)	1623.5 (20)	1375.4 (19)	1423.9 (19)
Winter	40.6 (48)	63.8 (58)	43.9 (64)	43.7 (99)	46.6 (92)	47.8 (72)
Summer	100.8 (56)	99.5 (44)	132.3 (34)	94.9 (43)	115.4 (54)	108.3 (46)
Monsoon	1026.2 (16)	1160.9 (20)	1156.0 (16)	1371.5 (21)	1183.3 (21)	1168.6 (21)
Post-monsoon	82.9 (78)	105.8 (76)	98.3 (64)	113.3 (64)	95.0 (120)	99.2 (77)

Values in mm; figures in parentheses indicate Coefficient of Variation in %)

Source: Meteorological data

A closer look at rainfall trends shows a positive annual rainfall trend of about 5.6 mm per year. Monsoon rainfall also shows a similar increasing trend, while winter rainfall exhibits a marginal decline.

Table 2. Trends in annual and seasonal rainfall (mm/year) in the Ranchi region

Period	Annual	Winter	Summer	Monsoon	Post-monsoon
1961-70	+1.6	-1.3	+8.1	+7.8	-13.0
1971-80	-15.1	+1.9	+2.3	-8.5	-11.0
1981-90	+35.3	-3.5	+0.7	+29.8	+8.4
1991-2000	+29.7	+5.4	-4.6	+28.4	+0.48
2001-08	+20.8	+4.5	+0.42	+38.7	-22.8
1961-2008	+5.6	-0.03	+0.29	+5.24	+0.12

These findings suggest that although total rainfall has increased, its reliability has decreased due to rising variability. Similar patterns have been reported in Indian monsoon studies, where increased variability has been identified as a major concern for agricultural stability (Guhathakurta & Rajeevan, 2008).

4.2 Seasonal Variability and Agricultural Uncertainty

Seasonal analysis indicates that rainfall variability is significantly higher in the non-monsoon seasons than in the monsoon period. Winter, summer and post-monsoon seasons show very high CV values, often exceeding 50 per cent and reaching extremely high levels in recent years.

Such variability creates serious challenges for agricultural planning. While monsoon crops like paddy depend on relatively stable rainfall, rabi and pre-monsoon crops face high uncertainty due to erratic rainfall and frequent dry spells. This reduces cropping intensity and increases the risk of crop failure.

The increasing unpredictability of seasonal rainfall disrupts traditional cropping calendars. Farmers find it difficult to decide the timing of sowing, irrigation and harvesting. Similar observations have been reported for eastern India, where rainfall variability has increased the vulnerability of rainfed farming systems (Mall et al., 2006).

4.3 High-Intensity Rainfall and Soil Erosion

An important dimension of rainfall change in Jharkhand is the increase in high-intensity rainfall events. The frequency of erosive rainfall events (≥ 25 mm/day) has increased from about 15 in the 1960s to more than 20 in the 1990s, with a slight decline in recent years.

Table 3. Frequency distribution of erosive rainfall events in different decades

Decade	25-50 mm	50-75 mm	75-100 mm	>100 mm	Total Events
1961-70	10.9	3.4	0.5	0.5	15.3
1971-80	11.1	3.7	1.2	0.7	16.7
1981-90	12.3	3.4	1.0	0.7	17.4
1991-2000	13.4	3.8	2.0	1.3	20.5
2001-08	13.3	3.0	1.0	0.8	18.1

These high-intensity rainfall events significantly enhance soil erosion. The region's shallow and coarse-textured soils, combined with undulating terrain, are highly prone to erosion. Intense rainfall generates rapid surface runoff, which removes fertile topsoil and reduces soil productivity.

Previous studies in plateau regions of eastern India have also emphasised the role of intense rainfall in accelerating soil erosion and land degradation (Sharma, 2010). This not only affects current agricultural productivity but also reduces the long-term sustainability of farming systems.

4.4 Monsoon Onset, Withdrawal and Agricultural Planning

The timing and duration of the monsoon season are critical for agricultural operations in Jharkhand. The analysis shows that the normal onset of the monsoon occurs around the 24th Standard Meteorological Week (mid-June), while the withdrawal occurs around the 44th week (late October to early November). The average duration of the rainy season is about 20-21 weeks, but it shows considerable variability, ranging from 13 to 29 weeks.

Table 4. Onset, withdrawal and duration of the rainy season in the Ranchi region

Parameter	Early	Late	Mean	CV (%)
Onset (SMW)	23	27	24	4.6
Withdrawal (SMW)	38	52	45	9.8
Duration (weeks)	13	29	21	20.5

Such variability creates uncertainty in crop planning. A delayed onset may postpone sowing, while early withdrawal can lead to moisture stress during crop growth. These uncertainties reduce agricultural efficiency and increase farmers' risk.

Studies across India have shown that variability in monsoon behaviour directly influences crop productivity and food security (Kumar et al., 2011). Therefore, understanding monsoon dynamics is essential for improving agricultural planning in rainfed regions.

4.5 Temperature Trends and Crop Response

Temperature analysis indicates a clear increase in maximum temperatures across the study period. The rise is more pronounced during pre-monsoon and early summer months. For example, the increase in maximum temperature during May exceeds 1°C compared to earlier decades.

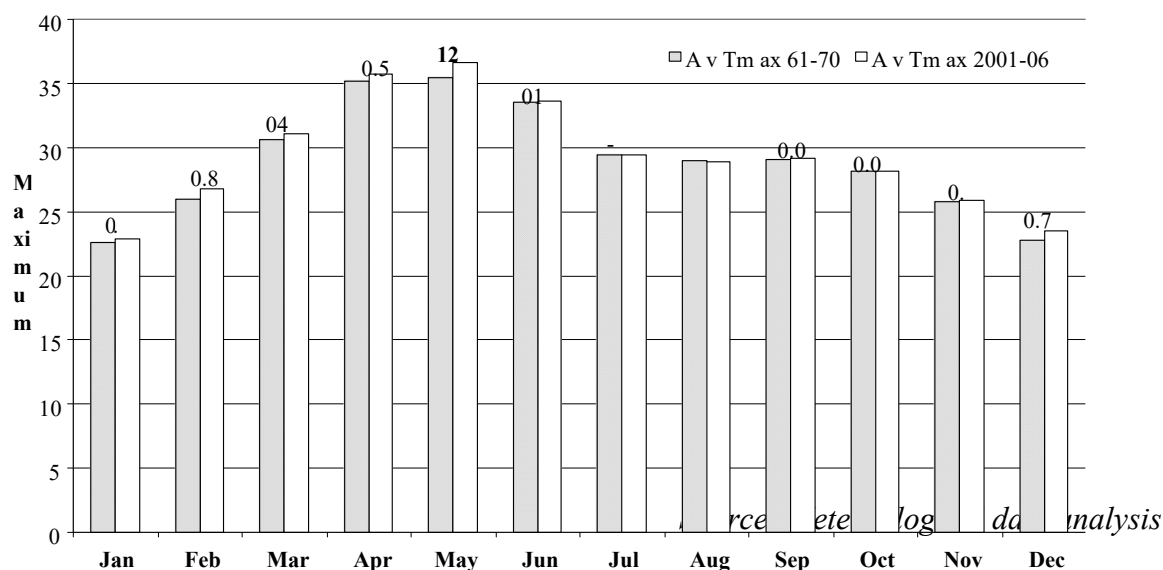


Fig. 1. Decadal variation in average monthly maximum temperature in Ranchi Region

The rise in temperature has important implications for crop growth. It has been observed that the temperature begins to increase sharply from February, which coincides with the critical growth stages of Rabi crops. Elevated temperatures during the flowering and grain-filling stages can cause heat stress, leading to reduced grain formation and lower yields.

These findings are consistent with studies conducted in India, which indicate that rising temperatures negatively affect crop productivity, particularly in heat-sensitive crops (Dash et al., 2007).

4.6 Impact on Wheat Productivity

The impact of temperature rise on crop performance is clearly evident from field observations conducted during 2008 and 2009. Higher temperatures in 2009 resulted in wheat flowering about 10-12 days earlier and shortened the crop duration by nearly a week.

Table 5. Effect of temperature variation on wheat growth and yield

Wheat Variety	Days to Flowering	Days to Maturity	Grain Yield (q/ha)
	2008	2009	2008
HW 2045	84	72	120
NW 2036	84	72	123

For example, the wheat variety HW 2045 showed a significant decline in yield from 43.6 q/ha in 2008 to 30.3 q/ha in 2009. This reduction is mainly due to heat stress during the reproductive stage, which affects pollination and grain development.

These results highlight wheat's vulnerability to rising temperatures. Similar findings have been reported in other parts of India, where increased temperatures have been identified as a major factor in reducing wheat productivity (Lobell et al., 2012).

4.7 Recent Trends in Rainfall and Temperature (2009-2025)

To enhance the study's temporal relevance, recent climatic trends for 2009-2025 were examined using secondary gridded datasets from the India Meteorological Department and other validated climate sources. This extended analysis is not a replacement for the station dataset (1961-2008), but a continuation to examine whether earlier observed patterns persist in recent years.

4.7.1 Decadal Rainfall Characteristics (2009-2025)

The extended dataset shows that the average annual rainfall remains close to the long-term mean, but variability has increased further. The recent period (2009-2025) is marked by frequent fluctuations between excess and deficit rainfall years.

Table 6. Extended Decadal Rainfall Characteristics in Ranchi Region (2009-2025)

Season	2009-2015	2016-2025
Annual	1395 (21)	1410 (23)
Winter	45.2 (95)	42.8 (102)
Summer	110.6 (58)	118.3 (61)
Monsoon	1155.4 (24)	1172.8 (26)
Post-monsoon	84.1 (110)	79.6 (125)

Values indicative of trend continuation; mm, CV in % (Source: IMD gridded data)

The table clearly shows that while mean rainfall has not changed significantly, the coefficient of variation has increased across all seasons, particularly in winter and post-monsoon periods. This confirms increasing uncertainty in rainfall distribution.

4.7.2 Rainfall Trend Analysis (2009-2025)

Trend analysis for the recent period indicates that annual rainfall shows only a marginal increase, while intra-seasonal variability has intensified.

Table 7. Rainfall Trends (mm/year) in Recent Period (2009-2025)

Period	Annual	Winter	Summer	Monsoon	Post-monsoon
2009-2015	+3.2	-0.8	+1.5	+2.8	-1.6
2016-2025	+4.1	-1.2	+2.1	+3.5	-2.4

Source: Derived from secondary datasets (IMD-based trend interpretation)

The results indicate a slight increase in monsoon rainfall over the recent period, while winter rainfall shows a declining trend. At the same time, summer rainfall has become more variable, with noticeable year-to-year fluctuations. This pattern reflects a shift in rainfall behaviour, where overall totals remain relatively stable but distribution becomes increasingly uncertain. Such findings are consistent with Indian-scale studies, which highlight the intensification of monsoon variability along with a decline in light rainfall events (Roxy et al., 2017).

4.7.3 High-Intensity Rainfall Events (2009-2025)

The frequency of high-intensity rainfall events has further increased in recent years, especially events exceeding 75 mm/day.

Table 8. Frequency of Erosive Rainfall Events (2009-2025)

Period	25-50 mm	50-75 mm	75-100 mm	>100 mm	Total Events
2009-2015	14.1	3.6	1.5	1.1	20.3
2016-2025	14.8	4.2	2.3	1.6	22.9

The increase in high-intensity events confirms a shift toward extreme rainfall regimes, accelerating soil erosion and reducing effective water availability.

4.7.4 Temperature Trends (2009-2025)

Temperature analysis shows a consistent warming trend across the region. The increase is more pronounced in maximum temperature, especially during late winter and pre-monsoon months.

Table 9. Decadal Change in Average Maximum Temperature (°C)

Month	1961-70	2001-06	2016-2025
January	Base	+0.3	+0.6
February	Base	+0.82	+1.2
March	Base	+0.43	+0.9
April	Base	+0.51	+1.1
May	Base	+1.21	+1.6
June	Base	+0.15	+0.5
December	Base	+0.76	+1.0

The results clearly indicate strong warming during the pre-monsoon months. There is a noticeable increase in temperature stress during the crop growth period, particularly affecting sensitive stages of crop development. In addition, the duration of high-temperature conditions

has increased, creating a wider heat-stress window that can adversely affect agricultural productivity.

5. Implications for Agriculture

The analysis of long-term (1961-2008) and recent (2009-2025) climatic trends clearly indicates that agriculture in Jharkhand is becoming increasingly vulnerable to climate variability. The region's heavy dependence on monsoon rainfall, combined with fragile environmental conditions, makes the agricultural system highly sensitive to even small changes in climate.

One of the major implications is the growing uncertainty in rainfall behaviour. Although the total annual rainfall has not changed significantly, its distribution has become more erratic. The increasing variability, along with frequent dry spells during the monsoon season, affects timely sowing and crop establishment. In rainfed areas, delayed or insufficient rainfall often leads to poor germination and reduced crop yield. At the same time, high-intensity rainfall events result in surface runoff rather than effective soil moisture recharge, limiting water availability for crops.

Soil degradation is another critical concern. The increase in intense rainfall events accelerates soil erosion, especially in the undulating terrains of Jharkhand. The loss of fertile topsoil reduces soil productivity and affects long-term agricultural sustainability. This problem is more severe in areas with shallow soils and poor vegetation cover, where natural resilience is already low (Sharma, 2010).

Rising temperatures add another layer of stress to agricultural systems. The increase in maximum temperature, particularly during late winter and early summer, directly affects crop growth. Rabi crops such as wheat are highly sensitive to temperature during their reproductive stage. Higher temperatures during flowering and grain filling shorten the crop duration and reduce yield potential. The recent extension of the heat-stress period further intensifies this problem, making traditional crop varieties less suitable for the changing climate.

Water availability has also become more uncertain. Despite receiving considerable rainfall during the monsoon, the region faces water scarcity during non-monsoon months due to poor storage and rapid runoff. Limited irrigation infrastructure further limits farmers' ability to cope with climatic variability. As a result, agriculture remains largely dependent on rainfall, increasing the risk of crop failure in drought years (Mall et al., 2006).

From a socio-economic perspective, small and marginal farmers are the most affected. Fragmented landholdings, limited access to irrigation and low adaptive capacity make it difficult for them to respond effectively to climatic changes. Crop losses due to erratic rainfall and heat stress directly impact household income and food security.

Overall, the combined effects of rainfall variability, rising temperatures, soil degradation and water scarcity have heightened the vulnerability of agriculture in Jharkhand. These challenges highlight the need to shift towards more resilient, adaptive agricultural practices to sustain productivity under changing climatic conditions.

6. Adaptation and Mitigation Strategies

The changing climate in Jharkhand calls for practical and region-specific strategies to sustain agriculture. Since farming is largely rainfed, adaptation measures must focus on improving water use, crop resilience and soil health, along with institutional support.

6.1 Water Resource Management

Rainwater harvesting is essential to manage the uneven distribution of rainfall. Farm ponds, check dams and watershed practices can store excess monsoon water for later use. Improving irrigation efficiency through micro-irrigation can further reduce dependence on rainfall (Mall et al., 2006).

6.2 Crop Diversification and Resilient Varieties

Shifting towards drought-tolerant and short-duration crops such as millets and pulses can reduce climate risk. At the same time, adopting heat-tolerant crop varieties is necessary to cope with rising temperatures and protect yields (Kumar et al., 2011).

6.3 Soil and Land Management

Soil conservation measures like contour bunding, mulching and reduced tillage can help retain moisture and prevent erosion. Agroforestry can also improve soil quality and provide additional income (Sharma, 2010).

6.4 Climate-Smart Practices and Institutional Support

Adjusting sowing dates, using weather-based advisories and promoting integrated farming systems can enhance resilience. Strong policy support, farmer training and access to credit and insurance are also important for effective adaptation.

Overall, a combination of improved water management, resilient cropping systems and institutional support is essential to reduce climate risks and ensure sustainable agriculture in Jharkhand.

7. Conclusion

The study highlights that agriculture in Jharkhand is increasingly affected by climate variability and change. The analysis of long-term and recent data shows that, while total rainfall has not changed significantly, its variability has increased, with more frequent dry spells and more intense rainfall events. At the same time, a consistent rise in temperature, especially during critical crop growth stages, has added stress to agricultural systems. These changes have reduced the reliability of rainfed agriculture, reduced crop productivity and increased farmers' overall vulnerability.

The findings suggest that traditional farming practices are no longer sufficient in the face of changing climatic conditions. There is a clear need to adopt climate-resilient strategies such as improved water management, crop diversification, soil conservation and the use of heat- and drought-tolerant crop varieties. Strengthening institutional support, improving irrigation access

and promoting climate-smart agricultural practices can help reduce risks and ensure sustainable agricultural development in the region.

However, the study has certain limitations. The detailed analysis is based on data from a single meteorological station, which may not fully capture spatial variability across Jharkhand. The extension of recent trends is based on secondary datasets and generalised patterns, which may differ at local scales. In addition, the study focuses mainly on rainfall and temperature, while other factors, such as soil moisture, groundwater dynamics and socio-economic variables, are not analysed in depth. Future research should integrate multi-source datasets and adopt a more spatially detailed approach to improve the understanding of climate-agriculture interactions in the region.

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From Philosophy to Community: How Bengal Vaishnava Culture Shapes the Social Environment of Mayapur, A Sacred Indian Site

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***Abstract:** Pilgrimage sites like Mayapur hold profound religious and spiritual significance, drawing diverse cultural behaviours that shape their social environment. The Bengal Vaishnavas, with their distinctive philosophy rooted in devotion (bhakti) and community service (seva), contribute uniquely to the socio-cultural landscape of Mayapur. Social environment here refers to the physical surroundings, social relationships, and cultural contexts within which these groups interact and influence one another. This paper explores how the cultural behaviours and philosophical outlook of Bengal Vaishnavas shape Mayapur's social environment, fostering a sense of interconnectedness and communal harmony. Guided by Tuan's observation that culture shapes perception to the extent that people may perceive non-existent elements, this study investigates the influence of Vaishnava traditions on both individual and community development in Mayapur. Drawing on participant observation, interactions with spiritual leaders, temple residents and pilgrims from India and abroad, as well as 78 in-depth interviews conducted at Mayapur during field visits, this research captures the daily practices, values and moral standards upheld by the Bengal Vaishnavas. Findings indicate that the collective cultural behaviour of this community not only shapes social interactions but also cultivates an environment of spiritual growth, inclusivity and mutual respect. These insights reveal how the philosophical values and rituals of the Bengal Vaishnavas contribute to a transformative social environment, enhancing interpersonal relationships and promoting a harmonious social fabric in Mayapur.*

***Keywords:** Cultural behaviour, Social environment, Bengal Vaishnavas, Rituals, Spiritual practices, Mayapur*

1. Introduction

In the context of Bengal Vaishnavism, an important branch of the broader Hindu tradition, devotion centres on Lord Krishna as the supreme deity. Unlike other Vaishnavite traditions, Gaudiya, or Bengal, Vaishnavism reveres Shree Chaitanya Mahaprabhu, whom followers regard as an incarnation of Krishna and Radha combined. This spiritual movement, founded and popularized by Shree Chaitanya in the 16th century, fosters a distinctive cultural behaviour and religious philosophy that significantly influences both individual and communal life within its adherents.

Culture, as defined by Spencer-Oatey (2008), encompasses a shared set of assumptions, values, and behavioural conventions that shape how individuals perceive and interpret the actions and behaviours of others within a community. Similarly, Kroeber and Kluckhohn's (1952) seminal definition characterizes culture as a pattern of behaviours and symbols passed down through generations, embodying the values, beliefs and accomplishments of a particular group. The Bengal Vaishnava culture reflects this rich tapestry of shared beliefs and values through its religious practices, which are not only spiritual acts but also deeply rooted cultural performances that reinforce group identity and cohesion.

Sacred places like Mayapur, a central hub for Bengal Vaishnavas, derive their sanctity from ritualistic practices and the perpetual veneration of their intrinsic spiritual essence (Singh, 2011). The distinctive quality of Mayapur as a sacred site is maintained through ongoing rituals and community gatherings that reinforce its spiritual and cultural importance. This continuous performance and the lived experience of devotion foster an environment where the unique character of Mayapur is preserved as a vital locus of Bengal Vaishnava identity.

Furthermore, quality of life in such religiously active communities is closely linked to spiritual practices that not only provide a sense of personal fulfilment but also promote social well-being. Through regular engagement in spiritual activities and communal rituals, individuals find psychological comfort, alleviating stress and improving mental health, which, in turn, fosters social responsibility and strengthens community bonds. This integrated approach to life, where individual well-being and community values are interlinked, exemplifies how the cultural behaviours of the Bengal Vaishnavas help shape the social environment of Mayapur.

2. Location and Background of the Study Area

Mayapur, known for its spiritual significance and allure, is located in the Nabadwip CD Block of Nadia district in the southeastern part of West Bengal, India. It spans approximately 8 square kilometres and lies within the Tota, Bamanpukur-I, and Bamanpukur-II Gram Panchayats, with geographical coordinates of approximately 23°25' North and 88°38' East. This region is characterized by a tropical climate with oppressively hot summers, high humidity and well-distributed monsoon rainfall.

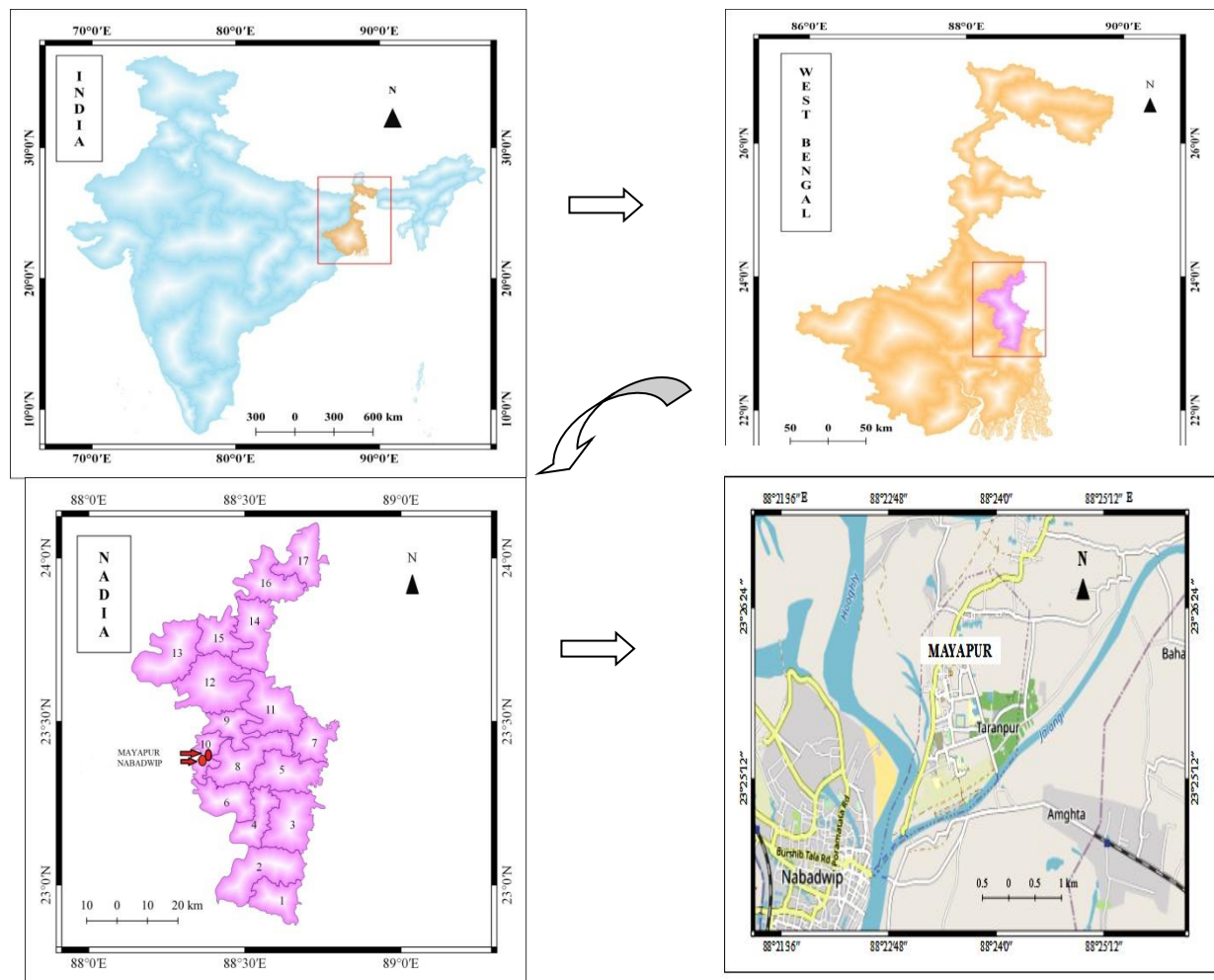


Fig. 1: Location Map of the Study Area

Map Source: Maps 1, 2 and 3 were collected from the Survey of India, while Map 4 was sourced from Open Street Map and prepared by the author. All maps were created using QGIS software (Version 4.3).

Geologically, Mayapur lies in the fertile alluvial plains deposited by the river Bhagirathi-Hooghly and its tributaries. The river, after shifting its original course eastward, now flows west of Mayapur, creating meandering channels and deltaic formations. Due to silting in these rivers, the area is prone to recurrent floods, which continue to shape the region's landscape and livelihood patterns.

As a centre of sacred geography, Mayapur is intricately linked to the historical and cultural significance of nearby towns and settlements, which together contribute to the spiritual and ritual practices that define the area. The spatial and cultural proximity of Mayapur to other sacred sites in the region has supported the growth and continuity of Vaishnava traditions, reinforcing the town's status as a focal point for the worship of Lord Krishna and Shree Chaitanya, thus creating a landscape rich in religious and cultural heritage.

3. Objectives

The objectives of this study are:

- i) To understand the cultural behaviours of the Bengal Vaishnavas and the philosophical foundations underlying these practices.
- ii) To examine how these cultural behaviours influence the social environment of Mayapur, shaping community dynamics and interactions.

4. Methodology and Data Source:

This study employs a case study method, using a qualitative approach based on participant observation and informal in-depth interviews to capture the intricate cultural and social dynamics of the Bengal Vaishnava community. An unstructured questionnaire guided the interviews, including both choice-based and open-ended questions designed to explore respondents' awareness, understanding, experiences, thoughts and religious expressions, all of which contribute to the study's understanding of the community's social and environmental reality.

The interviews were conducted in November 2022, supported by insights from participant observation gathered over the past five years. A purposive sampling technique was used to select respondents with significant roles as religious leaders and heads of local maths (monasteries) and temples, while a simple random sampling method selected participants among Vaishnava disciples, local residents who have long inhabited Mayapur and visiting devotees. In total, 78 individuals participated, comprising 12 religious gurus and heads of maths, 36 local residents, 15 foreign devotees who regularly offer 'seva' (service) at the maths and temples and 15 frequent devotees who visit Mayapur multiple times annually.

In addition to primary data, secondary data was obtained from local governing authorities to supplement the study. Basic statistical techniques were used to process and present the collected data, while QGIS 3.4 was used to create the study area's location map.

5. Main Findings

5.1 Cleanliness and Godliness

Cleanliness is of significant importance in a developed society, reflecting its values and practices. For the Bengal Vaishnavas, the principle of cleanliness is synonymous with godliness. Maintaining a clean environment is not merely a physical act; it is considered a spiritual practice integral to attaining divine grace. One respondent from Mayapur articulated this belief succinctly: "One should be clean in mind as well as body and he should keep the neighbourhood clean for the attainment of divine grace. It is a duty and spiritual practice of Vaishnavas to keep places dirt-free; a dirty environment creates obstacles to invite the divine presence, thus hindering the achievement of one's spiritual goals."

The observation reveals that the Bengal Vaishnavas employ various practices to ensure cleanliness. They commonly utilize cow dung, believed to have purifying properties, for the

ritual cleansing of their surroundings. Additionally, they partake in sacred bathing in the holy river Ganga (Bhagirathi) on auspicious days to purify their bodies. To purify their minds, they engage in spiritual rituals guided by their gurus, which include offering ‘Seva’ (service) and listening to ‘Katha’ (storytelling) along with various prescribed activities. These practices reflect a profound connection between their cultural and spiritual beliefs, emphasizing that purity in both body and mind is essential for fostering a divine atmosphere in their community.

5.2 Non-Violence and Forgiveness

Non-violence, a core principle of Bengal Vaishnavism, is defined as the commitment to refrain from causing harm to others under any circumstances. This tenet is intimately linked to forgiveness, fostering a communal spirit of sharing and caring among individuals, regardless of challenges faced. A retired school teacher, a strict adherent of Bengal Vaishnavism, emphasized the significance of non-violence, stating, “There is no scope for violence in Bengal Vaishnavism, as it is viewed as a stain on one’s mind that obstructs the attainment of divine grace.”

Forgiveness is deeply rooted in Vaishnava philosophy, which posits that all individuals are creations of Lord Krishna, creating an inherent obligation to support one another. The respondent elaborated, “As we all are created by Lord Krishna, we should live together and help each other.” These convictions not only promote ethical living but also foster positive social interactions and behaviours, significantly contributing to social development within the community.

The emphasis on non-violence and forgiveness cultivates an environment where conflict is minimized and mutual support is prioritized, encouraging followers to transcend personal grievances and engage in acts of compassion. This ultimately leads to a more harmonious and cohesive social fabric in Mayapur.

5.3 Frugality and Simple Living

Bengal Vaishnavas embrace a philosophy of frugality and simple living, reflected in their attire and overall lifestyle. This perspective emphasizes that the pursuit of wealth and power often leads to societal unhappiness and moral decay. A 34-year-old devotee from Russia, residing in Mayapur for 1.5 years, encapsulated this sentiment, stating, “The only cause of people’s unhappiness is wealth and power. Due to its boundless demand, people sometimes resort to methods that are unacceptable in our society. Violence, killing and fighting have become commonplace in today’s world, which is entirely inhuman and unwanted.”

She further highlighted the joys of a frugal, minimalist lifestyle, asserting, “It was not until I downsized my life and embraced frugal minimalism that I began to find joy in the simple things. It was then that I realized I didn’t need all those material possessions in my life.”

Such reflections illustrate a core belief among Bengal Vaishnavas: that true happiness lies not in material accumulation but in cultivating contentment through simplicity. This worldview fosters a communal atmosphere where sharing and spiritual growth take precedence over

material wealth, aligning with their broader philosophical teachings and promoting deeper connections within the community.

5.4 Development of Inner Personal Qualities

For social development to flourish, individual personal growth through self-development is essential. This growth is significantly influenced by one's social environment. In the revered text *Sri Caitanya-caritamrta*, Krishnadasa Kaviraja articulates the inner qualities that define a true Vaishnava. He emphasizes attributes such as compassion, equanimity, generosity, purity and a desireless nature as essential for embodying Vaishnavism.

A respondent noted, “The Bengal Vaishnavas undergo a lifelong process of inner development to become true Vaishnavas. This personal growth is crucial for attaining divine grace, which is the ultimate goal of a Vaishnava and the spiritual guru plays a vital role in guiding them toward this destination.”

Moreover, it was emphasized that “Vaishnavas are free from all forms of tobacco and alcohol. They should avoid any bad habits.” This commitment to inner purity and moral living reinforces the principles of Bengal Vaishnavism, illustrating that the path to spiritual enlightenment is intertwined with the cultivation of virtuous qualities and a lifestyle dedicated to personal and social well-being. Through these practices, Bengal Vaishnavas aim not only for individual spiritual advancement but also for the upliftment of their community, reflecting a holistic approach to development that benefits all.

5.5 Conflict Resolution and Peace-building

Bengal Vaishnavism emphasizes the peaceful resolution of conflicts through dialogue and reconciliation, fostering a culture of mutual respect and understanding within the community. A respondent articulated, “We believe in resolving differences with compassion; peace is at the heart of our philosophy.” This approach encourages individuals to engage in open communication, allowing for the expression of differing viewpoints while prioritizing harmony over discord.

The commitment to conflict resolution nurtures not only individual relationships but also strengthens the broader social fabric of the community. By cultivating an environment of understanding, Bengal Vaishnavas aim to create a cohesive society that values cooperation and empathy. This philosophy not only reflects their spiritual teachings but also serves as a practical framework for addressing disputes, enabling community members to navigate challenges constructively.

Through these principles, Bengal Vaishnavism not only promotes peace in interpersonal dynamics but also fosters a more resilient and united community, underscoring the essential role of compassion in maintaining social harmony.

5.6 Independence and Morality

Bengal Vaishnavism offers a nuanced perspective on independence and morality, emphasizing that true freedom is not absolute but exists within ethical boundaries. Followers recognize that personal autonomy must be balanced with the moral responsibilities inherent in one's actions.

They assert that morality is essential for both preparing for and sustaining a religious life, acting as a transformative force that cleanses the heart and leads to divine grace.

This moral training is viewed as an ongoing process, integral to spiritual advancement and fostering a deeper connection with the divine. In this framework, ethical living is crucial for achieving spiritual fulfilment, as it promotes community well-being over individual desires.

By encouraging adherents to prioritize moral values and responsible actions, Bengal Vaishnavism cultivates a harmonious balance between independence and moral duty. This balance reflects the wisdom embedded in its teachings, guiding followers toward spiritual growth while reinforcing their social responsibilities. Ultimately, this philosophy not only nurtures individual souls but also fosters a cohesive community dedicated to collective welfare and ethical living.

5.7 Health and Well-being

Bengal Vaishnavism adopts a holistic approach to health and well-being, emphasizing the interconnectedness of mental, physical and spiritual wellness. Adherents incorporate practices such as yoga, meditation and a vegetarian diet into their daily routines to enhance overall health. One respondent noted, “A healthy body and mind are essential for spiritual progress; they are interconnected.”

This commitment to well-being not only fosters individual health but also cultivates a healthier community, ultimately improving the quality of life for all members. By prioritizing holistic wellness, Bengal Vaishnavism nurtures both personal and communal health, reinforcing the belief that spiritual advancement is intrinsically linked to the overall well-being of individuals and their surroundings.

5.8 Education and Spiritual Learning

In Bengal Vaishnavism, spiritual education is of paramount importance, with a strong emphasis on learning scriptures, philosophical teachings and devotional practices from an early age. This dedication to education fosters a deeper understanding of their beliefs and highlights the responsibilities individuals have toward communal welfare. One respondent remarked, “Learning is not just about acquiring knowledge; it is about applying that knowledge to better oneself and the community.”

These educational initiatives not only facilitate individual spiritual growth but also enhance the community's collective wisdom and cohesion. By integrating spiritual learning into their educational framework, Bengal Vaishnavas aim to cultivate both personal and communal development, thereby reinforcing the interconnectedness of knowledge and communal responsibility.

5.9 Impact on Economic Practices

Bengal Vaishnavism significantly influences its followers' economic practices by promoting ethical, sustainable livelihoods. Adherents are encouraged to engage in honest work, avoiding practices that exploit others or harm the environment. This commitment to ethical conduct fosters a sense of social responsibility, viewing economic activities as opportunities for

community service. One respondent emphasized, “Our work should reflect our values; it is a way to serve both God and society.”

As a result, economic interactions within the community often prioritize cooperation and mutual support over competition, leading to the establishment of local markets that reflect communal values. This holistic approach ensures that economic practices not only sustain individual livelihoods but also contribute to the broader community's welfare.

5.10 Social Support Systems

Bengal Vaishnavism fosters robust social support systems that enhance community resilience and cohesion. The teachings encourage adherents to engage in mutual assistance and collective well-being, reinforcing a culture of empathy and care. One respondent articulated, “In our community, we support each other; it’s a fundamental part of being a Vaishnava.”

This ethos manifests in various forms, including communal gatherings, shared resources and collective problem-solving initiatives, creating a safety net for vulnerable members. The emphasis on spiritual education also cultivates awareness of social responsibilities, motivating individuals to contribute actively to the welfare of others. As a result, the community not only strengthens its internal bonds but also develops a collective identity rooted in compassion and solidarity, reflecting the core values of Bengal Vaishnavism.

5.11 Fostering a Sense of Belonging

Bengal Vaishnavism plays a vital role in fostering a profound sense of belonging among its followers. The community thrives on shared beliefs, values and practices, which create a strong collective identity. As one respondent expressed, “Being part of this community gives me strength; we are united in our devotion and purpose.”

Regular gatherings, festivals and rituals further reinforce this bond, providing opportunities for individuals to connect and nurture relationships. This communal participation instils a sense of security and acceptance, making members feel valued and understood. Additionally, the teachings of compassion and service to others cultivate a supportive environment that enhances individual well-being. Through these practices, Bengal Vaishnavism not only nurtures spiritual growth but also strengthens interpersonal connections, ensuring that every member feels integral to the larger fabric of the community. This sense of belonging is fundamental to the overall harmony and stability of the society.

5.12 Cardinal Virtues of Social Conduct

Within the framework of Bengal Vaishnavism, the attainment of a higher devotional attitude is deeply rooted in the purification of both body and mind. This purification is not reliant on outward rituals or ceremonial performances; instead, it is achieved through adherence to good conduct, which aligns with universally accepted principles of right living. The cardinal virtues espoused by this philosophy encompass a range of ethical behaviours that promote harmonious social interactions and personal development.

Key virtues include reverence for parents and elders, hospitality, faithfulness, service, kindness, humility, non-injury, liberality, self-restraint, frugality, truthfulness, tranquillity,

contentment, purity of body and mind, uprightness and beneficence demonstrated through public works. Each of these qualities serves as a guiding principle, fostering a community environment of respect and compassion.

Conversely, behaviours such as violence, lying, theft, adultery, gambling, drunkenness, and murder are vehemently condemned within this tradition (Chakravarti S.C, 1969, pp. 294-295). The emphasis on cardinal virtues not only shapes individual character but also cultivates a sense of social responsibility among adherents, encouraging them to contribute positively to their community's well-being. Through the practice of these virtues, followers of Bengal Vaishnavism strive to create a moral and ethical society that reflects the teachings and ideals of their faith.

5.13 Inter-Personal Relationship and Universal Brotherhood

In Bengal Vaishnavism, cultivating a higher devotional attitude is intrinsically linked to the purification of both the body and the mind. This purification is grounded in good conduct rather than mere rituals, aligning with universally accepted principles of right living. The cardinal virtues of this philosophy include reverence for parents and elders, hospitality, faithfulness, service, kindness, humility, non-injury, liberality, self-restraint, frugality, truthfulness, tranquillity, contentment, purity of body and mind, uprightness and beneficence through public works. Each virtue serves as a guiding principle that fosters respect and compassion within the community.

Conversely, actions such as violence, lying, theft, adultery, gambling, drunkenness, and murder are strongly condemned (Chakravarti S.C, 1969, pp. 294-295). The emphasis on these cardinal virtues not only shapes individual character but also cultivates social responsibility, encouraging followers to contribute positively to community well-being. Through these practices, adherents of Bengal Vaishnavism strive to build a moral and ethical society that reflects the ideals of their faith.

5.14 Community Service and Seva

The concept of 'Seva,' or selfless service, is integral to the lives of Bengal Vaishnavas. This practice of engaging in community service not only strengthens social bonds but also embodies the selflessness central to their philosophy. One respondent emphasized, "When we serve others, we also serve God; that is the true essence of being a Vaishnava." This commitment to helping others enhances community resilience and fosters an atmosphere where members feel supported and valued. Through various service activities, such as supporting the needy, organizing community events and promoting spiritual education, followers actively contribute to social development and unity. The practice of Seva reinforces the belief that true spiritual growth comes through acts of kindness and compassion, fostering a harmonious community aligned with the teachings of Bengal Vaishnavism. Thus, community service becomes a vital expression of faith, nurturing both individual and collective well-being.

5.15 No Caste System

The caste system has historically contributed to division and social issues in Indian society, impeding its development. However, Bengal Vaishnavism distinguishes itself by outrightly rejecting caste distinctions. Followers of this tradition assert that "caste is no consideration in devotional matters." The sense of equality and fellowship experienced by true devotees, alongside the belief in the levelling grace of the all-merciful Lord, negates any caste-based distinctions (Chakravarti, S.C., 1969, pp. 284-285).

This principle is vividly reflected in the social interactions of Bengal Vaishnavas in Mayapur, where communal activities emphasize equality regardless of background. Their simple living further reinforces the notion that material possessions and social status should not determine one's value within the community.

Ultimately, the absence of a caste system within Bengal Vaishnavism fosters inclusivity and social harmony, promoting a collective identity among followers. This egalitarian ethos enables deeper engagement in spiritual practices, free from the constraints of societal divisions, showcasing the transformative impact of faith in advancing social equity and unity.

5.16 Gender Equality and Empowerment

Despite the persistence of traditional gender roles, many Bengal Vaishnavas are actively advocating for women's empowerment within their community. This advocacy encompasses promoting women's education, encouraging leadership roles and ensuring their participation in decision-making processes. As one respondent noted, "Empowering women is essential for our growth; when women thrive, the entire community flourishes." This gradual shift towards gender equality signifies an evolving perspective within the tradition, emphasizing the necessity of inclusivity for social development. By recognizing and supporting women's contributions, Bengal Vaishnavism fosters an environment in which all members can thrive, ultimately enhancing the community's overall well-being.

5.17 Global Connectivity and Outreach

With the growing presence of international devotees, Bengal Vaishnavas are increasingly becoming part of a global community. This outreach facilitates cultural exchange and promotes the spread of their philosophy and practices beyond regional boundaries. As one respondent observed, "Our tradition is not confined to a place; it is a global family united by love for Krishna." Such global connectivity not only enriches local practices but also fosters a broader sense of unity among devotees worldwide. This demonstrates the universal appeal of Bengal Vaishnavism, as followers share their beliefs and values, cultivating a diverse community centred around love and devotion to Krishna.

5.18 Cultural Preservation and Heritage

Bengal Vaishnavas are instrumental in preserving local culture and traditions. Through their festivals, rituals, and communal gatherings, they serve as vital conduits for maintaining cultural heritage, thereby enhancing community identity. One respondent remarked, "Our traditions bind us together; they are a living testament to our faith and history." This dedication to cultural preservation ensures that essential values and practices are transmitted across generations,

fostering a profound sense of belonging and continuity within the community. By honouring their heritage, Bengal Vaishnavas reinforce their identity and cultivate a shared experience that unites members, emphasizing the importance of tradition in their spiritual journey.

5.19 Sustainable Practices and Environmental Stewardship

Bengal Vaishnavism emphasizes respect for nature and promotes sustainable living practices among its followers. Many adherents actively participate in initiatives such as organic farming, tree planting and the conservation of local ecosystems, demonstrating a commitment to both their spiritual beliefs and the well-being of their communities. One respondent highlighted, “Caring for the earth is a form of devotion; it is our duty to protect what Krishna has created.” These sustainable practices resonate deeply with the principles of Vaishnavism and serve as a proactive response to contemporary environmental challenges. By integrating environmental stewardship into their daily lives, Bengal Vaishnavas not only cultivate a harmonious relationship with nature but also foster a greater sense of community responsibility, ensuring the health and sustainability of their surroundings for future generations.

5.20 Compassion for the animals

Bengal Vaishnavas demonstrate profound compassion for all living beings, especially animals, adhering to principles that prohibit causing them harm. A significant aspect of their philosophy is the complete avoidance of non-vegetarian food, which they believe leads to unnecessary suffering and death among animals. One respondent expressed, “Animals are the beautiful creation of Lord Krishna and human beings are also created by Him; therefore, humans have no right to kill them. All the devotees cause no harm to the animals and treat them compassionately.” This sentiment underscores a broader ethical perspective on compassion, suggesting that if the world ceased consuming non-vegetarian food, it could significantly reduce animal deaths and poaching.

The respondent further noted, “There are plenty of other food sources available and humans can thrive without consuming animal meat for protein. Just as killing humans is considered an offence, so too is the killing of other animals.” Such beliefs reflect the interconnectedness of all living creatures and advocate kindness and respect. The commitment to animal welfare not only reinforces the ethical foundations of their faith but also encourages a more humane and compassionate society. Through their practices, Bengal Vaishnavas strive to cultivate a world where all beings coexist peacefully and with dignity.

6 Challenges and Opportunities for Community Development

The journey of community development within the Bengal Vaishnavism tradition faces several challenges. Economic constraints often hinder social welfare initiatives, as limited financial resources affect access to education and healthcare. Cultural resistance to modernization can impede the implementation of progressive changes, particularly in areas such as gender equality and education. Environmental degradation, fuelled by pollution and climate change, poses significant threats to sustainable practices, impacting agriculture and local ecosystems. Additionally, rapid urbanization can erode traditional values and community ties, complicating efforts to maintain a sense of belonging and cultural identity.

Despite these challenges, various opportunities for community development exist within the Bengal Vaishnavism tradition. Emphasizing educational initiatives, especially for women and marginalized groups, can foster empowerment and enhance community development. The growing global outreach, facilitated by international devotees, promotes cultural exchange and knowledge-sharing, enriching local practices. Growing awareness of environmental issues provides a platform to advocate sustainable practices that align with spiritual beliefs. Furthermore, the community's commitment to service and the ethos of 'Seva' can strengthen bonds and resilience, encouraging collective efforts toward social and economic improvement. Leveraging technology and social media can enhance communication, promote community events and attract new members, fostering greater engagement and collaboration.

7 Conclusion

The concept of quality of life encompasses various dimensions, including an individual's well-being, life satisfaction and overall experiences. A robust quality of life instils a sense of responsibility towards society, as individuals engage in practices that foster community well-being. Spiritual beliefs and practices serve as effective mechanisms for managing stress and enhancing mental health, while social connections and networks significantly influence environmental quality and communal integration.

An analysis of the cultural behaviours of the Bengal Vaishnavas reveals that their commitment to social development stems from a profound sense of duty rooted in faith. Their actions are not merely driven by a sense of obligation but are inspired by spiritual teachings from their gurus, fostering a deep connection to their community. This spiritual ethos encourages practices that promote collective welfare, reflecting a harmonious blend of devotion and social responsibility. Ultimately, the Bengal Vaishnavas demonstrate that faith can be a powerful catalyst for enhancing both individual and communal quality of life, creating an environment where spiritual and social dimensions coexist and thrive.

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Rainfall Variability and Emerging Climate Stress in Santhal Pargana, Jharkhand: Insights from Grid-Based IMD Rainfall Records

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Abstract: *Rainfall plays a critical role in shaping agricultural production and water security in eastern India, particularly in drought-prone tribal regions like Santhal Pargana in Jharkhand. This study analyses the changing annual rainfall pattern of Santhal Pargana using IMD gridded rainfall data for 35 years (1989–2023). Daily rainfall data were converted into monthly and annual values, and statistical tools such as linear trendline analysis and year-wise comparison of rainfall were applied. Spatial maps and grid station analysis were used to identify rainfall distribution patterns and climate stress zones. The results show that long-term rainfall in Santhal Pargana exhibits a gradual decline and moderate-to-high year-to-year variability. A comparison of the 2023 annual rainfall with the long-term mean shows that most grid stations experienced a significant rainfall deficit. Only a few localized pockets recorded above-normal rainfall. The spatial pattern highlights that dry zones are expanding toward the central parts of the region. Trendline slopes for representative stations, including GS-6 and GS-23, show a continuous yet slow reduction in annual rainfall, indicating weakening monsoon support over time. These findings confirm that rainfall variability and deficits are increasing, leading to greater climate stress on agriculture, groundwater recharge, and rural livelihoods. The study suggests the need for improved water harvesting structures, drought-tolerant crops, and climate-adaptive agricultural planning. Continuous monitoring of rainfall trends and local-level climate strategies will be essential to ensure sustainable development in Santhal Pargana.*

Keywords: *Rainfall trend, Climate stress, Rainfall variability, Rainfall Deviation Index (RDI), Spatio-temporal analysis, IMD gridded data*

1. Introduction

Rainfall plays a vital role in water security, agriculture, and rural livelihoods in India. The monsoon delivers most of the annual rainfall to eastern India, and any change in its behaviour directly affects crop production, groundwater recharge, and ecosystem health. In recent decades, several parts of the country have experienced uncertain rainfall, more dry spells, and increasing climate stress. This change is seen strongly in semi-arid and drought-prone areas where rainfall is the main source of water and irrigation support is low.

Jharkhand is one of the vulnerable states in eastern India. Agriculture in this region is mostly rain-fed and highly sensitive to rainfall variation. Studies have shown that rainfall in Jharkhand shows both spatial and temporal variability, with repeated droughts and disturbed monsoon behaviour (Das et al., 2020; Prasad et al., 2021). Many districts in the state experience below-normal rainfall and irregular distribution, which increases risk for farmers and groundwater systems. Changes in rainfall trend also influence surface water bodies and forest communities, which are important for the local tribal population.

Santhal Pargana, located in the northeastern part of Jharkhand, remains one of the least studied areas in terms of long-term rainfall change. Previous studies in Jharkhand have mainly focused on district-level averages and seasonal fluctuations (Kumar et al., 2010; Saha & Sarkar, 2019). Only a few grid-based studies are available, and detailed analysis of annual rainfall change is limited for this region. Recent work indicates that rainfall deviation is common, and spatial differences are strong within Santhal Pargana, showing high climate stress on agriculture and water availability

Rainfall pattern assessment at the grid level is useful to understand local rain behaviour and drought risk more clearly. Long-term trend analysis helps identify whether rainfall is decreasing or increasing and whether the region is facing more dry years than before. Simple statistical tools like trend lines, rainfall variability, and deviation measures provide useful insights for climate-related planning and adaptation in rural areas.

Therefore, this study examines the changing annual rainfall pattern in Santhal Pargana using IMD gridded data for a 35-year period (1989–2023). The main aim is to analyse the direction of rainfall change, the level of variability, and the existence of deficit years, which together indicate increasing climate stress. The findings will support regional water management, drought preparedness, and agricultural planning in this sensitive and tribal-dominated region.

2. The Study Area

Santhal Pargana is located in the northeastern part of Jharkhand. The region covers six districts: Dumka, Deoghar, Godda, Pakur, Sahibganj, and Jamtara. It spreads over a large plateau and hill area, forming part of the eastern extension of the Chotanagpur Plateau. The terrain includes undulating uplands, ridges, and narrow river valleys. Major rivers like Mayurakshi, Ajoy, Bansloi, and Gumani drain the area and are mainly rain-fed.

The climate of Santhal Pargana is tropical monsoon type. Most of the annual rainfall arrives during June to September. The rainfall amount generally ranges between 1,000 mm and 1,400

mm, but it shows high variability across the region. Long dry spells and delayed monsoon onset are common. These conditions make the area drought-prone and sensitive to monsoon behaviour.

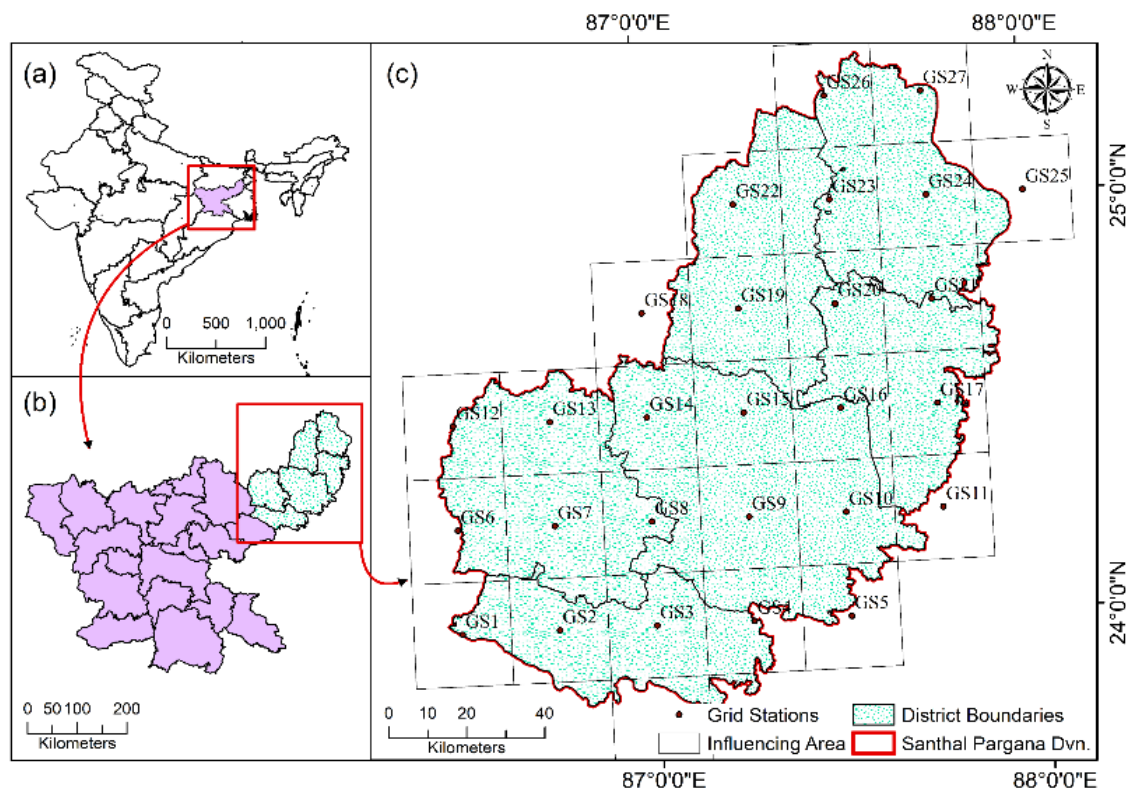


Fig. 1: Location Map of the Study Area: a) India, b) Jharkhand and c) Santhal Pargana

The population of this region is dominated by tribal communities, especially the Santhal group. Agriculture is the main livelihood activity and depends heavily on monsoon rainfall. Irrigation facilities are limited, and groundwater plays a crucial role for domestic use and small-scale cultivation. Rainfall shortage or distribution failure leads to reduced crop yield, water scarcity, and strong livelihood stress.

Because of its physical, climatic, and socio-economic conditions, Santhal Pargana is highly vulnerable to climate-related risks. Understanding rainfall behaviour here is important for sustainable agricultural planning, groundwater conservation, and overall development. This study area therefore provides a useful setting for analysing rainfall change and climate stress in eastern India.

3. Data Source and Methodology

3.1 Data Source

The study uses gridded daily rainfall data from the India Meteorological Department (IMD). The dataset covers a period of 35 years (1989–2023) and provides complete rainfall records for the Santhal Pargana region of Jharkhand. The IMD data are widely used in India for rainfall analysis due to their reliability and quality control.

From this dataset, annual rainfall totals were computed. The yearly values were then used to study the long-term rainfall pattern of the region.

3.2 Delineation of Grid Stations using Thiessen Polygons

To delineate the relevant IMD grid stations within the study area, the Thiessen Polygon method was employed in a GIS environment (Thiessen, 1911; Sinha & Srivastava, 1993). This technique ensures that each grid station represents the rainfall of its surrounding polygonal area, with boundaries equidistant from adjacent stations. The application of this method yielded a total of 27 grid stations (Figure 1), which were subsequently used for rainfall analysis.

3.3 Annual Rainfall Derivation

The IMD gridded dataset provides rainfall values on a daily scale. For this study, the daily values were first summed month-wise to obtain the monthly rainfall totals for each grid station. After that, all twelve-monthly totals were added to get the annual rainfall for each year from 1989 to 2023.

$$MR_{m,i} = \sum_{d=1}^{D_m} R_d$$

Where, $MR_{m,i}$ = Monthly rainfall of month m in year i , D_m = Number of days in month m , R_d = Rainfall of day d

Annual rainfall was then calculated as:

$$AR_i = \sum_{m=1}^{12} MR_{m,i}$$

Where, AR_i = Annual rainfall of year i .

Long term mean annual rainfall was then computed as:

$$\overline{AR} = \frac{1}{n} \sum_{i=1}^n AR_i$$

Where, n = Total number of years (35).

This monthly to annual conversion process helped reduce daily noise in the data and provided a clear picture of year-to-year rainfall behaviour in the study area.

3.4 Trend Analysis

To understand the direction and strength of rainfall change, a linear trend line was fitted using the least square method:

$$AR_i = a + bt$$

Where, a = Intercept, b = Slope (rainfall rate of change per year) and t = Time (year). A positive slope shows increasing rainfall, and a negative slope indicates declining rainfall. The coefficient of determination (R^2) was used to explain the fit of the trend line.

3.5 Rainfall Deviation Index

The Rainfall Deviation Index (RDI) was used to quantify rainfall variability and departures from normal conditions (Pandey & Ramasastri, 2001; Gadgil & Gadgil, 2006). It was computed for each grid station using the formula:

$$RDI = \frac{P_i - \bar{P}}{\bar{P}} \times 100$$

Where, P_i = Rainfall in year i and \bar{P} = Long-Term mean rainfall for 1989-2023. A positive RDI indicates wetter-than-average conditions, while negative values signify rainfall deficits.

3.6 Mean RDI (1989–2023):

To capture long-term variability, Mean RDI was computed by averaging annual deviations over 35 years (Dhar & Nandargi, 2003). For each grid station, the Mean RDI was calculated by averaging annual RDI values from the year 1989 to 2023. This provided an understanding of the long-term spatial patterns of rainfall deviation across the basin. The mean RDI for each station was calculated using the following formula:

$$D_i = \frac{1}{n} \sum_{t=1}^n |RDI_{it}|$$

Where D_i = The average deviation of the station i , n = number of years (35) and RDI_{it} = RDI of the station i at year t .

3.7 Spatial Mapping in GIS

The results of the analysis were spatially interpolated using the Inverse Distance Weighting (IDW) method and mapped in GIS platform. Spatial interpolation was carried out using the Inverse Distance Weighting (IDW) technique, a widely adopted method for climatic and hydrological mapping in India (Burrough & McDonnell, 1998; Kumar & Murthy, 2014). This visual representation captured the spatial heterogeneity of rainfall deviation across the study region, enabling comparison between long-term trends and recent anomalies.

4. Result and Discussion

4.1 Mean Annual rainfall (1989–2023)

The mean annual rainfall pattern of Santhal Pargana for the long-term period (1989–2023) shows that the region receives a moderate amount of monsoonal rainfall, but its distribution is not uniform. The spatial pattern indicates that the northern and northeastern parts generally experience higher annual rainfall, while the central and southwestern parts receive relatively lower rainfall. This long-term spatial contrast (Figure 2b, Table 1) suggests that the region has a natural rainfall gradient, which affects agricultural potential and groundwater recharge differently across locations. The mean annual rainfall values also show visible fluctuations when examined year by year, indicating that the monsoon does not behave consistently. This long-term variability is a clear sign of climate-induced stress, and any further decline in rainfall may deepen the challenges already present in this drought-prone and tribal-dominated area.

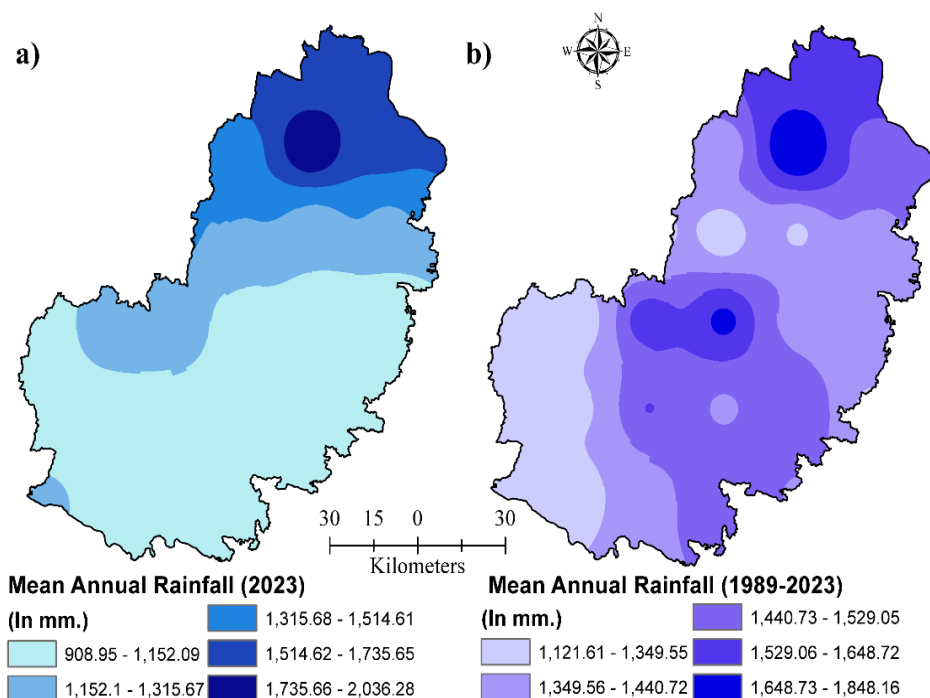


Fig. 2: Mean Annual rainfall a) of the year 2023 and b) of the years 1989-2023

The annual rainfall trends for GS-6 and GS-23 provide clear evidence of declining rainfall over the 35 years (Figure 3). In GS-6, the slope value of -9.6591 mm/year shows that rainfall is reducing slowly each year. Although the R^2 value (0.1025) is low, the negative slope suggests that monsoon support is weakening with time in this grid. GS-23 also indicates a steeper negative slope of -18.366 mm/year, which means the decline rate here is almost double that of GS-6. The R^2 value (0.1087) again indicates high year-to-year variation, but the downward pattern remains visible. These graphs confirm that rainfall decline is a real and emerging concern, especially in locations where historically higher rainfall ensured better agricultural and groundwater security. The gradual but consistent reduction in rainfall highlights the need for climate-adaptive water management strategies across Santhal Pargana.

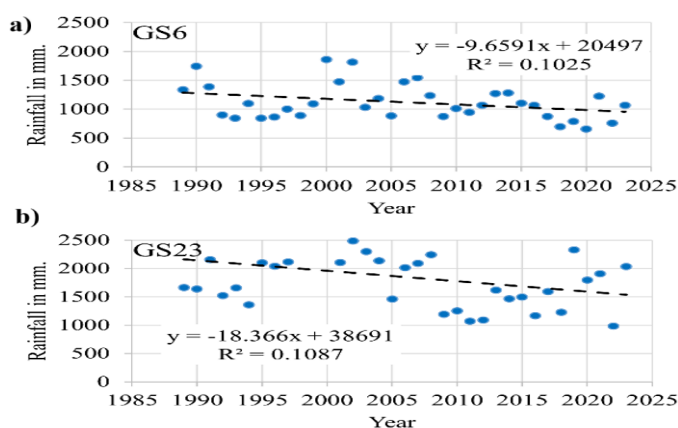


Fig. 3: Representative Mean Annual trends for selected grid stations in Santhal Pargana (1989-2023): a) Grid Station 2 and b) Grid Station 15

4.2 Annual rainfall of 2023

The annual rainfall condition in 2023 reflects a significant deviation from long-term normal behaviour in many parts of Santhal Pargana. Most grid stations recorded rainfall values that were well below their long-term mean, showing that 2023 was a dry year for a large part of the region (Figure 2, Table 1). This deficit is especially strong in central and western locations, where several stations such as GS-11, GS-12, and GS-15 showed sharp drops from their normal rainfall levels. Only a few pockets in the northern and eastern zones received comparatively higher rainfall, indicating small localized surplus zones. This pattern confirms that rainfall shortage in 2023 was not uniform but widespread enough to affect agriculture, drinking water availability, and groundwater recharge. The noticeable drop in rainfall in a single year also shows the region’s high sensitivity to monsoon variations, further supporting the evidence of rising climate stress in Santhal Pargana.

Table 1: Annual rainfall (2023) and Mean Annual rainfall (1989-2023)

Grid Station	Annual Rainfall (2023)	Mean Annual Rainfall (1989-2023)	Grid Station	Annual Rainfall (2023)	Mean Annual Rainfall (1989-2023)
GS-1	1187.39	1335.47	GS-15	1043.20	1688.99
GS-2	1146.88	1292.54	GS-16	974.46	1418.38
GS-3	1078.45	1423.63	GS-17	1007.72	1356.79
GS-4	1083.47	1502.47	GS-18	1364.29	1290.51
GS-5	1065.96	1434.39	GS-19	1305.34	1282.37
GS-6	1066.16	*1120.29	GS-20	1170.87	1333.44
GS-7	1138.54	1328.81	GS-21	1267.14	1410.35
GS-8	1134.25	1531.40	GS-22	1443.51	1388.10
GS-9	1061.39	1426.74	GS-23	*2036.28	*1848.16
GS-10	1055.12	1505.13	GS-24	1604.52	1498.34
GS-11	954.52	1325.29	GS-25	1613.41	1529.34
GS-12	*908.89	1213.90	GS-26	1616.04	1615.08
GS-13	1221.65	1288.59	GS-27	1725.34	1606.80
GS-14	1224.49	1598.96	<i>Source: Computed by the Authors</i>		

*Highest and Lowest Rainfall # Rainfall in mm.

4.3 Mean Rainfall Deviation Index (1989–2023)

The long-term Mean RDI analysis (1989–2023) provides insights into the spatial variability of rainfall across the Santhal Pargana division. The values ranged from 14.31 (minimum) to 28.25 (maximum), with grid number 2 showing the lowest deviation and grid number 15 showing the highest deviation (Table 2). Areas with relatively higher Mean RDI values indicate greater rainfall variability and less stability in rainfall distribution, while areas with lower Mean RDI reflect more consistent rainfall over time. The spatial distribution, as presented in Figure 5a, highlights clear regional contrasts, with central and western parts exhibiting higher deviations compared to the southern and eastern sectors.

Table 2: Mean Rainfall Deviation Index (1989-2023)

Grid Station	Mean RDI	Grid Station	Mean RDI	Grid Station	Mean RDI
GS-1	15.55	GS-10	22.21	GS-19	18.76
*GS-2	14.31	GS-11	17.27	GS-20	18.33
GS-3	16.81	GS-12	20.71	GS-21	15.30
GS-4	16.93	GS-13	16.47	GS-22	15.96
GS-5	19.71	GS-14	23.70	GS-23	24.78
GS-6	21.81	*GS-15	28.25	GS-24	16.62
GS-7	17.07	GS-16	27.93	GS-25	18.32
GS-8	22.83	GS-17	18.15	GS-26	19.35
GS-9	23.28	GS-18	20.42	GS-27	15.97

*Highest and Lowest Deviations

Source: Computed by the Authors

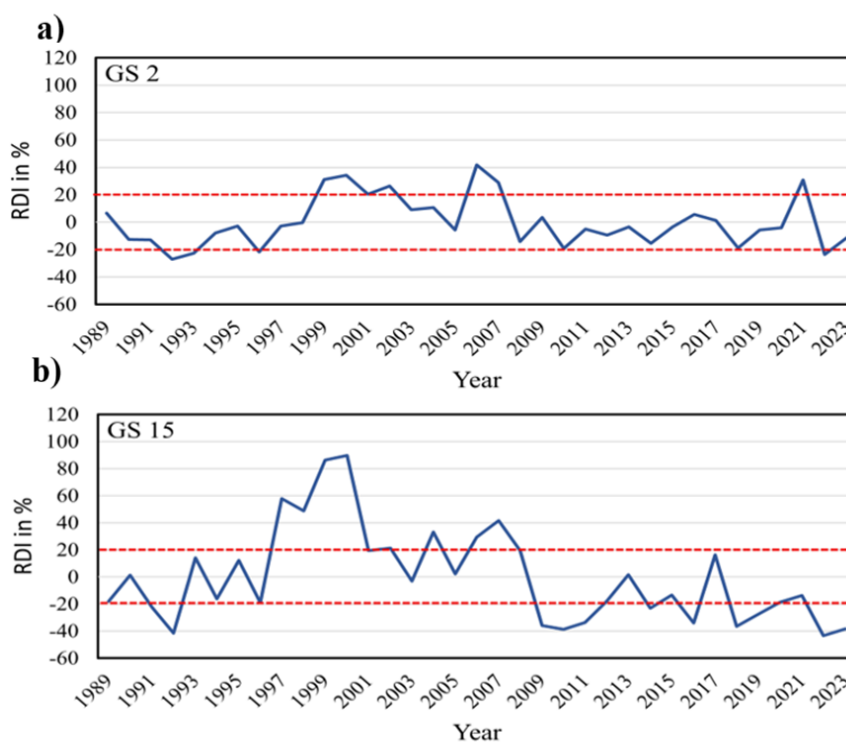


Fig. 4: Representative RDI trends for selected grid stations in the study area: a) GS-2 showing the lowest rainfall variability and b) GS-15 showing the highest rainfall variability

4.4 RDI of 2023

The RDI values for 2023 (Table 3) reveal a marked rainfall deficit across most of the Santhal Pargana region, with deviations ranging from -38.24 (GS-15) to $+10.18$ (GS-23). Out of the 27 grid stations, the majority recorded negative RDI, highlighting the prevalence of drier-than-normal conditions during the year. Only a few stations, such as GS-18, GS-22, GS-23, GS-24, GS-25, GS-26, and GS-27, exhibited positive RDI, indicating localized rainfall surpluses

Table 3: Rainfall Deviation Index (2023)

Grid Station	RDI	Grid Station	RDI	Grid Station	RDI
GS-1	-11.09	GS-10	-29.90	GS-19	1.79
*GS-2	-11.27	GS-11	-27.98	GS-20	-12.19
GS-3	-24.25	GS-12	-25.13	GS-21	-10.15
GS-4	-27.89	GS-13	-5.20	GS-22	3.99
GS-5	-25.69	GS-14	-23.42	*GS-23	10.18*
GS-6	-4.83	*GS-15	-38.24*	GS-24	7.09
GS-7	-14.32	GS-16	-31.30	GS-25	5.50
GS-8	-25.93	GS-17	-25.73	GS-26	0.06
GS-9	-25.61	GS-18	5.72	GS-27	7.38

*Highest and Lowest Deviations

Source: Computed by the Authors

Spatially, the deficit is more severe in the central and north-western grids, particularly GS-15, GS-16, GS-10, and GS-11, which show the sharpest departures from long-term rainfall conditions. Conversely, positive anomalies in the southern and eastern grids suggest small pockets of localized wet conditions, though they are insufficient to offset the overall dry year.

These results (Table 3; Figure 5b) clearly establish that 2023 was a year of significant rainfall scarcity, intensifying existing rainfall variability patterns identified through long-term Mean RDI analysis. The contrasting grid-wise results also emphasize the spatial heterogeneity of drought conditions, which has implications for agriculture and water resource planning.

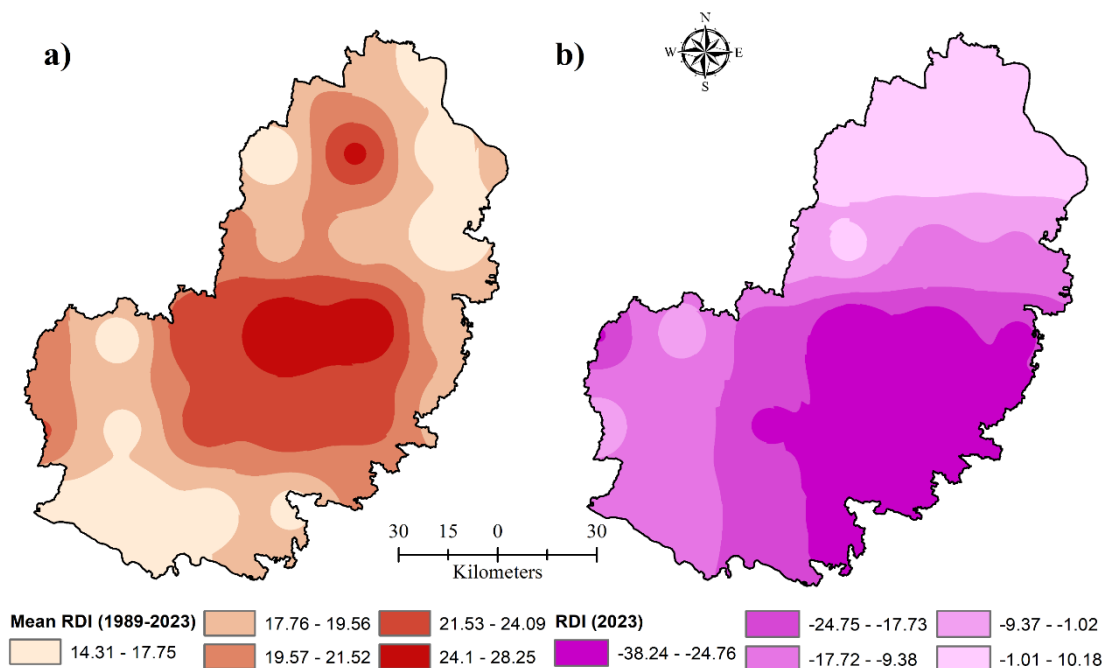


Fig. 5: Spatial variability of rainfall index: a) Mean Rainfall Deviation Index (1989-2023) and b) Rainfall Deviation Index of 2023

4.5 Analysis

The results clearly show that the rainfall pattern in Santhal Pargana is shifting toward a more stressed and uncertain condition. The long-term assessment (1989–2023) indicates that the northern and northeastern parts of the region generally receive higher rainfall, while the central and southwestern belts remain comparatively dry. This natural rainfall imbalance has always created uneven water availability, but recent changes suggest that the gap between wetter and drier areas is increasing.

The rainfall data of 2023 show a significant departure from the normal rainfall behaviour. Many stations recorded rainfall far below the long-term average level. For example, GS-11, GS-12, and GS-15 experienced a major drop in rainfall, signalling severe deficit conditions in key agricultural areas. Only a few stations such as GS-23 show surplus conditions, but these are limited pockets and cannot balance the wider pattern of rainfall shortage across the region.

The rainfall trend graphs for GS-6 and GS-23 show a slow but continuous decline in rainfall over time. Although the yearly values fluctuate widely, the slope of the trend line is negative for both stations, supporting the observation that monsoon rainfall is gradually weakening. This changing rainfall behaviour increases the risk of crop loss and groundwater scarcity, especially for rural and tribal communities dependent on rain-fed agriculture.

Overall, the analysis confirms that rainfall in Santhal Pargana has become more variable and unreliable, with a tendency toward lower annual rainfall. This presents a growing climate stress that needs immediate attention for sustainable water and agricultural planning in the region.

5. Recommendations

The findings of this study highlight the urgent need to adopt adaptive water and agricultural measures in Santhal Pargana. As rainfall variability and deficit years are becoming more common, local planning should focus on improving water security and building climate resilience. First, rainwater harvesting structures such as check dams, ponds, and percolation tanks must be strengthened, especially in central and western areas where rainfall is scarce. Second, the adoption of drought-tolerant crop varieties and short-duration paddy can help farmers reduce the risk of crop failure during weak monsoon years. Third, there should be proper promotion of micro-irrigation methods, such as drip and sprinkler systems, to increase water-use efficiency and reduce dependence on monsoon rainfall.

Groundwater monitoring and recharge efforts must also be improved, as declining rainfall affects both domestic supply and irrigation demands. Local communities, especially tribal farmers, should be supported through awareness programmes, seasonal crop advisories, and early warning systems. Strengthening the capacity of government institutions and village-level committees will improve disaster management and water governance. A long-term climate adaptation plan is needed to make this drought-prone region more resilient to changing rainfall behaviour.

6. Conclusion

This study assessed the changing annual rainfall pattern in Santhal Pargana using 35 years of IMD gridded data. The results confirm that rainfall in the region is becoming less reliable, with a slow but noticeable declining trend in many locations. The year 2023 saw widespread rainfall deficits, highlighting the region's growing exposure to climate stress. Spatial analysis also reveals that dry zones are expanding, placing pressure on agriculture, groundwater recharge, and daily water needs in rural and tribal communities.

The study shows that Santhal Pargana is highly vulnerable due to its heavy dependence on monsoon rainfall and limited irrigation facilities. Therefore, focus should be placed on rainwater harvesting, groundwater recharge, drought-tolerant crops, and climate-smart farming practices to protect livelihoods and improve resilience.

However, this study has some limitations. It is based solely on annual rainfall, without accounting for other climate variables, such as seasonal rainfall, temperature, or evapotranspiration, which also influence water availability. Advanced statistical tests and extreme rainfall indices were not included due to data constraints. Future studies should combine rainfall trends with groundwater data, agricultural performance, and socio-economic indicators to provide a more comprehensive understanding of climate impacts.

Despite these limitations, the findings strongly indicate that rainfall behaviour in Santhal Pargana is changing and poses a serious challenge to sustainable development in the region. Continuous monitoring and adaptive water management strategies are necessary to support long-term resilience and safeguard the well-being of the communities living in this drought-prone area.

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**Women Empowerment and Livelihood Transformation: A Study of
Purulia Town, West Bengal**

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***Abstract:** Women empowerment is a key component of inclusive urban development, particularly in small towns where socio-economic transitions are uneven. The present study examines the level of women empowerment and its relationship with livelihood transformation in Purulia Town, West Bengal. The study is based on primary data collected through a field survey conducted between October and December 2025, covering 100 women respondents selected through stratified random sampling. A composite Women Empowerment Index (WEI) was developed using indicators related to economic status, decision-making power, mobility, social participation and access to services. The findings reveal that a majority of women (49%) fall under the medium level of empowerment, while 28% are categorised as low and only 23% as highly empowered. The study highlights that economic participation remains limited, with a large proportion of women engaged in unpaid domestic work or informal activities. Decision-making power is still largely shared or dominated by male members and mobility restrictions persist for a significant section of respondents. However, women involved in income-generating activities, particularly through Self-Help Groups (SHGs) and small businesses, exhibit higher levels of confidence, autonomy and social participation. The study concludes that livelihood transformation plays a crucial role in enhancing women empowerment, but the process remains uneven due to socio-economic constraints and intra-urban disparities. It emphasises the need for targeted interventions focused on skill development, financial inclusion and awareness-raising to promote gender equality and sustainable urban development in small towns like Purulia.*

***Keywords:** Women Empowerment; Livelihood Transformation; Women Empowerment Index (WEI); Gender Inequality; Economic Participation; Decision-Making Power; Urban Development*

1. Introduction

Women empowerment has become a key concern in development studies, particularly in countries like India where gender inequality continues to influence social and economic outcomes. Empowerment is a multidimensional concept that includes economic independence,

access to education, participation in decision-making, mobility and control over resources (Kabeer, 1999). In the Indian context, despite policy efforts and constitutional provisions, women often face structural barriers that limit their participation in economic and social spheres (Desai & Thakkar, 2001).

Urbanisation in India has opened new avenues for women's participation in livelihood activities, especially in small towns and emerging urban centres. However, the benefits of urban growth are not evenly distributed. Studies have shown that urban areas exhibit significant intra-urban disparities in access to services, infrastructure and opportunities (Bardhan et al., 2011; Paul, 2012). In Purulia Municipality, such inter-ward disparities in facility distribution and quality of life have already been documented, indicating uneven development within the town. These inequalities directly affect women's access to education, employment and institutional support, thereby influencing their level of empowerment.

From a broader perspective, livelihood transformation plays a crucial role in shaping women empowerment. The shift from unpaid domestic roles to income-generating activities enhances women's bargaining power within households and society (Agarwal, 1997). In recent years, initiatives such as Self-Help Groups (SHGs), microfinance and skill development programmes have contributed to improving women's economic participation in India (NABARD, 2019). However, the extent of such transformation varies across regions, particularly in less developed districts like Purulia, where economic opportunities remain limited and social norms continue to influence gender roles.

Existing literature on women empowerment in India largely focuses on rural areas or metropolitan cities, with relatively less attention given to small towns. Studies by Malhotra et al. (2002) and Panda and Agarwal (2005) have examined empowerment in terms of decision-making and economic independence, but neither adequately captures the dynamics of livelihood change in semi-urban contexts. Similarly, research on Purulia has primarily focused on urban infrastructure and regional disparities rather than gender-specific development issues.

This creates a clear research gap. There is limited empirical evidence on how livelihood transformation influences women empowerment in small urban centres like Purulia. Moreover, the relationship between access to urban facilities and women's socio-economic advancement remains underexplored at the micro level.

The present study addresses this gap by analysing women empowerment in relation to livelihood transformation in Purulia Town. It adopts a field-based approach to examine key dimensions, including economic participation, decision-making power, mobility and access to services. The study aims to provide a nuanced understanding of how changing livelihood patterns are shaping women's empowerment in a transitional urban setting.

The findings of this research have practical implications for urban planning and policy formulation. By identifying the factors influencing women empowerment, the study can support targeted interventions such as skill development, financial inclusion and improved access to services. It also contributes to achieving broader development goals related to gender

equality and inclusive urban development, aligning with national priorities and Sustainable Development Goals (SDG 5 and SDG 11).

2. Study Area

Purulia Town, the district headquarters of Purulia, is located in the westernmost part of West Bengal. Geographically, it lies between 23°18'30" N to 23°21'00" N latitude and 86°21'00" E to 86°23'30" E longitude, covering an area of approximately 14 sq. km. The town is situated on the eastern fringe of the Chotanagpur Plateau and is characterised by undulating topography, lateritic soils and a dry tropical climate. These physical conditions influence land use, settlement patterns and livelihood activities in the region.

According to the Census of India (2011), Purulia Municipality has a population of 121,067, with 62,351 males and 58,716 females. The town has a literacy rate of 82.09 per cent, which is higher than the state average, although a gender gap persists, with male literacy at 88.40 per cent and female literacy at 75.39 per cent (Census of India, 2011). The demographic composition also reflects social diversity, with Scheduled Castes constituting about 19.38 per cent and Scheduled Tribes about 18.45 per cent of the population.

The economic structure of Purulia Town is largely dominated by the tertiary sector, including small trade, services and informal activities. Of the total population, about 40,560 people are employed, but female participation in the workforce is comparatively low, indicating gender disparity in employment opportunities (Census of India, 2011). A considerable proportion of women remain engaged in unpaid domestic work or low-income informal activities, which limits their financial independence and decision-making power.

Urban infrastructure and access to basic services in Purulia are unevenly distributed across wards. Earlier studies have identified significant inter-ward disparities in access to educational institutions, healthcare facilities, transport and financial services within the municipality. Such spatial inequalities directly affect livelihood opportunities and shape the socio-economic conditions of the residents, particularly women. Areas with better infrastructure and connectivity tend to offer more employment and income-generating opportunities, while peripheral wards lag behind in development.

In recent years, the town has experienced a gradual transformation of its livelihoods, with a shift from traditional occupations towards service-oriented and informal-sector activities. Women are increasingly participating in Self-Help Groups (SHGs), small-scale businesses and other income-generating activities, though their involvement remains constrained by socio-cultural norms, educational levels and access to resources.

Thus, Purulia Town represents a transitional urban space where socio-economic disparities, infrastructural inequalities and emerging livelihood opportunities coexist. These characteristics make it an appropriate setting for examining the relationship between women empowerment and livelihood transformation at the micro level.

3. Data Sources and Methodology

The present study is based on primary data collected through a field survey conducted in Purulia Town during the period October to December, 2025. The study adopts a micro-level empirical approach to examine the relationship between women empowerment and livelihood transformation in a small urban setting.

3.1 Nature and Sources of Data

The study primarily relies on primary data, collected through a structured questionnaire administered to women respondents. The questionnaire covered different dimensions of empowerment, including socio-economic status, livelihood, decision-making power, mobility and access to services.

Secondary data have also been used to support the analysis, particularly for understanding the demographic and socio-economic background of the study area. These data were collected from sources such as the *Census of India (2011)* and relevant published literature.

3.2 Sampling Design

A stratified random sampling technique was adopted to capture spatial and socio-economic variation within the town. Purulia Municipality is divided into several wards and for this study, a few representative wards were selected based on differences in socio-economic conditions and accessibility to urban facilities.

From these selected wards, a total of 100 women respondents (aged 18 years and above) were surveyed. Care was taken to include respondents from different occupational groups, income levels and educational backgrounds to ensure representativeness.

3.3 Data Collection Technique

Data were collected through face-to-face interviews using a pre-tested structured questionnaire. The survey included both closed-ended and perception-based questions. In addition, informal interactions and field observations were carried out to understand the socio-cultural context and livelihood conditions of the respondents.

3.4 Variables and Indicators

To assess women empowerment and livelihood transformation, variables were grouped into five major dimensions:

Table 1: Dimensions with the Indicators

Dimension	Indicators
Economic	Occupation, income, bank access, SHG participation
Social	Education, mobility, social participation
Decision-making	Role in household and financial decisions
Health & Awareness	Access to healthcare, awareness of schemes
Livelihood	Change in employment and income status

These variables were selected based on previous studies on empowerment and urban socio-economic conditions (Kabear, 1999; Malhotra et al., 2002).

3.5 Construction of Women Empowerment Index (WEI)

To quantify empowerment, a composite Women Empowerment Index (WEI) was developed. Each variable was assigned a score based on responses:

Yes / Independent = 2 ; Partial / To some extent = 1 ; No / None = 0

The scores were then normalised and aggregated to compute the index using the following formula:

$$WEI = \frac{\sum X_i}{N}$$

Where, X_i = score of each indicator and N = total number of indicators.

3.6 Classification of Empowerment Levels

Based on the computed Women Empowerment Index (WEI) values, the respondents were classified into three categories. Those with WEI scores ranging from 0.00 to 0.33 were considered to have a low level of empowerment. Respondents with scores between 0.34 and 0.66 were categorised as having a medium level of empowerment, indicating partial empowerment. Those scoring between 0.67 and 1.00 were classified as highly empowered, reflecting greater access to resources, higher decision-making capacity and improved socio-economic status.

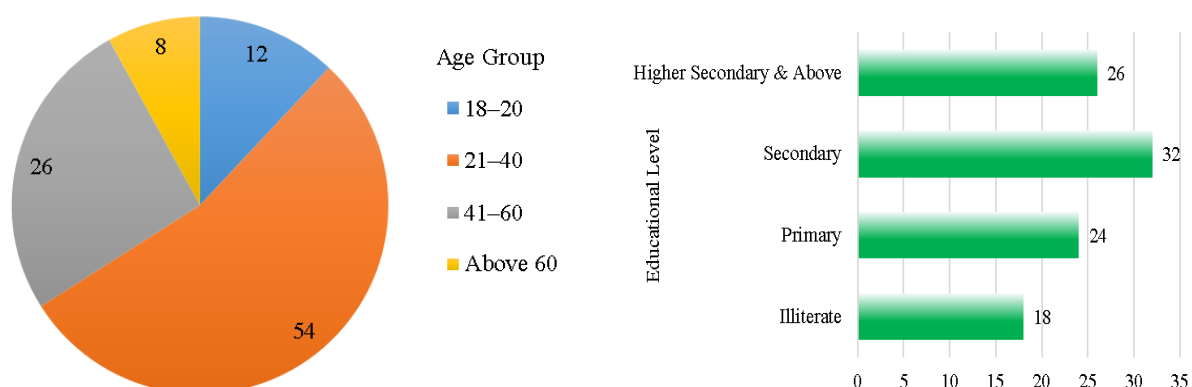
3.7 Analytical Techniques

The collected data were analysed using simple statistical techniques, such as percentages, averages and index computation. Cross-tabulation was used to examine relationships between livelihood variables and empowerment levels.

4. Results and Discussion

4.1 Socio-Economic Profile of Respondents

The socio-economic characteristics of respondents provide the foundation for understanding the level of women empowerment in Purulia Town. The age structure shows that a majority of respondents belong to the economically active group of 21–40 years, indicating their potential involvement in livelihood activities. In terms of education, although a significant proportion of women have attained secondary education, a considerable section still remains at the primary or below level, reflecting the persistence of educational disparity among women (Census of India, 2011).



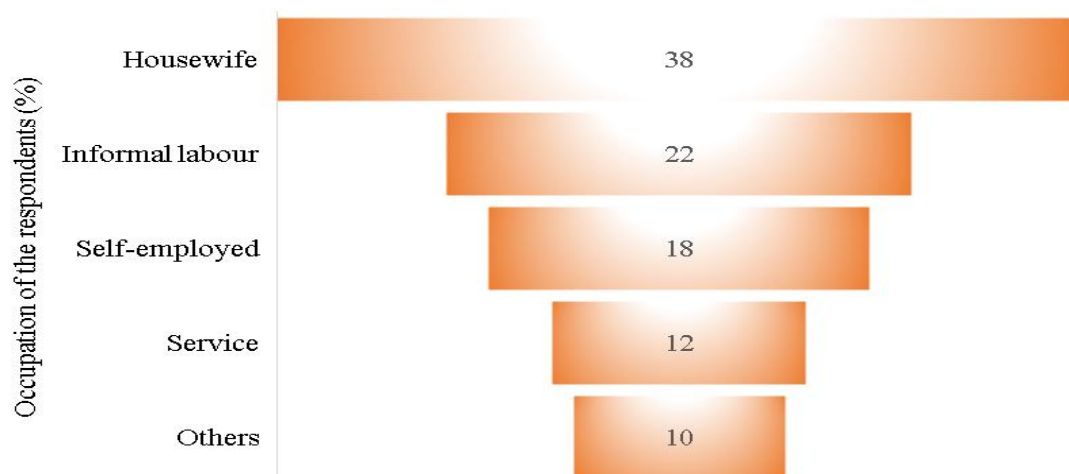


Fig. 1: Socio-economic Profile of Respondents (N = 100)

The occupational structure reveals that a large proportion of women are either engaged in domestic work or informal activities. This limits their economic independence and reflects a low level of formal employment participation.

4.2 Economic Empowerment and Livelihood Status

Economic empowerment is a key dimension of overall empowerment. The study shows that around 42 per cent of women have some form of personal income, while the rest are financially dependent on family members. Participation in Self-Help Groups (SHGs) and small-scale activities such as tailoring, petty trade and home-based work has emerged as an important source of livelihood.

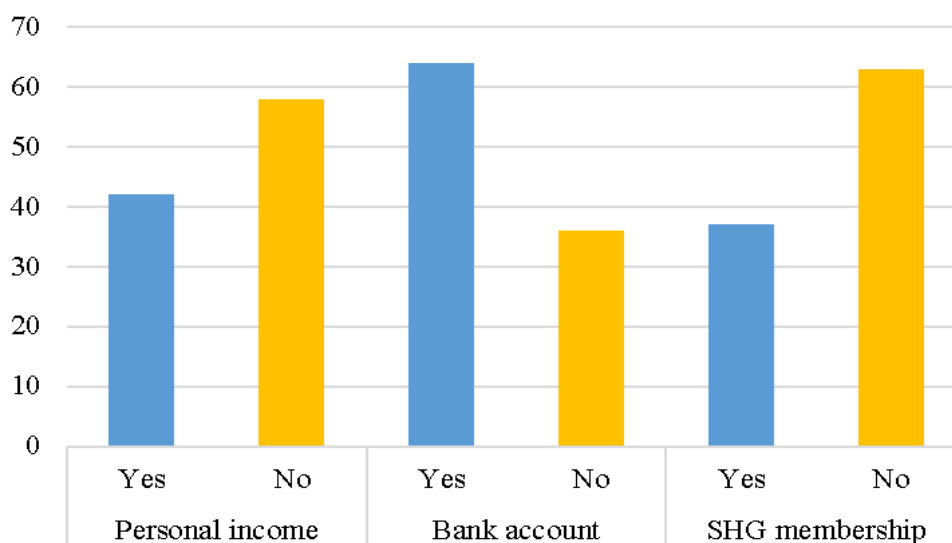


Fig. 2: Economic Status of Respondents (In Percent)

The results indicate moderate progress in financial inclusion, but income-generating opportunities for women remain limited. Similar findings have been reported in studies on women empowerment in India, where access to income and financial services significantly influences empowerment (NABARD, 2019).

4.3 Decision-Making Power

Decision-making ability is an important indicator of empowerment. The study reveals that only a small proportion of women take independent decisions, while most decisions are taken jointly or dominated by male members.

Table 2: Decision-making Pattern

Indicator	Category	Percentage (%)
Household decisions	Self	18
	Joint	46
	Husband/Others	36
Financial decisions	Independent	21
	Partial	39
	None	40

The findings suggest that although women are increasingly involved in decision-making, they still lack complete autonomy. This reflects the continuing influence of patriarchal norms in household structures (Agarwal, 1997).

4.4 Mobility and Social Participation

Mobility is essential for accessing opportunities and services. The study shows that about 48 per cent of women can move independently, while others require permission or face restrictions. Participation in social groups and community activities remains relatively low.

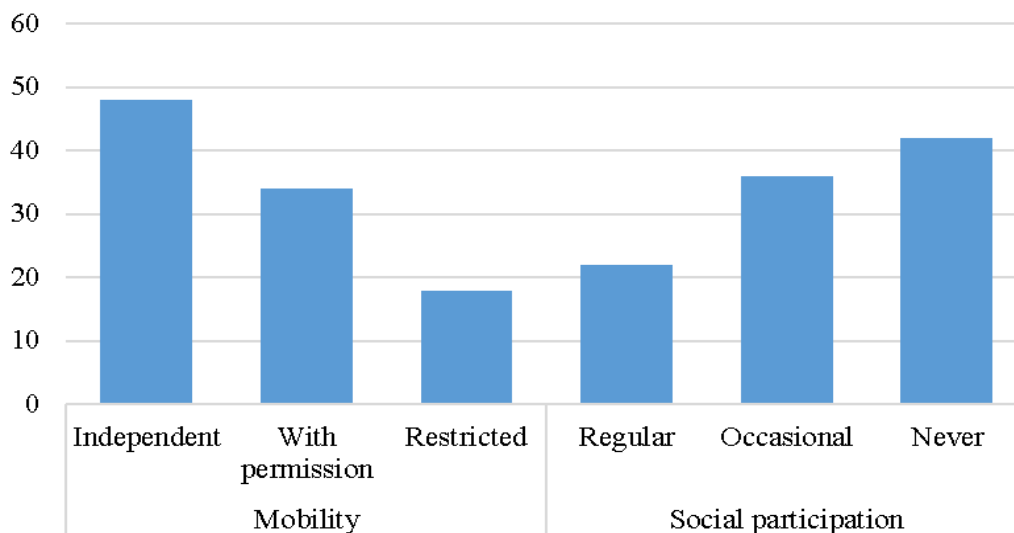


Fig. 3: Mobility and Social Participation (In Percentage)

Limited mobility restricts women’s access to employment, education and health services, thereby affecting their empowerment level.

4.5 Health and Awareness

Access to healthcare and awareness of government schemes are important aspects of empowerment. The results show that while most women have access to healthcare services, awareness of welfare schemes is relatively low.

Table 2: Health and Awareness Status

Indicator	Category	Percentage (%)
Healthcare access	Yes	72
	No	28
Awareness of schemes	Yes	44
	No	56

The gap between service availability and awareness highlights the need for better outreach and information dissemination.

4.6 Women Empowerment Index (WEI)

A composite Women Empowerment Index was calculated to assess overall empowerment levels.

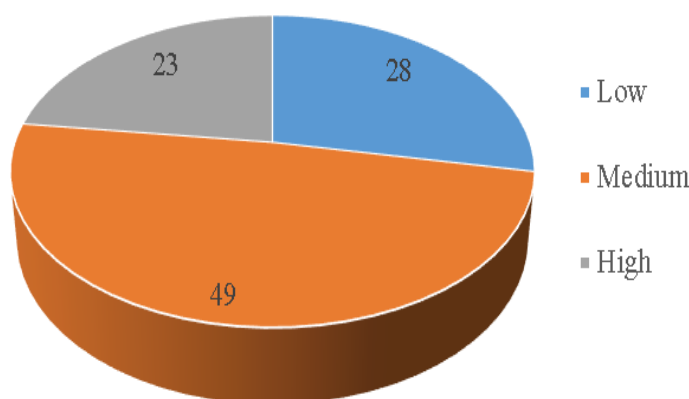


Fig. 4: Level of Women Empowerment (In Percent)

The results indicate that most women fall under the medium category, suggesting partial empowerment. Only a small proportion of women have achieved a high level of empowerment.

4.7 Livelihood Transformation and Empowerment

The analysis shows a positive relationship between livelihood transformation and empowerment. Women engaged in income-generating activities exhibit higher levels of confidence, decision-making ability and social participation compared to those dependent on household income.

The gradual shift towards self-employment, SHG participation and service-related activities indicates a transition in livelihood patterns. However, this transformation is uneven and influenced by education, access to resources and socio-cultural factors.

Overall, the results highlight that women empowerment in Purulia Town is improving, but still constrained by economic dependency, limited decision-making power and social restrictions. Livelihood transformation plays a crucial role in enhancing empowerment, but requires stronger institutional support and inclusive development policies.

5. Implications for Policy and Planning

5.1 Strengthening Economic Opportunities

The study indicates that a large proportion of women in Purulia Town are engaged in informal or unpaid activities. This limits their financial independence and overall empowerment. There is a need to promote skill development, vocational training and small-scale entrepreneurship among women. Programmes related to tailoring, food processing, handicrafts and service-based activities can create sustainable livelihood opportunities. Strengthening Self-Help Groups (SHGs) and linking them with formal financial institutions can further enhance income generation and economic participation (NABARD, 2019).

5.2 Enhancing Financial Inclusion

Although many women possess bank accounts, active financial participation remains limited. Policies should focus on improving financial literacy and access to credit. Easy access to microcredit and small loans can support women in starting or expanding livelihood activities. Digital banking and local financial services should also be strengthened to ensure greater financial autonomy among women.

5.3 Improving Education and Awareness

The findings reveal a gap between literacy and awareness. Many women are not fully aware of government schemes related to health, employment and social security. There is a need for targeted awareness campaigns at the ward level. Local institutions, NGOs and municipal bodies can play an important role in disseminating information and encouraging participation in welfare programmes.

5.4 Promoting Mobility and Social Participation

Limited mobility restricts women's access to employment and public services. Improving safety, transportation and public infrastructure can enhance women's freedom of movement. Creating supportive environments for participation in community activities and local governance can also strengthen social empowerment.

5.5 Reducing Intra-Urban Disparities

Unequal distribution of urban facilities across wards affects livelihood opportunities and quality of life. Previous studies have shown significant disparities in access to services within Purulia Municipality. Balanced development of infrastructure such as education, healthcare, transport and financial services is necessary to ensure inclusive growth and equal opportunities for women.

5.6 Need for Integrated Policy Approach

Women empowerment is a multidimensional issue that requires a coordinated policy approach. Economic initiatives must be supported by improvements in education, healthcare and social awareness. Local governance institutions should adopt gender-sensitive planning and ensure effective implementation of development programmes.

Overall, these policy measures can contribute to enhancing women empowerment and promoting sustainable livelihood transformation in Purulia Town.

6. Conclusion

The present study highlights that women empowerment in Purulia Town is evolving, but remains uneven and constrained by multiple socio-economic factors. While some progress has been observed in terms of education, financial inclusion and participation in livelihood activities, a large proportion of women still face limitations in economic independence and decision-making power. The dominance of informal employment, low-income levels and restricted mobility continues to affect their overall empowerment status.

The analysis clearly shows that livelihood transformation plays a significant role in enhancing women empowerment. Women engaged in income-generating activities demonstrate higher confidence, greater participation in household decisions and improved social interaction. However, this transformation is gradual and influenced by education, access to resources and institutional support. The presence of intra-urban disparities in infrastructure and services further intensifies these differences across town sections.

From a policy perspective, the study emphasises the need for integrated and inclusive strategies that focus on skill development, financial inclusion, awareness-raising and balanced urban development. Strengthening local institutions and promoting women-centric programmes can help in improving both livelihood opportunities and empowerment outcomes. Such efforts are essential for achieving broader goals of gender equality and sustainable urban development.

However, the study has certain limitations. The analysis is based on a limited sample size within selected wards of Purulia Town, which may not fully capture the diversity of experiences across the entire municipality. The study relies primarily on cross-sectional data collected over a short period and therefore does not reflect seasonal or long-term changes in livelihood patterns. In addition, the assessment of empowerment is based on selected indicators and other dimensions such as psychological empowerment or intra-household dynamics could not be explored in detail. Future research may adopt a larger sample, a longitudinal design and more comprehensive indicators to provide a deeper understanding of women's empowerment in similar urban contexts.

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**A Detailed Exploration of Sustainable Flexibility in Teams and
Organizational Development**

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***Abstract:** This study examines the role of sustainable flexibility in teams and its impact on organizational development through a systematic literature review of 75 research papers (1994–2028). Using a qualitative analytical approach, the study identifies key dimensions of flexibility, including flexible working hours, work-life balance, and employee-driven work arrangements. The findings indicate that flexibility significantly enhances employee engagement, productivity, organizational commitment, and retention, while also supporting work-life balance and well-being. However, challenges such as managerial resistance, time management issues, and lack of monitoring hinder effective implementation. The study highlights that employee-driven flexibility models yield more consistent positive outcomes compared to employer-driven approaches. The paper concludes by emphasizing the strategic importance of flexibility as a driver of organizational agility and sustainable growth.*

***Keywords:** Sustainability, Flexibility, Teams, Organizational Building, Adaptability, Agility, Resilience*

1. Introduction

In the recent past, flexibility in the workplace was typically handled on a case-by-case basis. For instance, an employee might need to adjust their hours to accommodate personal responsibilities, and supervisors would accommodate these requests as needed. However, such flexibility was more of an exception rather than the norm.

Prior to the pandemic, remote work was relatively uncommon, with most employees working in traditional office settings. However, the landscape changed drastically in 2020 when the global pandemic forced organizations to embrace remote work and reconsider traditional notions of workplace culture and productivity. Today, the concept of "business as usual" has

evolved significantly. With the shift to remote work during the pandemic, employees found themselves with newfound bargaining power.

In today's workplace, companies are striving to foster a culture of trust by providing employees with flexibility in their work schedules.

To begin, the paper reviews prior research findings concerning flexible working hours. By analysing existing evidence, it evaluates flexible working hours from the perspectives of both employees and employers, highlighting that employer and employee both can be benefitted by the implementation of the flexibility in the team. Despite extensive research on flexible work arrangements and work-life balance, there remains a lack of integrated understanding of how sustainable flexibility specifically contributes to team effectiveness and organizational development in a long-term context. Existing studies often focus on isolated outcomes such as employee satisfaction or productivity, but limited attention has been given to the combined impact of flexibility, team dynamics, and organizational agility, particularly in post-pandemic work environments. This study attempts to bridge this gap by providing a holistic and synthesis-based perspective on sustainable flexibility.

The primary objective of the paper is to examine flexibility in team arrangement and its effect on organizational building.

The specific objectives are to:

1. Identify key dimensions and determinants of sustainable flexibility in teams.
2. Examine the relationship between flexible work practices and organizational development.
3. Analyse challenges and opportunities in implementing flexibility for long-term sustainability.
4. Evaluate the impact of employee-driven versus employer-driven flexibility models.

2. Flexible Working Hours

Flexibility in the workplace encompasses more than just changes in work hours and location; it also involves job sharing, taking career breaks such as maternity or paternity leave, working part-time, and adjusting schedules to align with school term times. (Coyle-Shapiro and Hoque)

In another research paper about flexible work arrangements (FWA), scholars explored three main types of FWA: flexible scheduling (referred to as flexitime), remote telecommuting (known as tele homeworking), and reduced hours (described as part-time work), each offering various levels of flexibility in terms of when, where, and how long individuals work (Possenriede and Plantenga) It's essential to highlight that FWAs, provide convenience in organizing work schedules without necessarily reducing working hours. Therefore, work flexibility can be defined as employees having control over both the duration of their working hours and the option to work remotely from the office. This scheduling flexibility is typically expected to be provided by the employer. (Chung).

The study indicates that FWA is crucial in implementing diversity initiatives. However, organizational priorities, especially managerial apprehensions regarding client interactions, limit the adoption of FWAs, thereby limiting their effectiveness in promoting greater diversity.

Since FWAs have varying impacts based on whether employees are available remotely or not, their acceptability is not universally inclusive but rather contingent on the nature and level of the job. (Michielsens et al.)

The various dimensions and classifications of FWAs are summarized in Table 1 below.

Table 1: Dimensions and Types of Flexible Work Arrangements (FWAs)

Dimension	Type of FWA	Description	Source/Author
Time Flexibility	Flexi-time	Adjustable start and end times	Daniel Possenriede (2011)
Location Flexibility	Remote work / Telecommuting	Working from home or another location	Chung (2009)
Workload Flexibility	Part-time / Reduced hours	Reduced or customized working hours	Elisabeth Michielsens (2013)
Career Break Flexibility	Sabbatical / Maternity/Paternity Leave	Temporarily leaving and returning to work	J. Coyle-Shapiro (2013)

2.1 Advantages for Employers: Employers have implemented flexible work packages, as part of their work-life policies, to attract, hire, and retain highly skilled personnel for their companies. By granting employees the autonomy to manage their own work schedules, they perceive that their employer values their well-being and respects their life outside of work. (Casper and Harris).

Based on additional earlier research, FWAs lead to enhanced employee loyalty, engagement, and heightened organizational commitment, alongside increased job satisfaction. Moreover, flexible work packages aid in attracting and retaining skilled employees for the organization. (Sutanto et al.) Additionally, benefits for employers include heightened productivity, decreased employee turnover, and reduced absenteeism because of flexible working arrangements. (Hussainy). Therefore, flexible working practices are advantageous for employers. Flexibility has been integrated into the work structure to provide employees with the option to choose when, for how long, and from where they work.

2.2 Advantages for Employees: According to the research, there are distinct gender differences in how flexible working practices are perceived and utilized. Men tend to view flexible working to strengthen their commitment to the organization, possibly by demonstrating their dedication and willingness to adapt to different work arrangements. On the other hand, women often see flexibility as a critical tool for achieving a better work-life balance, enabling them to fulfil their professional responsibilities while also attending to personal and family needs.

These differing perspectives may stem from societal expectations and traditional gender roles. Women, especially mothers, are often expected to juggle multiple roles and responsibilities,

leading them to prioritize flexibility in their work arrangements. This could explain why women are more likely to seek and benefit from flexible working options compared to men.

Furthermore, organizational culture and policies may also play a role in shaping these perceptions. (Wonneberger) Companies that promote a supportive and inclusive work environment, with policies that accommodate diverse needs and lifestyles, are more likely to attract and retain female employees who value flexibility. (Lewis).

Table 2 presents a comparative overview of how flexibility benefits both employers and employees.

Table 2: Benefits of Flexibility for Employers vs. Employees

Benefit Category	Employers	Employees
Productivity	Increased efficiency and output	Better focus and time management
Retention	Lower turnover and absenteeism	Improved job satisfaction
Work-Life Balance	Improved organizational image	Enhanced mental well-being and reduced stress
Loyalty & Engagement	Higher employee engagement	Greater sense of value and autonomy
Source	Hussainy (2019), Casper (2008)	Lewis (2010), Amritha & Reddy (2017)

3. Work Life Balance (WLB)

The concept of WLB has become increasingly prominent in discussions about workplace well-being and productivity. This attention is not limited to employees with specific demographics, such as relationship status, family size, or the presence of children, but is recognized as important for all individuals in the workforce.

At its core, work-life balance refers to the equilibrium between professional responsibilities and personal activities or commitments outside of work. Achieving this balance is crucial for overall well-being, job satisfaction, and productivity. (“The Work-Life Balance and Job Satisfaction”). However, many employees face challenges in maintaining this balance due to various factors. (Tijani and Opawole).

In a study examining support for work-life balance, researchers discovered a positive correlation between emotional and instrumental support provided to employees during work and their satisfaction with work-life balance (Marecki). This suggests that both emotional encouragement and practical assistance contribute to fostering a sense of balance between work and personal life, leading to higher levels of satisfaction among employees (Abendroth and den Dulk).

3.1 Stress and Work Life Balance. By taking proactive steps to manage stress and regain control over work-related factors, individuals can improve their overall well-being and

productivity. (Shanker). Research indicates that employees facing WLB challenges tend to experience higher levels of stress compared to those who have successfully achieved a balance between their work and life responsibilities. This suggests that maintaining a healthy equilibrium between professional and personal commitments is essential for reducing stress and enhancing overall well-being in the workplace (Gragnano et al.).

3.2. Wellbeing and Work Life Balance (WLB). Employers play a crucial role in promoting employee well-being by creating a workplace culture that prioritizes health, wellness, and overall quality of life. This includes initiatives such as providing access to health resources, promoting work-life balance, offering mental health support, and fostering a positive and supportive work environment (Monteiro and Joseph). By investing in employee well-being, organizations can improve morale, productivity, and overall satisfaction among their workforces (Kossek et al.). Furthermore, the research highlights the interconnectedness of physiological and mental well-being, emphasizing their importance in achieving a harmonious WLB. Additionally, studies have shown that employee well-being not only influences productivity and performance but also impacts organizational commitment, job satisfaction, and overall work-life balance. (Gulzar and Abbas).

4. Flexible Working Hours (FWHS) And Work-Life Balance (WLB).

FWHs have been implemented as a perk for parents and caregivers to assist them in managing their work and life commitments and attaining a healthy work-life balance. Recent research on WLB indicates that employees perceive flexible working arrangements as a morale booster in the workplace, potentially enhancing WLB. Moreover, employees feel that employers are capable of aiding them in balancing their professional and personal roles. For instance, flexible working hours are cited as one of the most effective strategies for enhancing employee well-being, as they enable employees to handle responsibilities outside of work more effectively. (Amritha and Reddy).

Building trust between employers and employees is crucial, especially concerning FWHs. Without proper monitoring by managers, FWAs can potentially lead to challenges in the workplace. It is essential to conduct further research on FWHs to comprehensively understand both their benefits and drawbacks. Only after thoroughly investigating the positive and negative aspects of flexible working practices can organizations make informed decisions about implementing flexibility in the workplace. This balanced approach is necessary to ensure that flexible working arrangements are effective and beneficial for both employers and employees. (Shagvaliyeva and Yazdanifard).

5. Flexibility In Teams And Organizational Building

Flexible working arrangements (FWA) that allow employees to control their place and time of work, particularly those aimed at enhancing WLB and driven by employees themselves, can lead to positive outcomes for organizations. Employees who choose employee-driven FWAs such as working from home or telecommuting are often highly motivated, self-sufficient, disciplined, organized, and effective communicators. (Menezes and Kelliher). Consequently, they tend to achieve higher levels of performance, benefiting companies that can offer such

flexibility to attract and retain them. It reveals that while flexibility enhances learning and innovation, high perceived support unexpectedly weakens this relationship. Using data from 1,350 Indian IT firms, the study emphasizes the strategic value of internal resources like flexibility, learning, and support for competitive advantage. (Husain et al.)

While employer-driven FWAs have also been associated with positive impacts on organizational performance, their effectiveness has been found to be less consistent compared to employee-driven approaches. Therefore, organizations striving for optimal performance should recognize the importance of involving their employees in decisions related to their working arrangements (Ryan and Deci). This collaborative approach can lead to more effective implementation of FWAs and ultimately contribute to improved organizational outcomes. (Austin-Egole and Nwokorie).

While the direct association may require further investigation, it is widely acknowledged that many flexible work practices, such as flexitime, telework, and support with dependent care services, come with low financial costs. These costs are primarily related to program administration and do not necessitate significant initial resource investment (Warner and Wäger). This suggests that implementing flexible work practices can yield benefits for both employees and organizations without imposing substantial financial burdens. (Omondi). Study offer significant and valuable insights in several aspects. Firstly, concerning workforce flexibility and effective teamwork, the study suggests that it's possible to reap the benefits of both simultaneously. It demonstrates that employees who engage in a diverse range of manufacturing tasks throughout the plant (functional flexibility) may display higher levels of team performance when working in teams.

Secondly, findings challenge the notion that superior team performance only occurs within stable, established teams. Instead, it suggests that team effectiveness can be achieved even when team composition varies.

Thirdly, the study emphasizes that the relationship between workforce flexibility and teamwork is not limited to cellular manufacturing but extends to various modern manufacturing philosophies. Concepts such as just-in-time, lean manufacturing, total quality management, world-class manufacturing, and flexible manufacturing systems all advocate for labour flexibility and teamwork as essential components for achieving their objectives. (Fraser and Hvolby) This study found that absenteeism, a non-financial indicator, showed significant relationships with FWAs, while subjective measures of performance-like quality of service were more closely associated with the presence of FWAs compared to objective financial measures. The finding of the study underscores the importance of incorporating employee-driven FWAs into management strategies to enhance organizational performance and employee well-being simultaneously. (Klindžić and Marić).

The study found that employees' flexibility is shaped by their role, age, initiative, self-efficacy, and organizational factors like trust and task structure. Willingness depends on fair treatment, while ability links to self-efficacy. (van den Berg and van der Velde).

In this study it's been systematically analysed 75 papers published from 1994 to 2028 And concluded with the given definition 'Organizational Agility is a learned, permanently-available dynamic capability that can be performed to a necessary degree in a quick and efficient fashion, and whenever needed in order to increase business performance in a volatile market environment.' (Walter).

A survey of 3,044 public service employees found that negative attitudes toward increased functional flexibility were weakly linked to low extrinsic satisfaction, perceived reward inequity, low organizational commitment, and age. Job scope and most biographical factors, except age, had little predictive value for these attitudes. (Cordery et al.).

A study by (Olson and Tetrick) examined organizational restructuring and its effects on employee attitudes and perceptions. Findings highlighted the psychological impact of change and the importance of managing employee responses during restructuring. (Olson and Tetrick).

Modern manufacturing demands a customer-focused strategy and proactive role orientation, but empirical research is limited. Studies show strategic orientation improves with new practices, while flexible roles need autonomous work structures. (Parker et al.).

6. Discussion

To examine how flexibility in team arrangement and its effect on organisational building come up with the factors related to the flexibility like FWHs and WLB. FWHs having benefit for both employee and well employer. and study suggested that it is having positive impact on organizational building.

Employers have found that flexibility in the workplace yields several significant advantages. These include increased job and employer satisfaction, enhanced employee productivity, stronger employee engagement, and reduced turnover and absenteeism. These benefits ultimately contribute to improved productivity and profitability for the company.

However, it's important to note that work-related stress can spill over into employees' personal lives, affecting their ability to achieve a WLB and leading to psychological and physiological health concerns, that can harm productivity and well-being. Employers bear the responsibility of fostering a wellness-oriented workplace, characterized by reduced stress and a culture of trust, to boost employee productivity. While flexible working arrangements were historically associated with women balancing family responsibilities, they are now equally important for men in evolving family dynamics where both parents share caregiving roles and contribute to dual family incomes.

Some study revealed that there are some challenges in implementation of flexibility in work arrangement like; employee faced controlling issue in working hour and that leads to pressure hence many employees face difficulty in maintaining the balance due to several factor lack of control leads uncertainty and elevate stress level. falling in proper time management during the flexible work arrangement also create pressure to fulfil commitment.

Sense of autonomy among the employee, create a feeling that employer value wellbeing of employees, it prompt loyalty, commitment and job satisfaction. It is also helpful in retaining and attracting high performance employees.

While flexibility offers numerous advantages, organizations face several challenges in implementation, as summarized in Table 3.

Table 3: Challenges in Implementing Flexibility

Challenge	Description	Impact
Lack of Monitoring	Difficulty in tracking performance in remote settings	May reduce accountability
Time Management Issues	Employees struggling to set boundaries and meet deadlines	Increased stress, reduced output
Managerial Resistance	Fear of losing control or team cohesion	Delay in adopting FWA policies
Cultural Barriers	Traditional mindsets regarding physical presence at work	Hinders flexibility adoption
Source	Discussion & Shagvaliyeva (2014), Michielsens (2013)	

The findings of this study reinforce the argument that flexibility is not merely an operational adjustment but a strategic capability that contributes to organizational agility and resilience. Consistent with prior studies, employee-driven flexibility emerges as a more effective approach, as it enhances autonomy, motivation, and engagement. However, the study also highlights a critical paradox—while flexibility promotes work-life balance, inadequate structure and control mechanisms may lead to increased stress and reduced efficiency. This indicates the need for a balanced framework combining flexibility with accountability and managerial support.

7. Summery

Flexible work arrangements in organizations, especially those intended to support WLB can lead to positive results for the organization. It's important for every organization aiming for optimal performance to recognize the importance of involving employees in decisions regarding their work arrangements.

A summary of selected key studies referenced in this review is provided in Table 4 for quick reference.

Table 4: Literature Summary of Key Studies Reviewed

Author(s)	Year	Focus Area	Key Findings
Amritha & Reddy	2017	Flexible hours & work-life balance	Boosts morale and work-life satisfaction
Klindžić & Marić	2019	Employee vs. employer-driven FWA	Employee-driven FWAs have more positive outcomes

Fraser & Hvolby	2010	Flexibility and team performance	Functional flexibility improves team outcomes
Walter	2021	Organizational agility	Defined agility as dynamic, performance-enhancing

8. Limitations

This study is based on a systematic review of secondary data, which may limit the generalizability of findings due to dependence on previously published research. The absence of primary empirical data restricts the ability to validate findings in real-time organizational settings. Additionally, the study focuses broadly on multiple industries and contexts, which may overlook sector-specific variations in the implementation of flexible work practices. Future research may address these limitations by conducting empirical studies, longitudinal analysis, and industry-specific investigations.

9. Recommendations

The following recommendations are made:

Organizations should adopt employee-oriented flexible work arrangements for their teams. Research shows that such arrangements help maintain work-life balance, positively impact employees' abilities, interests, and enthusiasm for their jobs, and indirectly improve overall performance within the organization.

Embrace change and challenge traditional work practices to enhance performance and productivity. This may involve reevaluating rigid structures and policies to create a more adaptable and responsive work environment

Research should aim to understand how the advantage of FWAs vary based on who primarily benefits from them, whether it's the employee or the employer. Understanding these nuances can lead to more sustainable and effective implementation of flexible work policies.

10. Conclusion

This study concludes that sustainable flexibility is a critical determinant of modern organizational success. It not only enhances employee well-being and engagement but also contributes to improved organizational performance and adaptability in dynamic environments. The findings suggest that organizations must move beyond traditional rigid work structures and adopt strategically designed, employee-centric flexibility models. However, successful implementation requires addressing managerial, cultural, and operational challenges. Thus, flexibility should be viewed as a long-term strategic investment rather than a short-term operational adjustment.

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**Empowering Tribal Women through Workforce Participation: A Study of
Pakur District, Jharkhand**

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***Abstract:** As more women participate in economic and decision-making activities, they are moving closer to empowerment. Women's active engagement in the workforce is the main driver of their empowerment. Women's participation in the workforce has decreased recently, which has created barriers to both economic growth and gender equality. Using secondary data from the 2011 census, the current study focuses on the tribal district of Pakur in Jharkhand in order to determine the kinds of jobs that tribal women pursue and investigate the major obstacles that prevent their empowerment with regard to workforce participation.*

***Keywords:** Women empowerment, Women participation in workforce, Tribal women, Gender equality, Economic growth, Economic and decision making, Jharkhand state, Pakur district, Census 2011.*

1. Introduction

Tribal communities constitute approximately 8.2% (Census of India, 2011) of India's population, with women being the predominant members of these communities. Yet, despite their demographic importance and the constitutional protection by the Indian Constitution, the realities faced by tribal women remain deeply concerning. Tribal women often get left behind when it comes to development in India. They live in deep poverty and don't have enough support for basic needs like schooling, good healthcare, owning land, or finding work. Many government programs exist, but these women still face major roadblocks in building better lives for themselves.

However, despite these challenges, tribal women are involved in multifaceted activities besides farming, like the collection of forest products, animal husbandry, wage labour, traditional handicrafts, etc. But many times, their immense contributions to economic efforts are unrecognised—both nationally and within their own families. This lack of recognition not only

conceals their vital role in the economy but also enhances their social and economic vulnerability. But the fact is that Tribal women are essential contributors to economic activity—both directly and indirectly, for the broader development of any nation. Ensuring they may engage fully in education, land ownership, financial services, and employment markets is not only an issue of equity—it is smart economics.

Jharkhand is one of India's most tribal-dominated states, with Scheduled Tribes comprising 26.2% of its population—among the highest in the country. In Pakur district, this number rises even further, 42.1% of the overall population in Jharkhand, and the tribal women constitute, like any other social group, about half of the total population.

2. Review of Literatures

Sukhija and Mishra (2024) examine the barriers to education and skills among Santhal and Munda women in Jharkhand, highlighting the facts like early marriage, cultural resistance to formal education, as well as economic hardships and inadequate educational infrastructure.

Rupla and Dasaratharamaiah (2019) show that education enhances tribal women's literacy, confidence, decision-making, employment prospects, and community participation, but progress is hindered by poverty, poor infrastructure, and restrictive social customs, requiring better facilities, financial support, and awareness.

Dr Rashmi Pramanik, in *Contribution of Tribal Women towards Household Economy*, highlights challenges faced by tribal women in the workforce, including insecure livelihoods, limited education, poor health, and low wages.

Giridhar, S. (2018) found that although Panchayat Raj Institutions facilitate tribal women's entry into politics, low educational attainment remains a major barrier to meaningful participation.

Paray, M. R. (2019) demonstrated that education significantly empowers tribal women in terms of literacy, confidence, decision-making, employment, and community engagement, but barriers like poverty, lack of facilities, and restrictive social norms persist.

Soumitro Chakravarty and A.N. JHA's (2011) study "Women Empowerment Through SHGs – A Case Study of Jharkhand State in India" shows that SHGs in Jharkhand empower women through financial inclusion and social participation but face structural and cultural barriers.

Kundu (2021) shows that tribal women play a key role in local economies through agriculture, forest produce, livestock, labour, and small businesses, but their contributions remain undervalued due to inequalities, gender barriers, and market exploitation.

Studies by Reddy and Rao (2017) notably focus on forest-based livelihoods, highlighting that the collection and sale of forest products are a key source of income for

2.1 Gaps in Existing Research

From the review of literature, it is clear that education plays a key role in empowering tribal women by improving literacy, confidence, decision-making, and economic participation.

However, most studies look at tribal women in Jharkhand as a whole and do not specifically focus on Pakur district, where the majority population belongs to tribal communities.

While earlier studies highlight barriers such as poverty, poor infrastructure, early marriage, restrictive customs, and lack of facilities, there is little research on how these factors actually affect tribal women in Pakur district. The link between education, skill development, and economic empowerment is also not well studied in this region.

2.2 Objectives of the Study

This research seeks to achieve the following key objectives

1. To identify the types of work undertaken by tribal women and assess the extent to which such participation contributes to their economic empowerment.
2. To investigate the key obstacles that limit their empowerment in the context of workforce participation

3. Research Methodology

The present study adopts a descriptive research design and relies primarily on secondary sources of data. The data has been drawn from multiple authentic sources, including the Census of India 2011, the National Sample Survey (NSS) 60th Round, scholarly books on tribal women's education and development, peer-reviewed journals, academic articles, government reports and publications, reference papers, and credible websites related to the subject.

The use of secondary data has been considered appropriate for this study as it provides access to large-scale, reliable, and nationally representative datasets that are otherwise difficult to generate within the scope of individual research. Moreover, secondary data allows for comparative analysis, historical trend examination, and cost-effectiveness, making it a suitable approach for understanding the educational and developmental challenges faced by tribal women in Jharkhand, particularly in Pakur district.

3.1 Study Area

In the state of Jharkhand, Pakur district was separated from Sahibganj district on January 28, 1994. Sahibganj was formed on May 17, 1983, from the former Santhal Pargana district. It is bordered to the north by Sahibganj district (Jharkhand), to the south by Dumka district (Jharkhand), to the east by Birbhum district (West Bengal), and to the west by Dumka and Godda districts (Jharkhand). The district is predominantly tribal, with communities such as the Santhals, Paharias, and Lohras constituting a significant share of the population. Being a tribal-dominated region, Pakur reflects a unique cultural identity with distinct traditions.

In terms of administration, Pakur consists of one statutory town, six community development blocks, and one subdivision called Pakur. Here are names of the blocks: Amrapara, Hiranpur, Pakur, Maheshpur, Pakuria, Litipara

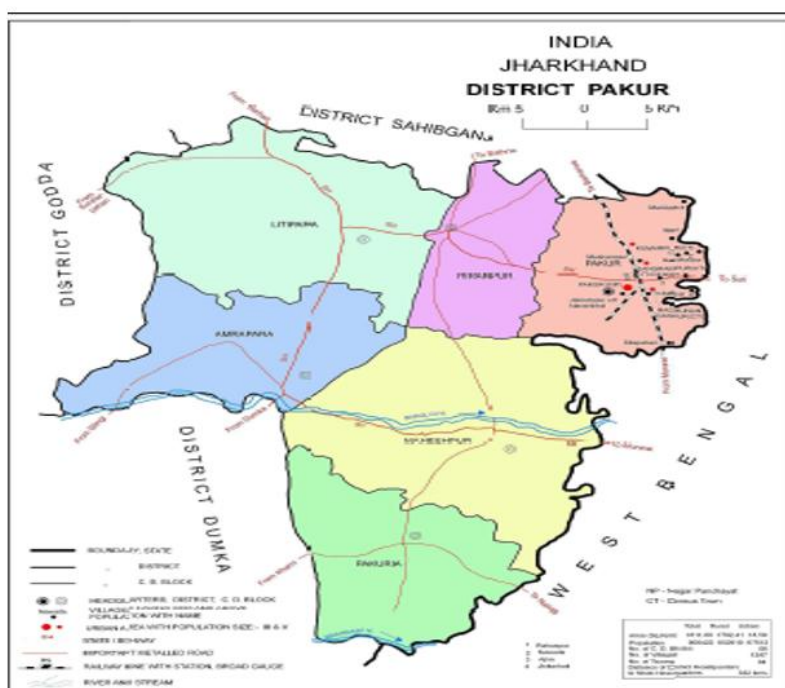


Fig. 1: Geographical map of Pakur district, Jharkhand

3.2 Data Analysis and Findings

3.2.1 Tribal Women's Status in Jharkhand and Pakur District

Table 1: Status of the Tribal Women in Jharkhand and Pakur District

	Total Scheduled Tribes Population in Jharkhand)		Total Scheduled Tribe Population in Pakur District	
	Count	%	Count	%
Persons	86,45,042	26.21	3,79,054	42.1
Males	43,15,407	49.91	1,86,967	49.32
Females	43,29,635	50.08	1,92,087	50.67

Source: Census, 2011

The above table shows that in Jharkhand, the Scheduled Tribe population is about 26.21 per cent. The concentration of the Tribal population is much higher in Pakur district (census 2011) compared to the overall state average of Jharkhand. This establishes Pakur as a tribal-dominated district. The data also reveals that in both Jharkhand and districts like Pakur, there is a balanced sex ratio in the tribal population. Infact tribal women constitute slightly more than half of the tribal population in Jharkhand and pakur district. This implies that tribal women’s participation in the workforce is much needed for the upliftment of society.

3.2.2 Educational Status of Tribal Women in Pakur District

Table 2: Educational Status of Tribal Women

Residence	Total Literates	Male Literates	% of Males	Female Literates	% of Females
Total	1,27,393	77,064	60%	50,329	40%
Rural	1,25,787	76,249	61%	49,538	39%
Urban	1,606	815	51%	791	49%

Source: Census, 2011

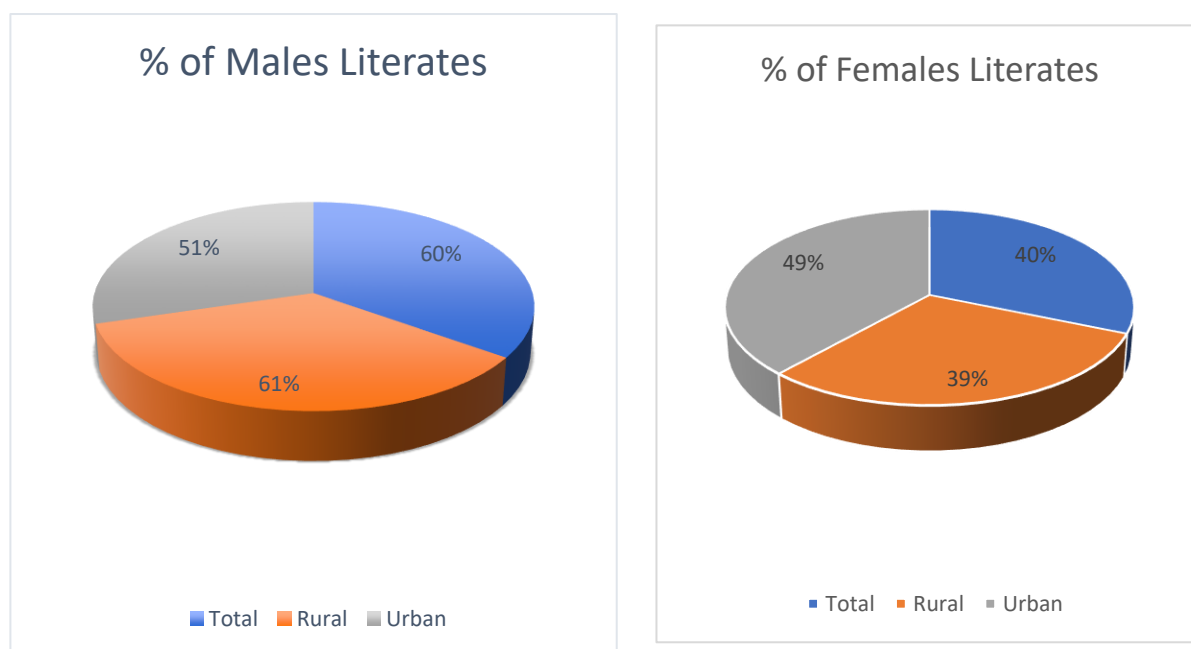


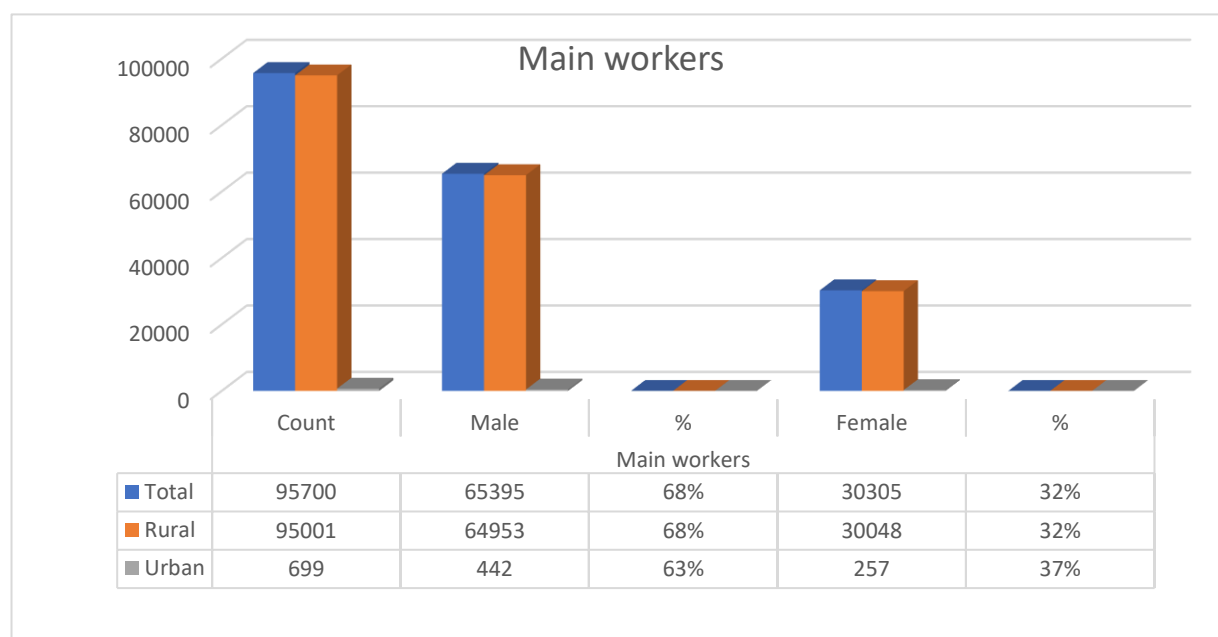
Fig. 2: Literacy Distribution of the Tribal population in Pakur District

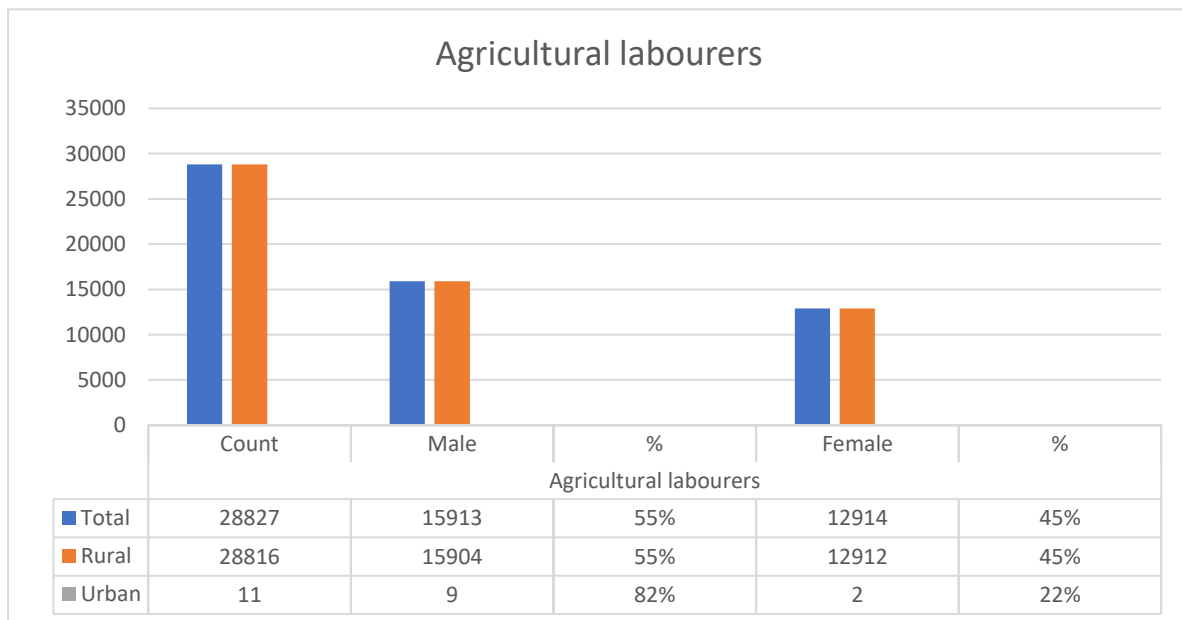
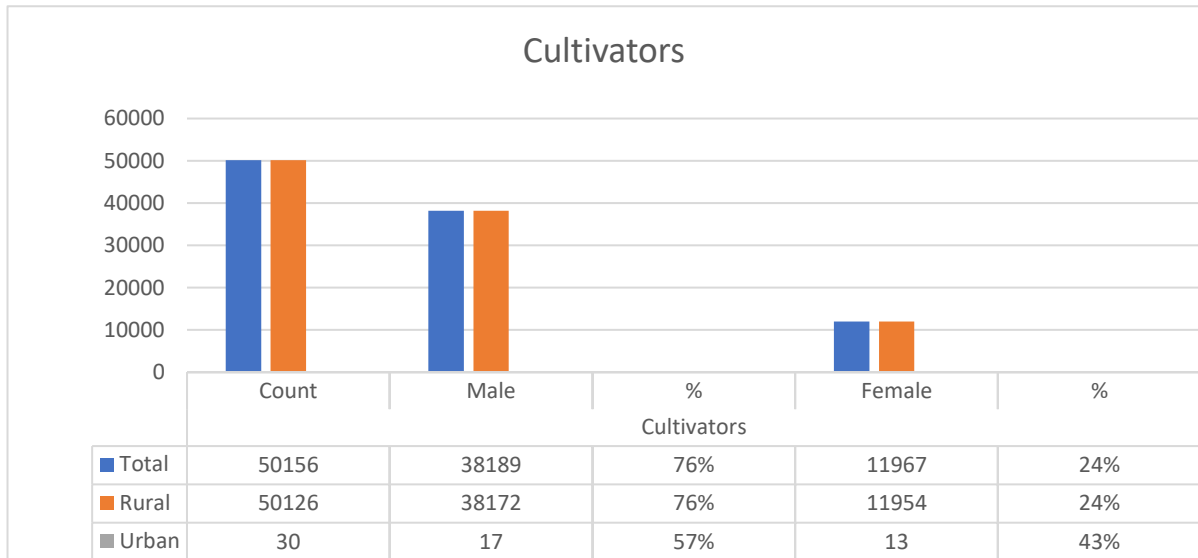
The data from the above tables and diagrams highlight the existence of a gender gap in literacy. Males are in a comparatively better position than females. If we consider both rural and urban perspectives, the urban segment shows a relatively more balanced distribution compared to the rural segment.

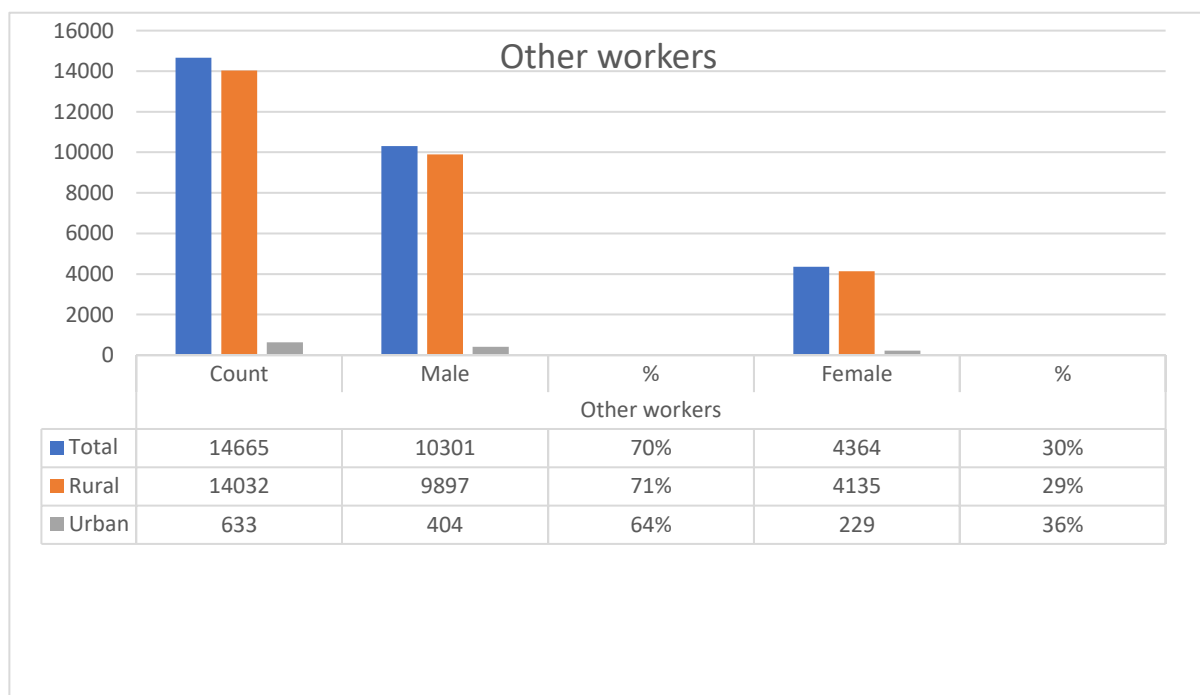
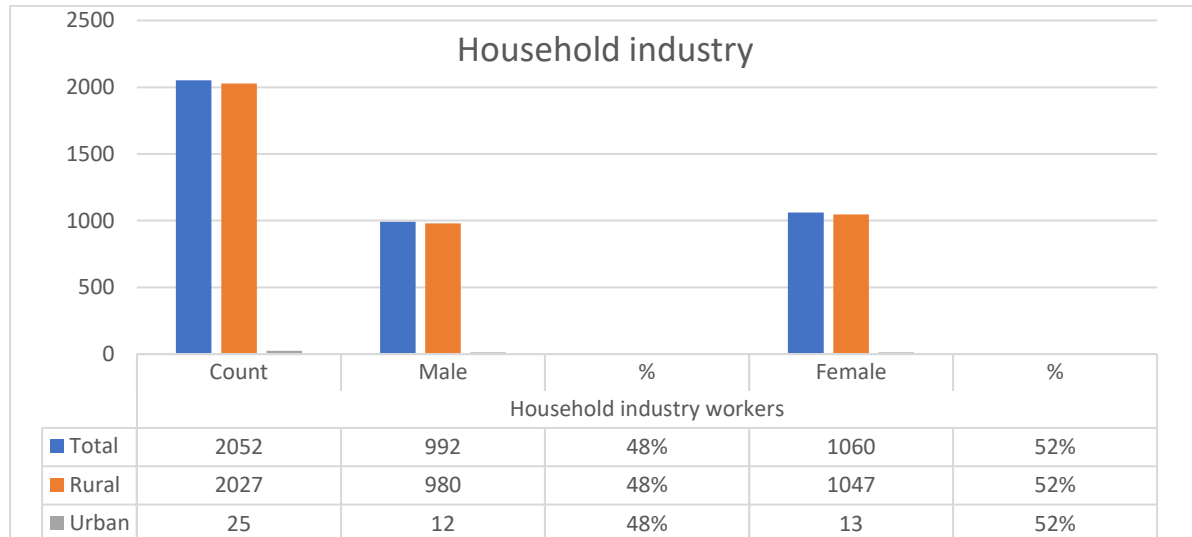
3.2.3 Women’s Occupational Structure in Tribal Societies

Table 3: Participation of workers in different categories (Source: Census 2011)

	Main workers					Cultivators				
	Count	Male	%	Female	%	Count	Male	%	Female	%
Total	95700	65395	68%	30305	32%	50156	38189	76%	11967	24%
Rural	95001	64953	68%	30048	32%	50126	38172	76%	11954	24%
Urban	699	442	63%	257	37%	30	17	57%	13	43%
	Agricultural labourers					Household industry workers				
	Count	Male	%	Female	%	Count	Male	%	Female	%
Total	28827	15913	55%	12914	45%	2052	992	48%	1060	52%
Rural	28816	15904	55%	12912	45%	2027	980	48%	1047	52%
Urban	11	9	82%	2	22%	25	12	48%	13	52%
	Other workers					Marginal workers				
	Count	Male	%	Female	%	Count	Male	%	Female	%
Total	14665	10301	70%	4364	30%	97519	37723	39%	59796	61%
Rural	14032	9897	71%	4135	29%	97330	37607	39%	59723	61%
Urban	633	404	64%	229	36%	189	116	61%	73	39%







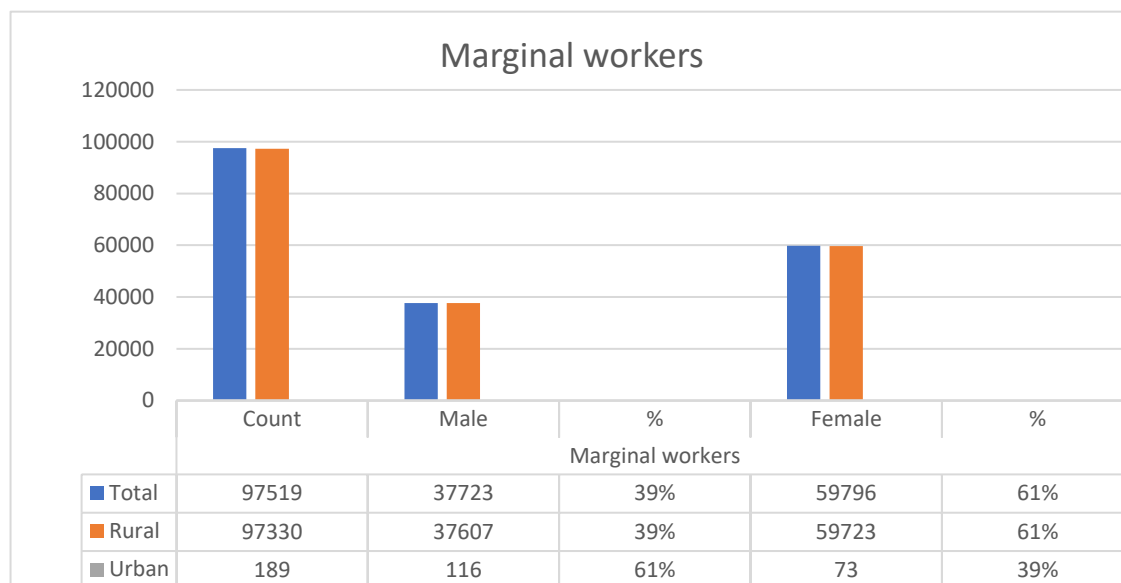


Fig. 3: Category-wise participation of Tribal Women Workers

From the census of India main worker is defined as a person who engages in economically productive activity for at least 183 days in a year. The above tables highlight that the participation of females as the main worker is lower compared to that of males. Women dominate marginal jobs and household industries. Boserup (1970) and Agarwal (1994) show in their studies that women’s agricultural work is often unrecognised because they work as unpaid family workers. In Pakur, women’s role in sowing, harvesting, fuelwood, and water collection is crucial, but is recorded as marginal or secondary.

The participation of rural tribal women as agricultural labourers is significantly higher than that of urban women due to the lack of proper education, skills, training, and alternative income opportunities. A study by Jharkhand Tribal Development Society (2019) shows that male migration and extreme poverty force women to participate in work force as marginal workers. In Pakur district, tribal women are engaged in various types of informal household industries like bidi making, leaf plate making, forest product collecting, etc which are low-paid, home-based.

Due to a lack of proper education and alternative sources of income, tribal women are confined to their local activities, which are not sufficient to support their families. Singh & Kundu (2017) note that women in Jharkhand are concentrated in low-wage, insecure, and seasonal jobs, while men dominate better-paying, stable jobs. Subhajt Kundu (2019) finds that tribal women play a central role in non-farm household industries as a survival strategy. In Pakur, their dominance (52%) in household industries reflects this finding.

3.2.4 Obstacles to Tribal Women’s Empowerment

From the 2011 census data, it has been revealed that the workforce participation in almost all major high-paid categories is dominated by men; women’s participation is significantly unsatisfactory. This presents a picture of the traditional patriarchal Indian society, where

women's role in decision-making is negligible. Women are concentrated in seasonal, insecure, home-based activities that undervalue women's labour.

However, the data also reveals that tribal women have an adequate capacity to participate in the workforce and are efficient in contributing to the upliftment of the economy. With appropriate interventions—such as enhancing access to education and skills, ensuring land rights, strengthening women's cooperatives, and improving market access—these roles can be transformed from survival strategies into avenues of empowerment. In sum, women in Pakur already form the backbone of agricultural and household economies. Recognising, valuing, and strengthening their contributions is not only essential for gender justice but also for sustainable rural and tribal development.

4. Recommendation

- Provide proper, free education.
- Design Skill-based training programs on local demand
- Provide basic facilities
- Provide alternative sources of income
- Policy integration.

5. Conclusion

The entire study reflects that the role of tribal women in workforce participation is not up to the mark. They are undervalued, unrecognised. But tribal women constitute almost half of the total tribal population. So almost half human resources are underutilised. These patterns are reinforced by poverty, tribal socio-cultural practices, language barriers in education, lack of infrastructure, and limited access to skills and markets. For the better economic growth and the improvement of society tribal women's active participation in the workforce and their economic empowerment are necessary. This underscores the need for gender-sensitive educational policies, livelihood diversification, and infrastructural support to empower tribal women and bridge the socio-economic gaps in the district.

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A Systematic Review of Environmental and Health Impacts of Agricultural Stubble Burning and Sustainable Management Strategies in India

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Abstract: *Agricultural stubble burning in India is a prevalent practice that significantly contributes to air pollution, adversely affecting environmental quality and public health. This systematic review analyzes the extent of air pollution caused by stubble burning, its impact on human health, and the environmental consequences. The review also evaluates various sustainable strategies, including alternative residue management techniques, policy interventions, and community awareness. In India, the practice of burning agricultural biomass, including residues from crops such as wheat, rice, and sugarcane, has a notable negative impact on air quality. Farmers resort to burning crop residues primarily to rapidly clear fields for subsequent planting, due to the absence of adequate tools and technologies to manage leftover plant material. Burning of crop residues produces harmful pollutants like particulate matter, carbon monoxide, carbon monoxide, methane, sulfur compounds, nitrogen oxides, and greenhouse gases, resulting in environmental pollution and health issues. Exposure to smoke from stubble burning is associated with respiratory problems, cardiovascular diseases, and other health issues in affected populations. In India, residue burning presents a serious environmental issue by degrading air quality, public health, and soil health. To mitigate these impacts, sustainable practices such as composting, residue incorporation, nutrient management, biogas, bioenergy, and biochar production have been identified as effective alternatives. These methods enhance soil fertility, reduce pollution, and promote sustainable agricultural practices. This study highlights the critical importance of implementing sustainable agricultural practices through farmer awareness and participation. Therefore, curbing agricultural burning is essential to improve air and soil quality, thereby safeguarding environmental health and promoting long-term agricultural sustainability in India.*

Keywords: *Agriculture wastes, Bioenergy, Crop residue, Particulate matter, Sustainability*

Introduction

Stubble or crop residues are the remains of crops left in fields post-harvest. Crop residue burning, commonly practiced after harvesting and before planting, serves to remove leftover crop material, dispose of agro-waste, and eliminate pests and weeds (Gatkal et al., 2024). Despite its widespread

traditional use in many regions, this practice significantly contributes to atmospheric pollution by releasing aerosols and trace gases, which have detrimental effects on human health, climate, and the environment (Huang et al., 2012; Shyamsundar et al., 2019). Proper management of these residues is vital for maintaining soil fertility and facilitating nutrient cycling, which influences subsequent agricultural practices. However, the common practice of burning these residues leads to significant air pollution, contributing to pollution from industrial and vehicular sources (Gurjar et al. 2016). Addressing residue management is therefore essential both for sustainable farming and environmental protection. Burning crop residues, like rice straw, is common in farming but negatively impacts soil health, reduces crop yield, and wastes water (Goswami et al. 2020). This practice leads to loss of important nutrients, with about 5.5 kg of nitrogen lost for every tonne of rice straw burned, and it also releases nitrous oxide, a harmful greenhouse gas (Kaur et al. 2021). In India, the practice of burning crop residues is widespread, especially for rice, wheat, and sugarcane, with rice accounting for 80% of the burned residues (Jain et al. 2014). This method of residue management can lead to a higher reliance on synthetic fertilizers, which may negatively impact soil health. Additionally, the burning process contributes to environmental pollution, raising concerns about sustainability and ecological balance (Cheng et al. 2014; Chivenge et al. 2020). The practice of burning crop residues in agricultural fields differs widely depending on the region and crop type. This uncontrolled burning emits a variety of harmful pollutants into the atmosphere, including particulate matter (PM₁₀, PM_{2.5}), methane, carbon compounds, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxides, ammonia, volatile organic compounds, and polycyclic aromatic hydrocarbons. These emissions contribute significantly to air pollution problems, particularly in countries such as India, China, and across Southeast Asia, where crop residue burning is prevalent. (Awasthi et al. 2011; Jain et al. 2014; Zhang et al. 2018; Kim Oanh et al. 2018). South Asian countries primarily cultivate rice, wheat, and maize, generating large amounts of crop residues annually after harvest (Gathala et al. 2017). This practice deteriorates soil structure, increases erosion, and contributes to greenhouse gas emissions and ground-level ozone formation, which harms crops and promotes pests and diseases (Sarkar et al. 2020). The resulting smoke degrades air quality, especially in winter, increasing respiratory infections among local populations, particularly children (Gupta 2019; Chakrabarti et al. 2019). Bhuvaneshwari et al. (2019) explore the persistent issue of crop residue burning in India, identifying that sustainable management practices supported by robust government policies are key to resolving the problem. The Indian Ministry of New and Renewable Energy (MNRE) reports that India produces approximately 500 million tons of crop residue each year (NPMCR 2014). These large volume of crop residue presents opportunities for renewable energy and sustainable waste management. Crops residue burning raises subsoil temperatures to 33.8–42.2 °C at 10 mm depth, and the long-term thermal impact of such burning extends deeper, affecting soil temperatures up to 15 cm (Gupta et al. 2004). Consequently, increased soil temperatures may affect soil properties and biological activity over time. Therefore, crop residue burning negatively impacts agriculture, the environment, and human health. Higher crop production results in more crop residue generation. Therefore, identifying sustainable ways to manage crop residue is essential as an alternative to burning.

Methods

The present review studies conducted peer-reviewed scientific literature, annual institutional reports, and conference proceedings published within a specific timeframe. The methodology

involved identifying relevant literature, screening for relevance, assessing eligibility, and conducting a qualitative synthesis. The study comprised 258 research articles, including annual reports, and conference publications within the defined period. The study involved systematic searches across prominent databases such as Google Scholar, Scopus, and Web of Science to gather relevant literature on crop residue burning in South Asia. Specific search terms included "biomass burning," "agriculture wastes," "crops left over," "stubble burning," and "air pollution from crop burning." To maintain scientific rigor and relevance, the study selected only peer-reviewed articles published in English within the last 12–18 years, including annual reports and conference proceedings with primary data. Excluded were articles without full text, studies lacking complete methodological details, duplicate publications, and papers unrelated to the review's focus. These inclusion and exclusion criteria ensured the reliability, consistency, and contemporary relevance of the data extracted for the study. A flow chart from PRIMSA illustrates the process (Figure 1).

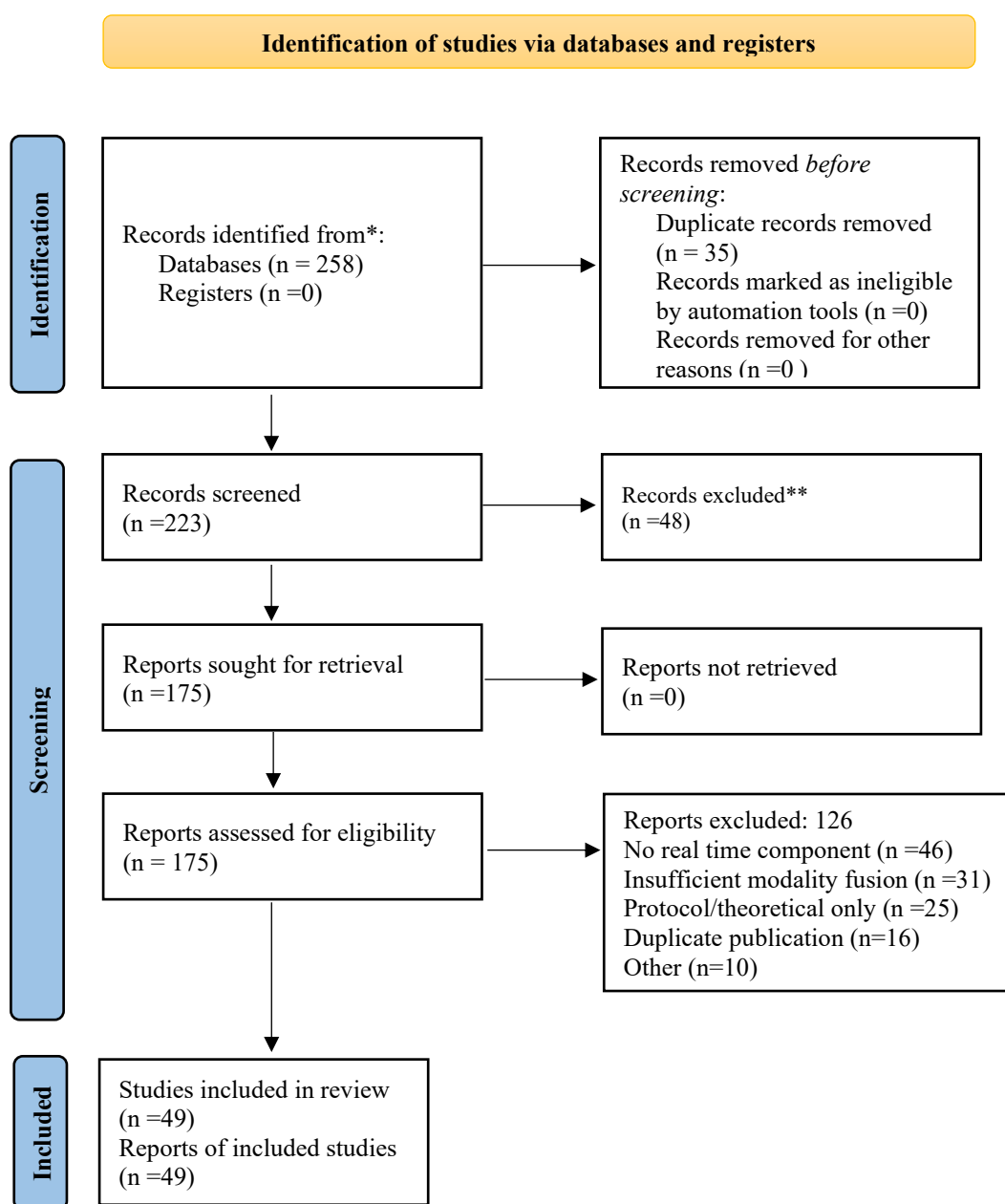


Fig. 1: PRISMA Flow Diagram of Study Selection (Page et al. 2020)

Results

Challenges

Crop residues left in agricultural fields pose a significant challenge for farmers. Removing these residues manually requires considerable time and financial resources. To avoid these costs, many farmers opt to burn the residues directly in the fields (Kaushal and Prashar 2021). This practice helps them save both time and money, although it may have other environmental and agronomic implications. Moreover, farmers have only 7 to 10 days between harvesting and planting, leading them to burn crop residues to clear fields quickly (Kumar and Singh 2020). To manage weeds and pests, they believe the ash improves soil nutrients like potassium (Irfan et al. 2014). Rice straw is not good for animal feed due to low nutritional value, and there is no market for stalks and stubble, promoting burning (Kaur 2017; Kaushal 2020; Kaur et al. 2021). Farmers often don't know about the health and environmental risks of this practice. Larger farms produce more crop leftovers, but farmers who don't have animals or who are far from their fields usually do not gather these leftovers. This situation leads to more burning of crop residue (Ahmed et al. 2015; Rafiq et al. 2019; Bajracharya et al. 2021).

Present scenario

Crop residue burning is a prevalent agricultural practice in South Asia, producing substantial emissions of greenhouse gases and air pollutants. In 2009, India generated approximately 620,000 Gigagrams (Gg) of crop residue, with 16% burned on farms (Jain et al. 2014), while Pakistan produced 62,470 Gg in 2014, burning about 20,000 Gg (Azhar et al. 2019). Nepal's crop residue burning increased from 2,280 Gg in 2003/04 to 2,908 Gg in 2016/17, with 25% burned (Das et al. 2020). Bangladesh's rice residue, primarily from Aman rice, is frequently burned post-monsoon in the Indo-Gangetic Plains (IGP) (Haider 2013). In Nepal, over 80% of air pollutants, such as CO₂, CO, CH₄, SO₂ and PM_{2.5}, come from crop burning between February and May (Das et al. 2020). Indian states such as Punjab, Haryana, Maharashtra, and Uttar Pradesh report the highest incidence (Jain et al. 2014; Shyamsundar et al. 2019; Kaushal and Prashar 2021). In 2017, residue burning contributed notably to N₂O emissions, accounting for about 24%, and other emissions are projected to rise by 45% by 2050 without intervention (Ravindra et al. 2019).

The Intergovernmental Panel on Climate Change (IPCC) identifies Uttar Pradesh as the leading state in crop residue burning, followed by Punjab and Haryana. It estimates that more than 25% of total crop residues are burnt on farms nationwide. The proportion of paddy residue burned varies significantly across different states, ranging from 8% to 80% (Jain et al. 2014). Among crop types, rice residues account for the largest share of burning at 43%, followed by wheat at 21%, sugarcane at 19%, and oilseed crops at 5% (Sahai et al. 2011). These findings highlight the significant regional and crop-specific contributions to agricultural residue burning in India.

India's agricultural system generates substantial quantities of crop residues annually, including cereal straws, woody stalks, and other crop wastes (Kang et al. 2009). A significant portion of crop residues remains unused and is left in agricultural fields despite some being used for fodder, cooking, and fuel (Roy and Kaur 2015). Moreover, turnover period of rice residue in soil is prolonged primarily because of its poor nitrogen content with high carbon-to-nitrogen (C:N) ratio,

resulting slows down microbial decomposition processes. Additionally, absence of adequate soil moisture at the end of the harvesting period further inhibits the breakdown of the residue (Goswami et al. 2020). Consequently, rice residue remains in the soil for an extended duration, affecting nutrient cycling and soil health.

Discussion

Impact on the environment

Burning of agricultural residues, especially stubble burning, is a major problem in many regions worldwide (Shyamsundar et al. 2019). Stubble burning is a common farming practice used around the world, especially in developing countries, to get rid of crop leftovers after harvest. This practice releases harmful gases and particulate matter, causing serious air pollution that harms both health and the environment (Anu Rani Sharma et al. 2010). These burning is a harmful agricultural practice that leads to various forms of environmental degradation. It deteriorates air quality by releasing pollutants, contaminates the upper soil surface, and reduces soil fertility. This degradation ultimately decreases land productivity, negatively impacting farmers' profitability (Lohan et al. 2018; Abdurrahman et al. 2020). It also disrupts the environment by contributing to climate change, reducing soil fertility, and affects economic development (Reddy et al. 2019). The environmental impacts include rising global temperatures and further damage to the ozone layer, which threatens ecological balance and human health (Reddy et al. 2019). Additionally, burning crop residues results in a significant loss of carbon, reducing the environment's ability to store carbon and worsening climate change issues (Singh et al. 2020). Moreover, rice cultivation accounts for more than 10% of global agricultural greenhouse gas emissions and approximately 1.3% to 1.8% of total anthropogenic greenhouse gas emissions worldwide (Maraseni et al. 2018). So, it is important to address stubble burning for sustainable farming and environmental protection. Overall impacts of crop residues (CR) burning in various sectors are depicted in Figure 2.

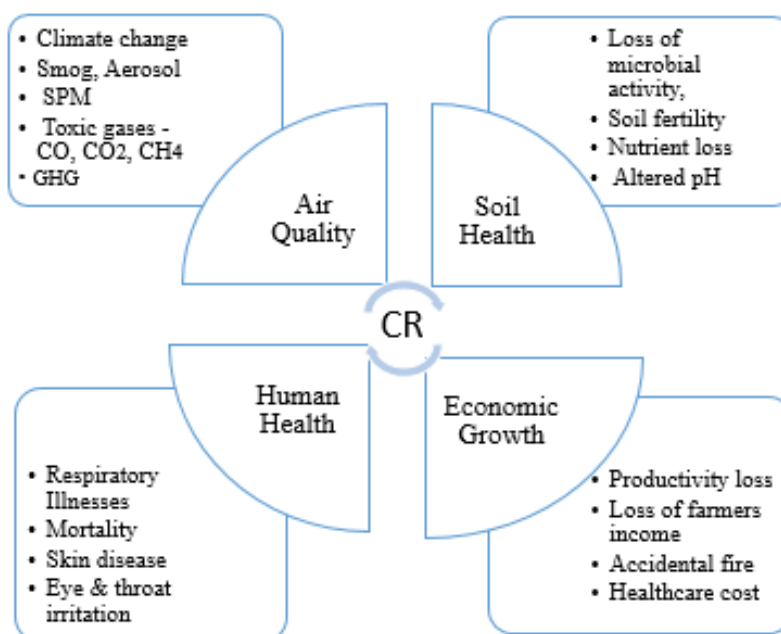


Fig. 2: Overall impacts of crop residues (CR) burning in various sectors

Air pollution

Crop residue burning is a major contributor to air pollution, releasing a wide range of harmful substances into the atmosphere. These pollutants include greenhouse gases like carbon dioxide (CO₂) and carbon monoxide (CO), as well as ammonia (NH₃), nitrogen oxides (NO_x), sulfur oxides (SO_x), non-methane hydrocarbons (NMHC), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and black carbon, and particulate matter of PM_{2.5} and PM₁₀ (Zhang et al. 2011). The increased presence of these pollutants contributes detrimental effects on air quality and negatively impact human health and the environment (Ravindra et al. 2019; Chanana et al. 2023). Emissions of particulate matter (PM) with various gaseous compounds from burning of major crop residue are presented in Figure 3

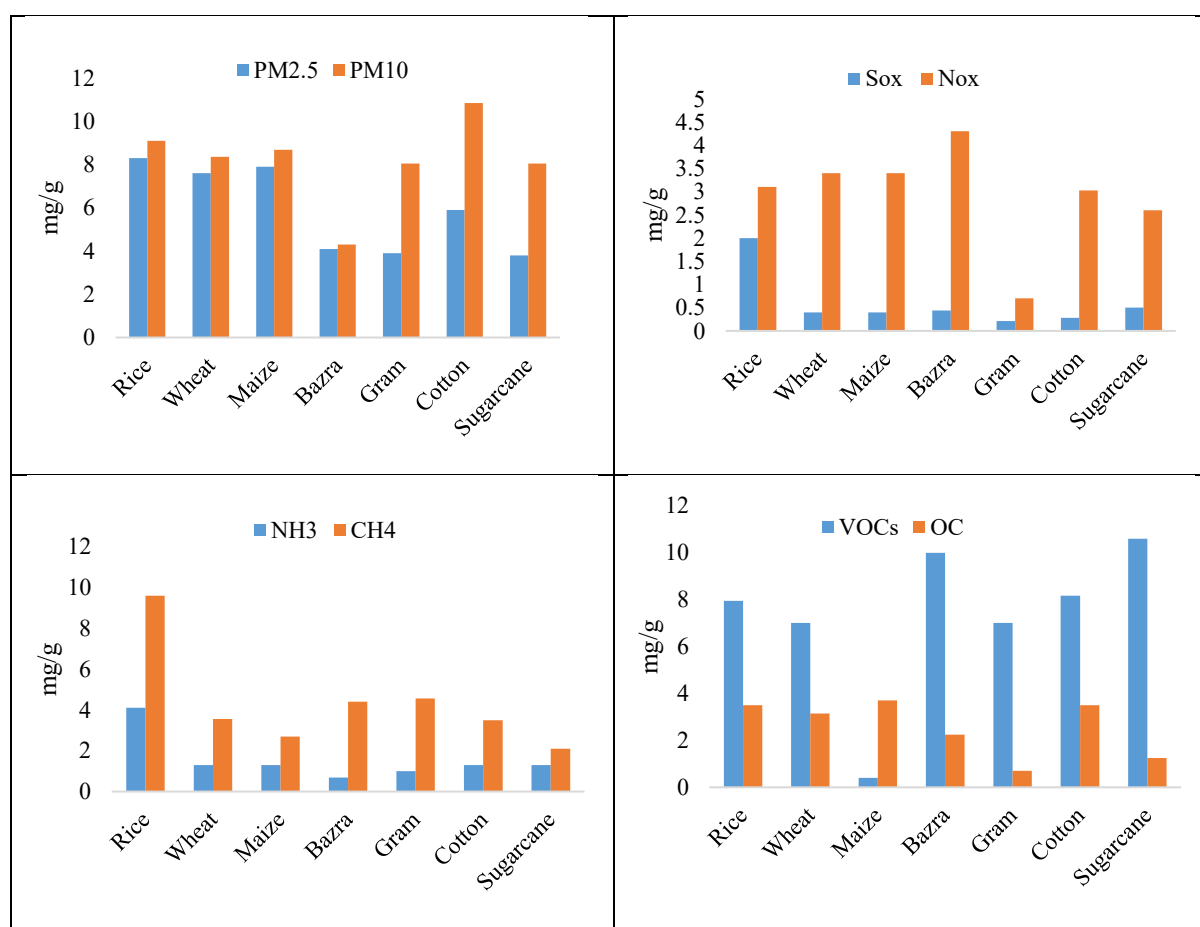


Fig. 3: Emissions of particulate matter (PM) with various gaseous compounds from burning of major crop residue (Sahu et al. 2021; Ravindra et al. 2019).

Agricultural productivity

Particulate pollution from staple burning disrupts agricultural productivity. Plants exposed to this pollution can suffer from problems like chlorosis and bifacial necrosis, affecting their growth and yield (Ghosh et al., 2019). Crop residue burning has detrimental effects on agricultural ecosystems. It reduces soil microbial diversity, which is crucial for maintaining soil health and fertility.

Additionally, burning crop residues leads to an increase in pest populations within agricultural fields, posing challenges for crop protection. Furthermore, this practice depletes essential soil nutrients, thereby threatening the sustainability and productivity of crops over the long term (Parambil-Peedika et al. 2025). Hence, the risks of ongoing air pollution from biomass burning require sustainable practices to protect crop health.

Impact on soil

Stubble burning, often used in farming, damages the environment and soil health. It worsens air quality by releasing harmful pollutants and decreases soil fertility because burning destroys essential minerals needed for productive soil. This causes a double problem: increased air pollution and reduced soil nutrients, which can harm crop yields and long-term farming sustainability (Singh et al., 2018). Burning also significantly affects soil enzymes such as β -glucosidase, urease, acid phosphatase and protease, mainly due to thermal damage and changes in microbial communities (Sun et al. 2021). Fungi are more impacted by burning than bacteria, but these effects are temporary, allowing microbial communities to recover over time. Mesothermic microbes, which prefer moderate temperatures, experience the most severe effects (Dutta et al. 2022).

Human health

Stubble burning produces harmful fine particulate matter (PM_{2.5}) that can enter the lungs and bloodstream, causing eye and lung problems and raising healthcare costs (Anu Rani Sharma et al. 2010). This pollution is a major health issue in South Asia, particularly in India, where it increases the risk of respiratory infections (Krishna et al. 2017). Wind spreads these pollutants to neighbouring countries like Pakistan, Nepal, and Bangladesh, worsening air quality and health effects in those areas (Sarkar et al. 2018; Bikkina et al. 2019). Overall, burning crop residue leads to more cardiac and respiratory illnesses and deaths both indoors and outdoors (Chen et al. 2017).

Alternate practices

Crop residue management is essential for sustainable agriculture, offering benefits like improved soil health, reduced greenhouse gas emissions, and renewable energy generation. By implementing good management practices, farmers can protect natural resources and support their local economy. It is important to understand the value of crop residues and handle them properly to maximize their use (Jain et al. 2014). These residues play a key role in various applications, enhancing agricultural sustainability and environmental health (Keenan et al. 2015). Sustainable farming practices fosters environmental protection and a resilient agricultural future, and supporting farmers is crucial for achieving these goals. Crop residues like maize stover and wheat straw can be used in several ways, including biofuel production, livestock feed, and paper industry, promoting economic growth and reducing waste. Overall, the utilization of crop leftovers supports environmental sustainability and circular economy. Alternative initiatives of based practice for management of crop residues are depicted in Figure: 4.

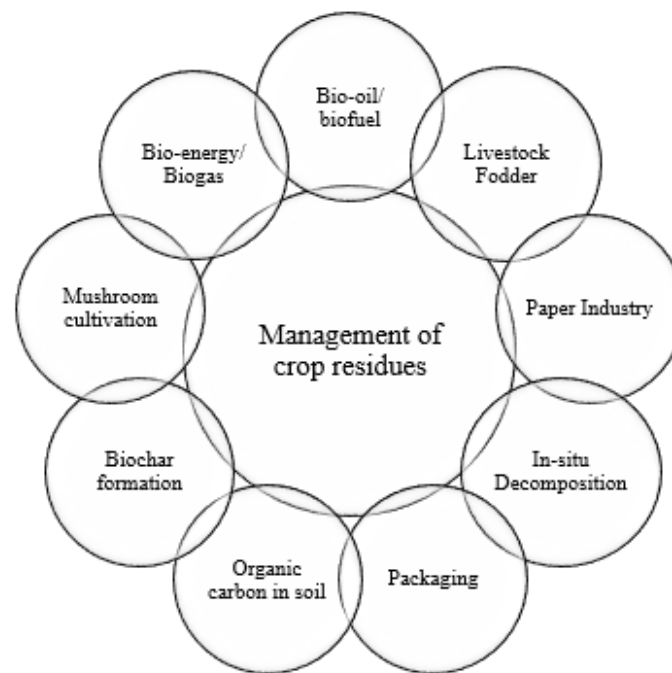


Fig. 4: Sustainable initiatives of based practice for management of crop residues

Nutrient Management

The practice of incorporating crop residues into agricultural fields is encouraged as a means to maintain soil organic matter and improve soil fertility (Ravindra et al. 2018). Incorporating crop leftovers back into the soil helps recycle nutrients and reduces the need for chemical fertilizers. This natural process maintains soil health and leads to more sustainable farming by minimizing the use of external fertilizers. Crop straw naturally contains important nutrients like nitrogen, phosphorus, and potassium. Adding straw to the soil recycles these nutrients, making the soil more fertile (Yin et al. 2017). This method promotes sustainable farming and leads to better crop growth by improving nutrient availability and soil quality. Crop residues serve as a natural organic fertilizer rich in nutrients, improving soil quality and potentially replacing chemical fertilizers and pesticides (Gottipati et al. 2021; Singh et al. 2021).

Composting

Composting is an effective way to utilize crop leftovers by combining them with other organic waste materials. This process results in nutrient-rich compost that enhances soil fertility. Crop residues contain high concentrations of nutrients that plants can easily absorb. The compost typically contains vital nutrients such as nitrogen (2%), phosphorus (1.5%), and potassium (1.4-1.6%), which are essential for plant growth (Abdurrahman et al 2020). This method not only recycles agricultural waste but also contributes to sustainable farming practices by improving soil health and reducing the need for chemical fertilizers. Composting of crop residues with organic amendments and microbial inoculants facilitates rapid decomposition, producing nutrient-rich compost that enriches soil organic matter and nutrient cycling. These practices support sustainable agricultural productivity by enriching soil fertility.

Biogas generation

Biogas production utilizing biomass such as rice straw represents a highly attractive renewable energy option. It is energy-efficient, non-toxic, and environmentally sustainable, contributing to reduced carbon emissions (Satpathy and Pradhan 2023). The biomass from rice leftovers can be converted into biogas through methods like anaerobic digestion, gasification, and pyrolysis. These processes convert rice residues into biogas, helping reduce atmospheric carbon dioxide levels. One tonne of rice residue can produce about 300 cubic meters of biogas through anaerobic digestion (Venkatramanan et al. 2021). This is an efficient and eco-friendly alternative energy source from agricultural waste. Rice straw is a source for biofuel production, which generates biogas, a mixture of gases including methane (CH₄), carbon dioxide (CO₂), hydrogen sulphide (H₂S), oxygen, nitrogen, and trace gases. Among these, methane is the most valuable component due to its high energy density (Ngan et al. 2020).

Bio-oil generation

Bio-oil is a dense liquid made from organic waste materials such as bagasse, wheat residue, and rice hull through pyrolysis at over 500°C (Dutta et al. 2022). This process transforms biomass into a valuable energy resource. Studies have explored the extraction of bio-oil from rice residue under varying temperature and gaseous environments (Balagurumurthy et al. 2015). Bio-oils serve multiple purposes, including use in boilers, heat generation systems, gas turbines, and transportation fuels (Kumar et al. 2015). The renewable origin makes them a promising alternative to conventional oil, contributing to sustainable oil production.

Energy production

This approach supports sustainable waste management and enhances renewable energy and soil fertility. Researchers have explored various lignocellulosic biomass pre-treatment methods to enhance biofuel production (Kumar et al. 2009). Utilizing crop residues can fulfill approximately 17% of India's total energy requirements. India's total bioenergy generation potential is 16,700 MT per year, with Uttar Pradesh having the highest, followed by Maharashtra, Gujarat, and Punjab. This distribution highlights the regional variation in bioenergy resources across the country (Hiloidhari et al. 2014).

Paper industry

Paddy straw, a by-product of rice cultivation, is used in making paper, pulp board, packaging padding, and floor tiles (Saini et al. 2023). Using straw in paper production helps reduce environmental harm from burning agricultural residues. In Punjab, straw makes up about 50% of the paper industry's raw materials (Manikandan et al. 2023). Moreover, combining rice and wheat straw provides a sustainable source for paper, using established chemical methods (Dutta et al. 2022). This sustainable practice lowers straw burning and aids both industry and environmental protection. According to Kumar and Singh (2020), approximately 50% of the paper industry in Punjab uses straw as a raw material, resulting in reducing the practice of crop residue burning and environmental disruption.

Mushroom cultivation

Mushroom cultivation helps farmers financially and reduces agricultural waste by using paddy straw. It is a profitable and eco-friendly business that employs rice and wheat straw as growing

materials. Clean, dry, and mould-free straw is needed, preferably collected right before harvesting (Le VinhThuc et al., 2020). The paddy straw mushroom is highly popular, making up 50-60% of global production (Ahlawat et al. 2011). Rice straw serves as a substrate, producing 5-10% mushroom yield. The oyster mushroom is also commonly grown on rice straw, turning low-quality straw into nutritious food and promoting sustainable farming practices (Naresh et al., 2021). This approach promotes sustainable practices by adding value to agricultural residues.

Industrial uses

Crop residues are generated from major crops like rice, which leaves husk and bran; wheat, which leaves bran and straw; maize, which produces stover, husk, and skins; millet, which yields stover and sugarcane, which results in tops, bagasse, and molasses (Arvanitoyannis and Tserkezou 2008). These residues are by-products of harvesting and processing crops and can be used for different agricultural and industrial purposes. Additionally, agricultural waste can be treated using anaerobic and aerobic methods, including composting, biogas production, vermicomposting, biomethanation, and bio-pile farming (Garg 2017).

Household use

Rice residue, particularly rice stubble and paddy straw, serves multiple domestic purposes in India. In northern states such as Uttarakhand, Himachal Pradesh, and Jammu & Kashmir, rice stubble is commonly used as fuel wood alongside cow dung cakes (Jain et al. 2014). In other regions like Tamil Nadu, Gujarat, Maharashtra, West Bengal, and Assam, paddy straw is utilized for thatching roofs, domestic fuel, mulching, paddy parboiling combustion, and as fodder (Singh et al. 2011). These traditional uses highlight the resourcefulness in managing agricultural by-products for various household and agricultural needs. Furthermore, rice straw plays a vital role as an alternative feed source for livestock, especially when green fodder availability is limited (Dutta et al. 2022). This practice shows how agricultural by-products are effectively used, supporting sustainable livestock feeding strategies.

Technology of Crop Residue Management

Using technology to manage crop residues offers many benefits for agriculture and industry, including improved soil and water conservation and higher productivity. However, how well these methods work can differ based on farming practices, how residues are used, the resources available, and farmers' economic situations. Advances in machinery, especially for harvesting, are important for reducing soil damage and lowering carbon and water loss. It is crucial to adapt these technological solutions to fit local circumstances for effective and sustainable crop residue management. Lohan et al. (2018) emphasize the importance of in-situ paddy residue management using conservation agriculture machinery to promote sustainable farming and reduce environmental hazards in North-West India. Tools like the Happy Seeder enable effective in-situ residue management, promoting soil health and reducing pollution. Innovative equipment use for in-situ management of crop residues is presented in Figure 5.

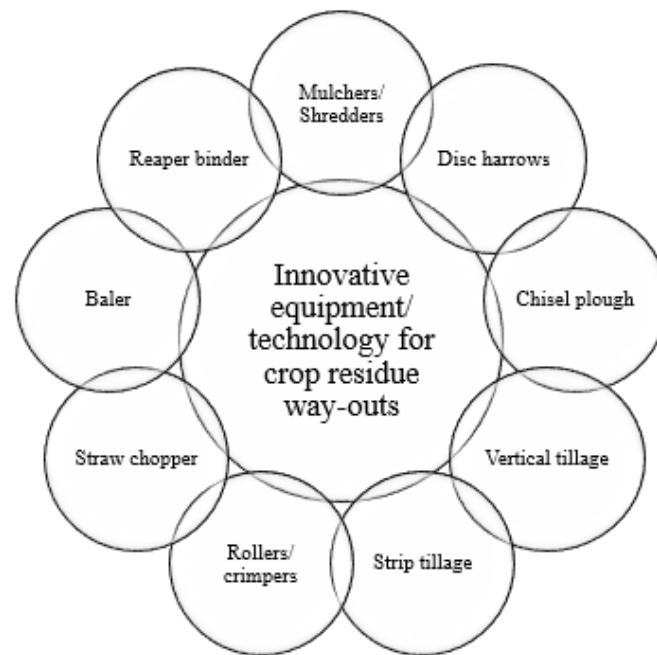


Fig. 5: Innovative equipment used for in-situ management of crop residues

Policy implications

National schemes and policies have been created to manage and reduce crop residue burning. These policies provide farmers with incentives, machinery support, and awareness programs to minimize open burning while aiming to keep agricultural productivity and protect the environment. The National Policy for Management of Crop Residue (NPMCR 2014) in India focuses on reducing environmental damage from burning. It promotes in-situ management techniques like direct soil incorporation and mulching, and encourages the use of farming equipment and remote sensing technologies to monitor burning. To monitor crop residue management in collaboration with the National Remote Sensing Agency (NRSA) and the Central Pollution Control Board (CPCB). This approach aims to reduce air pollution and promote sustainable farming practices by minimizing the negative impacts of traditional residue burning.

The Central Electrical Authority (CEA 2017) proposed a policy that requires coal-based power plants to blend 5-10% biomass pellets with coal to encourage biomass use and utilize crop residues.

The National Biofuel Policy (NBP 2018) aims to increase biofuel production from crop leftovers and surplus grains unfit for eating, helping meet energy needs and reduce climate change effects. Using rice residue to create bio-gas and bio-CNG offers a sustainable way to deal with agricultural waste, addressing pollution from burning and supporting renewable energy. This approach boosts energy security, lowers greenhouse gas emissions, and encourages cleaner farming practices, aligning with the goals of the Ministry of New and Renewable Energy (MNRE, 2018).

The National Clean Air Programme (NCAP 2019) is designed to lower air pollution in India by managing pollutants and addressing stubble burning, with a significant budget aimed at improving air quality in Delhi and its surrounding areas.

The National Green Tribunal Act (2010) requires states to take tough actions against crop burning, promoting recycling and public awareness about its environmental dangers (Bhuvaneshwari et al. 2019). On December 10, 2015, the National Green Tribunal issued an order prohibiting the burning of agricultural residue across multiple National Capital Territory (NCT) of Delhi regions in India including, Delhi, Rajasthan, Punjab, Uttar Pradesh, and Haryana (Jitendra et al. 2017). The order reflects a judicial effort to enforce environmental protection measures and promote sustainable agricultural practices in the affected regions. On the other hand, National Green Tribunal (NGT) issued directives in 2015 to curb crop waste burning by farmers, imposing environmental compensation fines based on farm size. Small farmers owning less than 2 acres are fined INR 2,500 per incident, those with 2 to 5 acres pay INR 5,000, and farmers with more than 5 acres face a fine of INR 15,000 per incident. These measures aim to reduce environmental pollution caused by crop residue burning and encourage sustainable agricultural practices.

Conclusion

Stubble burning in India significantly increases the concentration of greenhouse gases and toxic compounds, which elevate health risks for farmers and nearby villagers. These burning releases large amounts of particulate matter, carbon dioxide, methane, and other greenhouse gases, contributing to air pollution and climate change. Conversely, the sustainable use of crop residues is crucial not only for promoting sustainable agriculture but also for maintaining societal equilibrium. Utilizing crop residues as soil amendments enhances soil fertility and supports ecological balance, offering an environmentally friendly alternative to burning practices. Moreover, it helps improve irrigation and keeps moisture in the soil. By providing organic material, it supports soil bacteria and boosts soil fertility. Good management of leftovers reduces soil erosion and enhances soil health. As the demand for food increases with a growing population, more crop residues are produced due to increasing farming practices, creating chances to use these resources for both environmental and agricultural benefits. Techniques include leaving residue on the field, using it as animal feed, or turning it into compost. Effective mitigation requires government policies, farmer education, and incentives to encourage sustainable practices and reduce reliance on stubble burning. Overall, it is concluded that crop residue management is important for sustainable farming.

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Sustainable Development Policy Frameworks and Their Implementation

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***Abstract:** Sustainable development policies represent the tools and frameworks through which governments and international organizations translate the ambition of a sustainable future into practical action. This article provides a comprehensive overview of how such policies have evolved, how they are designed, and how they function across different levels of governance. Beginning with the early environmental regulations of the 1970s, this article traces the journey through the Brundtland Commission, the Rio Earth Summit, and the adoption of the Paris Agreement and the Sustainable Development Goals in 2015. It introduces an explicit analytical framework based on five evaluative criteria (effectiveness, efficiency, equity, coherence, and political feasibility) and applies these criteria throughout. This article examines policy instruments including regulations, economic incentives, and information-based approaches, and emphasizes policy integration across sectors. It explores key policy domains—climate change, biodiversity, circular economy, social equity, gender, Indigenous governance, and urban policy—and illustrates these concepts through case studies including the European Green Deal, Costa Rica's conservation success, carbon pricing mechanisms, and the substantive policy failure of Germany's SoliWG renewable energy surcharge. This article highlights the central relevance of the Sustainable Development Goals, acknowledging persistent implementation gaps. It discusses limitations of carbon pricing and protected areas, engages with degrowth/post-growth critiques, and includes a comparative table of policy instrument effectiveness. This article concludes by discussing persistent challenges such as political resistance and emerging frontiers including supply chain due diligence and rights of nature. Ultimately, this article argues that sustainable development policies are not merely technical instruments but represent fundamental choices about how societies wish to live, grow, and share the planet's resources.*

Keywords: sustainable development, public policy, governance, Sustainable Development Goals, climate policy, environmental regulation, just transition, policy instruments, political economy

1. Introduction

The concept of sustainable development has become one of the most widely recognized ideas of our time. Most people agree that economic progress should not come at the expense of the

environment or the well-being of future generations. Yet for all the agreement on the idea, there remains a large gap between aspiration and action. This is where sustainable development policies become essential.

Sustainable development policies are the rules, laws, incentives, and institutional arrangements that governments create to put sustainability into practice. Without such policies, the goals of environmental protection, social equity, and economic prosperity remain little more than good intentions. For instance, between 2015 and 2022, global CO₂ emissions continued to rise, reaching a record 36.8 gigatons in 2022, demonstrating that aspirational goals without binding policy instruments are insufficient to drive absolute decoupling of emissions from economic growth (International Energy Agency [IEA], 2023). More recently, the 2023 UAE Consensus at COP28 marked the first global agreement to "transition away from fossil fuels," yet implementation mechanisms remain weak (UNFCCC, 2023). In 2024, the European Union adopted the Nature Restoration Law (Regulation 2024/1991), requiring member states to restore at least 20% of degraded ecosystems by 2030—a recent example of binding policy translating ambition into action (European Union, 2024).

This article examines the world of sustainable development policies. It asks how these policies have evolved over time, what forms they take, and how they work across different levels of governance. The central argument of this article is that effective sustainable development policies represent a fundamental shift from reactive, fragmented regulation to proactive, integrated governance. This article introduces an explicit analytical framework (Section 3.4) with five evaluative criteria—effectiveness, efficiency, equity, coherence, and political feasibility—which we apply systematically to case studies and policy instruments.

The article begins by tracing the historical evolution of sustainable development policy. It then presents a framework for understanding the different types of policy instruments available to decision-makers. Following this, it explores several key policy domains in depth, including gender, Indigenous governance, and urban policy—topics often marginalized in mainstream policy discussions. The article highlights throughout the relevance of the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, showing how these global goals depend upon effective national and local policies for their realization. Finally, the article considers persistent challenges—including policy failures—and emerging directions such as degrowth critiques and supply chain due diligence.

2. The Evolution of Sustainable Development Policy

2.1 Early Environmental Policy

The modern history of environmental policy began in the 1970s, a period often called the environmental decade. During these years, many industrialized nations established environmental protection agencies and passed foundational laws. In the United States, for example, the Clean Air Act of 1970 and the Clean Water Act of 1972 set standards for pollution control (United States Environmental Protection Agency [EPA], 2020). By 2020, aggregate emissions of seven major pollutants had fallen by 77% despite a 184% increase in GDP and a

60% increase in vehicle miles traveled (EPA, 2021). Similar laws emerged across Europe and other developed nations.

These early policies shared a common approach: "command-and-control" regulations (Stavins, 2019). Governments set specific limits on pollution, required particular technologies, and enforced compliance through inspections and penalties. This approach had important successes. However, critics noted that command-and-control could be inflexible, did not always encourage innovation beyond minimum standards, and could impose high costs without achieving the greatest environmental benefit per dollar spent (Tietenberg & Lewis, 2018).

2.2 The Brundtland Commission and the Birth of Sustainable Development

The concept of sustainable development entered global policy discourse in 1987 with the publication of "Our Common Future" by the World Commission on Environment and Development, chaired by Gro Harlem Brundtland (World Commission on Environment and Development [WCED], 1987). The report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

This definition explicitly linked environmental protection with development and equity. The Brundtland Commission argued that poverty and environmental degradation were connected problems requiring integrated solutions. At the time, over 1.1 billion people lived on less than \$1 per day (WCED, 1987). This perspective challenged the view that environmental protection could be addressed after economic growth had been achieved.

2.3 The Rio Era: Multilateralism and Market-Based Instruments

The 1992 Rio Earth Summit marked a turning point. Formally the United Nations Conference on Environment and Development, the summit brought together 172 governments and produced landmark agreements including the Rio Declaration, Agenda 21, and framework conventions on climate change and biodiversity (United Nations [UN], 1992). The UNFCCC today has near-universal membership with 198 parties.

The Rio era also saw the rise of market-based instruments. These tools use economic signals to encourage sustainable behavior. Examples include emissions trading systems, carbon taxes, and payments for ecosystem services (Stavins, 2019). Market-based approaches offered advantages: they could achieve environmental goals at lower overall cost by allowing flexibility. For example, the U.S. Acid Rain Program (1990), a cap-and-trade system for SO₂ emissions, achieved its 50% reduction target at a cost of \$1–2 billion annually, compared to projected costs of \$4–6 billion under command-and-control (Chan et al., 2012). However, market-based instruments also faced political opposition and raised equity concerns, which we discuss in Sections 5.4 and 8.4.

2.4 The Paris Agreement and the Sustainable Development Goals

The year 2015 represented another milestone. Two major international agreements were adopted that together form the current framework for global action.

First, the UN General Assembly adopted the 2030 Agenda for Sustainable Development, including 17 SDGs and 169 associated targets (UN, 2015). Unlike earlier development goals focused primarily on developing countries, the SDGs apply to all nations. As of 2024, progress assessments indicate that only about 15% of SDG targets are on track, with many targets regressing (UN, 2024). For example, SDG 14 (Life Below Water) is the most off-track goal, with ocean acidification up 30% since pre-industrial times (UN, 2023).

Second, the Paris Agreement on climate change was adopted under the UNFCCC (UNFCCC, 2015). It requires each country to submit nationally determined contributions (NDCs). As of 2024, 195 parties have ratified the agreement. Under current NDCs, global warming is projected to reach 2.5–2.9°C by 2100, far above the 1.5°C target (United Nations Environment Programme [UNEP], 2023). This implementation gap—the distance between policy commitments and actual outcomes—is a central challenge we analyze in Sections 6.5 and 8.1.

3. The Architecture of Sustainable Development Policies

3.1 Policy Instrument

Sustainable development policies take many forms. Effective approaches usually combine multiple instruments. Regulatory instruments are laws and rules that require or prohibit specific actions. Examples include bans on single-use plastics, fuel efficiency standards, and zoning laws that protect natural areas. The European Union's ban on single-use plastics (Directive 2019/904) is projected to reduce marine plastic litter by 40% by 2025 (European Union, 2019).

Economic instruments use prices and market signals to influence behavior. These include carbon taxes, subsidies for renewable energy, cap-and-trade systems, and waste disposal fees. Globally, carbon pricing mechanisms covered approximately 23% of global greenhouse gas emissions in 2024, generating over \$100 billion in revenue (World Bank, 2024). However, as we discuss in Section 8.2, carbon pricing has significant limitations.

Informational instruments work by providing information that enables better decisions. Examples include energy efficiency labels, corporate environmental disclosure requirements, and sustainability certifications. The EU Energy Label has driven an average 10% annual efficiency improvement for labeled appliances (European Commission, 2020).

Voluntary instruments include agreements not legally required, such as industry covenants and corporate sustainability pledges. A meta-analysis of 148 voluntary environmental programs found that only 32% achieved significant environmental improvements beyond business-as-usual (Darnall et al., 2022).

3.2 Policy Integration and Coherence

One central challenge is fragmentation. Environmental issues are often handled by one government department, economic development by another, and social welfare by yet another. Policy integration means ensuring sustainability considerations are incorporated across all government functions. Evidence from 38 OECD countries shows that countries with higher levels of policy integration achieve environmental outcomes 22% better relative to GDP than those with fragmented governance (Organisation for Economic Co-operation and Development

[OECD], 2021). As of 2023, 155 countries have developed national SDG strategies, but only 48 have fully integrated them into national budget processes (UN Department of Economic and Social Affairs [UNDESA], 2023).

3.3 Multi-Level Governance

Sustainable development policies operate at multiple levels: global (international treaties), regional (e.g., European Union), national (climate laws, renewable energy targets), and subnational/local (city climate action plans). The C40 Cities network, including nearly 100 major cities, has reduced collective emissions by 25% since 2005 while adding 30 million residents (C40 Cities, 2023). Local governments are often closest to affected communities and can tailor approaches to local conditions.

3.4 Analytical Framework: Evaluative Criteria for Policy Assessment

To move from description to critical analysis, this article adopts an explicit analytical framework with five evaluative criteria. These criteria are applied throughout the case studies (Section 6) and policy instrument discussions.

Table 1: Evaluative Criteria for Sustainable Development Policies

Criterion	Definition	Key Questions	Measurement Approach
Effectiveness	Degree to which policy achieves stated environmental/social outcomes	Did emissions fall? Was biodiversity protected?	Quantitative targets (e.g., tCO ₂ reduced); counterfactual analysis
Efficiency	Ratio of policy benefits to costs (economic and administrative)	Are benefits worth costs? Could same outcome be achieved cheaper?	Cost-benefit analysis; cost-effectiveness ratios
Equity	Distribution of costs and benefits across populations, generations, and regions	Are vulnerable groups protected? Is the burden fairly shared?	Distributional impact assessments; Gini coefficients of policy incidence
Coherence	Consistency across policy domains and governance levels	Do policies conflict across ministries? Are signals aligned?	Policy mapping; institutional coordination indices
Political Feasibility	Acceptability to veto players, interest groups, and citizens	Can policy be adopted and sustained? What coalitions support/oppose?	Stakeholder analysis; legislative success rates; public opinion data

Source: Adapted from Howlett et al. (2020); Cashore & Howlett (2007); Schmidt (2022).

Applying these criteria, we note that many early command-and-control regulations scored high on effectiveness and equity but low on efficiency. Market-based instruments often score higher on efficiency but face challenges on equity (regressive impacts) and political feasibility (opposition from fossil fuel interests). Voluntary instruments typically score low on

effectiveness and political feasibility (capture by industry). We return to this comparative assessment in Table 2 (Section 8.6).

4. Key Policy Domains

4.1 Climate Change Policy

Climate change policy encompasses mitigation (reducing emissions) and adaptation (coping with impacts). Mitigation policies include carbon pricing, renewable energy mandates, and energy efficiency standards. As of 2024, carbon prices range from less than \$1/tCO₂ in Mexico to over \$130/tCO₂ in Sweden, yet 75% of covered emissions are priced below the \$50–100/tCO₂ range the IPCC estimates is needed (World Bank, 2024). Renewable energy capacity increased by 50% in 2023 alone, reaching 3,870 GW globally (International Renewable Energy Agency [IRENA], 2024). Annual global adaptation costs are estimated at \$160–340 billion by 2030, yet current finance flows are only \$30–50 billion annually (UNEP, 2023).

The concept of just transition has gained prominence, referring to policies ensuring the shift to a low-carbon economy is fair. Spain's 2019 Just Transition Agreement allocated €250 million to coal regions, supporting 1,200 workers and creating 1,000 new green jobs (European Commission, 2022).

4.2 Biodiversity and Natural Capital Policy

Biodiversity loss is urgent. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) documented that around one million species are at risk of extinction. Since 1970, global wildlife populations have declined by an average of 69% (World Wildlife Fund [WWF], 2022).

Protected areas have been a cornerstone of biodiversity policy. The Kunming-Montreal Global Biodiversity Framework (2022) includes the "30x30" target: protecting at least 30% of land and sea areas by 2030 (Convention on Biological Diversity [CBD], 2022). As of 2024, 17% of land and 8% of marine areas are protected (UNEP-World Conservation Monitoring Centre [WCMC], 2024). However, protected areas have significant limitations: only 20% are considered effectively managed (CBD, 2022), and many are "paper parks" existing only on maps without enforcement. Moreover, protected areas can create equity problems by displacing Indigenous peoples (see Section 4.6).

Natural capital accounting aims to incorporate nature's value into economic decisions. The global value of ecosystem services is estimated at \$125–140 trillion annually—more than 1.5 times global GDP (Costanza et al., 2014). As of 2024, 89 countries have adopted or are implementing natural capital accounting (World Bank, 2024).

4.3 Circular Economy and Resource Management Policy

The traditional linear economic model (take-make-dispose) contrasts with the circular economy, where materials are kept in use and waste minimized (Ellen MacArthur Foundation, 2015). Global material extraction reached 106 billion tons in 2023, with only 8.6% cycled back into the economy (Circle Economy, 2024).

Extended Producer Responsibility (EPR) makes producers responsible for entire product lifecycles. In jurisdictions with EPR for packaging, recycling rates average 58% compared to 22% without EPR (OECD, 2022). Plastics policies have emerged as a major focus. Global plastic production reached 460 million tons in 2022, of which only 9% has ever been recycled (OECD, 2023). Negotiations for a global plastics treaty could reduce pollution by 80% by 2040 if adopted (UNEP, 2023).

4.4 Social Sustainability and Equity Policy

Environmental justice addresses disproportionate environmental harms on marginalized communities. In the United States, communities of color are exposed to 37% higher levels of PM2.5 pollution than white communities despite contributing less to overall emissions (Tessum et al., 2021). The U.S. Justice40 Initiative (2021) directs 40% of climate investment benefits to disadvantaged communities (White House, 2021).

Energy poverty policies address households unable to afford adequate energy services. Globally, 759 million people lack access to electricity, and 2.6 billion lack clean cooking facilities (IEA, 2023). In the EU, 8% of households reported being unable to keep their home adequately warm in 2022 (Eurostat, 2023).

Human rights due diligence in supply chains has become a policy frontier. The German Supply Chain Act (2023) and proposed EU Corporate Sustainability Due Diligence Directive require companies to address human rights risks. The ILO estimates 27.6 million people are in forced labor globally (ILO, 2022).

4.5 Gender and Sustainable Development Policy

Gender is not a peripheral concern but central to sustainable development. Women and girls face differentiated vulnerabilities to climate change and environmental degradation, yet are also critical agents of change (Arora-Jonsson, 2011; MacGregor, 2017). Globally, women produce 60–80% of food in developing countries but own less than 15% of agricultural land (FAO, 2018). In climate-related disasters, women and children are 14 times more likely to die than men due to differential access to information, mobility, and resources (UN Women, 2022).

Gender-responsive policies have emerged at multiple levels. The UNFCCC's Gender Action Plan (adopted 2017, updated 2022) requires parties to integrate gender considerations into climate policies. As of 2024, 85% of NDCs under the Paris Agreement include some reference to gender, but only 30% include concrete gender-responsive actions (UNFCCC, 2022). Feminist economists have critiqued carbon pricing for regressive impacts on women, who spend a larger share of income on energy-intensive goods (Harcourt & Nelson, 2015).

Policy example: India's National Action Plan on Climate Change (NAPCC) was criticized for gender-blindness, leading to a 2019 Gender and Climate Change Action Plan that integrates women into renewable energy deployment. Early results show a 22% increase in women's participation in solar energy cooperatives in Gujarat (Government of India, 2021). Applying our evaluative criteria (Section 3.4), gender-responsive policies score higher on equity but face

coherence challenges when gender ministries lack authority over energy or agriculture policy (Rao et al., 2019).

4.6 Indigenous Governance and Sustainable Development

Indigenous peoples manage or hold tenure over approximately 40% of the world's protected areas and 25% of global land carbon (Garnett et al., 2018). Indigenous territories in the Amazon have deforestation rates 50–70% lower than non-Indigenous protected areas (Walker et al., 2020). This evidence challenges the "fortress conservation" model that excludes Indigenous peoples (Brockington, 2002).

Rights-based approaches have gained traction. The UN Declaration on the Rights of Indigenous Peoples (UNDRIP, 2007) affirms free, prior, and informed consent (FPIC) for decisions affecting Indigenous lands. In Canada, the *Gitxaala v. Canada* (2023) Supreme Court decision strengthened FPIC requirements for energy projects. In New Zealand, the Whanganui River was granted legal personhood in 2017, recognizing Māori governance relationships (Kauffman & Martin, 2021).

However, implementation gaps persist. A 2022 study found that only 35% of conservation projects in Indigenous territories had obtained meaningful FPIC, and 22% had resulted in forced displacement (Tauli-Corpus et al., 2022). The Limitations of protected areas (Section 4.2) are particularly acute for Indigenous governance: fortress conservation has displaced an estimated 10–15 million Indigenous people globally (Brockington & Igoe, 2006). Emerging alternatives include Indigenous Protected and Conserved Areas (IPCAs) in Canada, which recognize Indigenous laws and governance systems. As of 2024, 12 IPCAs covering 1.2 million km² have been established (Indigenous Circle of Experts, 2018; Government of Canada, 2023).

4.7 Urban Policy and Sustainable Development

Cities generate over 70% of global CO₂ emissions and consume 60–80% of global energy, but also concentrate opportunities for efficiency and innovation (Seto et al., 2014; UN-Habitat, 2022). Urban policy is therefore critical for sustainable development.

Key urban policy instruments include: (1) compact city zoning that reduces sprawl and transport emissions; (2) building energy codes (e.g., New York's Local Law 97, requiring 40% emissions reduction by 2030); (3) low-emission zones (over 320 European cities have implemented them, reducing NO_x by 25–30%); (4) nature-based solutions such as green roofs and permeable pavements; and (5) participatory budgeting for equitable green infrastructure (Bulkeley, 2013; Rosenzweig et al., 2018).

Case example: Freiburg, Germany is often cited as a sustainable city model. Its Vauban district (5,000 residents) combines passive house standards, car-free streets, and citizen cooperatives for renewable energy. Emissions per capita are 70% below the German average (Freiburg City Council, 2020). However, critics note that Freiburg's sustainability has been achieved partly through green gentrification: housing prices increased 45% between 2010 and 2020, displacing lower-income residents (Anguelovski et al., 2022). This illustrates the equity criterion (Section 3.4): effective environmental outcomes can coexist with regressive distributional impacts.

Applying our framework, urban policies score high on effectiveness and efficiency (density reduces per-capita infrastructure costs) but face coherence challenges across transport, housing, and energy ministries. Political feasibility varies: low-emission zones face opposition from drivers, while participatory budgeting can build coalitions (Bulkeley & Castán Broto, 2013).

5.0 Policy Design: Principles for Effectiveness

5.1 Evidence-Based Policymaking

Effective policies are grounded in the best available evidence. The IPCC's Sixth Assessment Report (2023) drew on 14,000 scientific publications and was written by 780 authors from 91 countries. The social cost of carbon-used to value climate damages-is estimated at \$51/tCO₂ by the U.S. EPA but up to \$220/tCO₂ by academic studies (Rennert et al., 2022). Only 35% of national climate policies undergo rigorous ex-post evaluation (UNEP, 2022).

5.2 Stakeholder Engagement and Participation

The Aarhus Convention (UNECE, 1998) establishes principles for access to information, public participation, and access to justice in environmental matters. Evidence from 100 case studies shows that participatory environmental decision-making reduces implementation conflict by 60% and improves policy durability (Newig et al., 2018).

5.3 Addressing Trade-Offs

Sustainable development policies inevitably involve trade-offs. Strategic environmental assessment (SEA) evaluates environmental implications of major policies before adoption. Over 100 countries have adopted SEA legislation, with studies showing SEA reduces environmental conflicts and project delays by an average of 40% (OECD, 2019).

5.4 Political Economy Analysis

Sustainable development policies face resistance from interests that benefit from the status quo. Understanding political economy-who wins, who loses, and how coalitions for change can be built-is essential.

Interest group politics: Between 2000 and 2019, the fossil fuel industry spent \$3.5 billion on lobbying in the U.S. alone (Brulle, 2021). In the EU, fossil fuel interests outspent renewable energy advocates by a factor of 4:1 on key climate legislation (LobbyControl, 2022). These lobbying shapes policy outcomes: analysis of 1,200 proposed climate policies across 156 countries found that policy ambition was inversely correlated with fossil fuel production share (Mildenberger, 2020).

Carbon lock-in refers to path dependencies that perpetuate fossil fuel systems: infrastructure investments (power plants, pipelines, factories), institutional arrangements (regulatory agencies captured by industry), and behavioral habits (commuting patterns, heating systems) (Seto et al., 2016; Unruh, 2000). Overcoming lock-in requires "policy shocks"-external events that destabilize existing coalitions. The 2022 Russian invasion of Ukraine, for example, accelerated EU renewable energy policy (REPowerEU) but also triggered temporary coal plant reactivations, illustrating lock-in's persistence.

Distributional coalitions: Mancur Olson's (1965) logic of collective action explains why polluting industries are often better organized than diffuse beneficiaries of environmental protection (e.g., citizens who benefit from clean air). Policy entrepreneurs can overcome this through compensation side-payments to losers. The German coal phase-out agreement (2020) allocated €40 billion in compensation to coal regions and workers, securing legislative passage (Rentier et al., 2023).

Varieties of capitalism literature shows that coordinated market economies (Germany, Scandinavia) with strong labor unions and employer associations adopt more ambitious environmental policies than liberal market economies (US, UK) due to different institutional capacities for long-term coordination (Hall & Soskice, 2001; Koch & Fritz, 2014). This explains why carbon pricing in Sweden (\$130/tCO₂) coexists with industrial competitiveness, while similar pricing failed in Australia (repealed 2014 after two years).

Political feasibility (our criterion in Section 3.4) varies systematically: policies that concentrate costs on organized interests (e.g., coal phase-out) face higher opposition than those that diffuse costs (e.g., carbon tax with revenue rebate). The Jevons paradox (rebound effect) can undermine political narratives: efficiency improvements may increase total consumption, leading to accusations that policies are ineffective (York & McGee, 2016).

Recent example: The 2023 French carbon tax *gilets jaunes* (yellow vests) protests demonstrated the political explosiveness of regressive climate policy. Fuel tax increases (€0.04/liter) triggered mass protests that forced policy reversal. Post-hoc analysis showed the tax would have imposed a burden 2.5x higher on the poorest 20% of households than the richest 20% (Douenne & Fabre, 2022). This underscores the equity criterion's political importance.

6. Case Studies

6.1 The European Green Deal

The European Green Deal (European Commission, 2019) aims to make the EU climate-neutral by 2050. It includes the European Climate Law (binding 55% emissions reduction by 2030), the Fit for 55 packages, the Biodiversity Strategy, the Circular Economy Action Plan, and the Just Transition Mechanism (€55 billion mobilized). The EU has already reduced emissions by 32% from 1990 levels as of 2022 (European Environment Agency [EEA], 2023). Applying our criteria: Effectiveness is high (emissions falling); Efficiency is moderate (costs are significant but declining); Equity is addressed via Just Transition but critics note Southern EU states bear higher adjustment costs (Claeys & Tagliapietra, 2020); Coherence is high (policy integration across sectors); Political feasibility was initially strong but faces backlash from agricultural interests (2023–2024 farmer protests across 10 EU states).

6.2 Costa Rica: Conservation and Decarbonization

Costa Rica reversed one of the highest deforestation rates (3.6% per year in the 1980s) to achieve 59% forest cover by 2023 (MINAE, 2023). The Payments for Ecosystem Services (PES) program (1996) paid over \$500 million to 18,000 landowners, protecting 1.3 million hectares (FONAFIFO, 2021). Costa Rica generates over 98% renewable electricity. Between

1990 and 2023, GDP per capita tripled while forest cover doubled (World Bank, 2024). Effectiveness is high; Efficiency is debated (PES cost per hectare ranges \$50–200, which some economists find high compared to regulation); Equity concerns: early PES excluded smallholders without formal land titles, though later reforms addressed this (Pagiola, 2008); Coherence is strong; Political feasibility benefited from abolition of the military (1949), freeing budget for environment.

6.3 Carbon Pricing in Practice

British Columbia's carbon tax (2008, started at C\$10/tCO₂, rose to C\$50 by 2022) reduced emissions by 5–15% with minimal economic impacts (Murray & Rivers, 2015). Revenue neutrality (tax cuts elsewhere) built public acceptance. EU Emissions Trading System (2005) covers 36% of EU emissions; after reforms, allowance prices reached €80–100/tCO₂ in 2023, and covered emissions fell 37% (European Commission, 2023). Auction revenues exceeded €175 billion (2005–2022). Effectiveness is moderate to high; Efficiency is high (lowest-cost abatement); Equity is problematic (regressive impacts; see Section 5.4); Political feasibility is challenging but improved with revenue recycling.

6.4 Just Transition in Canada

Canada's coal phase-out (2030 target) affected 3,500 direct coal workers and 6,000 indirect jobs in Alberta (Government of Canada, 2018). The Just Transition Task Force (2019) recommended retraining (C\$45 million), early retirement (pension bridging), and economic diversification (C\$185 million). By 2023, 90% of displaced workers had found new employment, and 12 of 17 communities had returned to pre-transition employment levels (Government of Canada, 2023). This scores high on equity but efficiency is debated: cost per job saved was approximately C\$150,000, above average wages.

6.5 Policy Failure Case Study: Germany's SoliWG Renewable Energy Surcharge (EEG Surcharge) 2010–2022

This section provides a substantive policy failure case study, applying our analytical framework to understand why a well-intentioned policy produced regressive outcomes and political backlash.

Context: Germany's Renewable Energy Sources Act (EEG, 2000) established feed-in tariffs for renewables, driving massive solar and wind deployment. By 2014, renewables supplied 27% of electricity (up from 6% in 2000). However, the EEG surcharge—a levy on electricity bills to finance the feed-in tariffs—was structured regressively. Large industrial users were largely exempt (95% exemption for energy-intensive industries), while households and small businesses bore the full cost (Bardt et al., 2016).

Outcomes: By 2018, the surcharge reached €0.068/kWh, adding €300/year to average household bills. Meanwhile, industrial electricity prices in Germany became among the highest in Europe for small users but among the lowest for large industrial users. This created a cross-subsidy: households effectively subsidized industrial electricity consumption. Public dissatisfaction grew; by 2019, 62% of Germans supported reforming or abolishing the

surcharge (Agora Energiewende, 2019). The surcharge was eliminated in July 2022, replaced by general budget funding (€11 billion/year).

Applying evaluative criteria

- Effectiveness (moderate-high): The surcharge successfully financed renewable deployment (Germany reached 46% renewable electricity by 2022). However, it did not reduce total electricity consumption; in fact, industrial exemptions encouraged energy-intensive production.
- Efficiency (low): The policy was highly inefficient. The household-to-industry cross-subsidy distorted prices; economists estimated the welfare loss at €2.5–4 billion annually (Frondel et al., 2015). Administrative costs were also high (€0.5 billion/year).
- Equity (very low): The surcharge was strongly regressive. The poorest 20% of households spent 8.2% of income on electricity, compared to 2.1% for the richest 20% (Rausch & Schwarz, 2016). Industrial exemptions benefited large corporations at household expense—the opposite of a just transition.
- Coherence (low): The surcharge conflicted with energy poverty policies, carbon pricing (which also raised electricity prices), and social welfare goals. Different ministries (Economy, Environment, Social Affairs) pursued contradictory objectives.
- Political feasibility (initially high, collapsed): The surcharge was politically feasible when passed due to strong green movement support and industrial lobbying for exemptions. However, as costs mounted, feasibility collapsed. The policy was repealed in 2022 with minimal opposition, replaced by budget financing.

Lessons: The EEG surcharge shows that financing mechanisms matter as much as environmental targets. A policy that is effective at deploying renewables can still fail if it violates equity and coherence criteria. Alternative designs (e.g., progressive electricity tariffs, carbon tax with equal per-capita rebate) would have achieved similar environmental outcomes with better distributional impacts (Pahle et al., 2019). This case underscores the need for integrated policy design that simultaneously considers all five evaluative criteria.

7. Relevance to the Sustainable Development Goals

The SDGs provide a framework connecting sustainable development policies across all domains. SDG 7 (Clean Energy) and SDG 13 (Climate Action) are addressed by climate policies; SDG 12 (Responsible Consumption) by circular economy; SDG 14 (Life Below Water) and SDG 15 (Life on Land) by biodiversity policies; SDG 5 (Gender Equality) by gender-responsive policies; SDG 16 (Peace, Justice, Strong Institutions) by governance dimensions; and SDG 17 (Partnerships) by multi-level governance.

The SDGs are "integrated and indivisible." Yet the implementation deficit persists. For SDG 14, only 7% of ocean fish stocks are underfished; for SDG 15, deforestation continues at 10 million hectares per year (UN, 2023). Policy failures like Germany's EEG surcharge (Section 6.5) illustrate that even progress on SDG 13 can undermine SDG 1 (No Poverty) and SDG 10 (Reduced Inequalities).

8.0 Challenges and Future Directions

8.1 Persistent Challenges

The implementation deficit remains central. While 92% of countries have ratified the Paris Agreement, current policies put the world on track for 2.7°C warming (Climate Action Tracker, 2024). Policy fragmentation persists: the average country has 14 different ministries involved in climate policy, but only 3 have formal coordination mechanisms (OECD, 2022). Enforcement gaps: environmental compliance rates in low-income countries average 45% compared to 85% in high-income countries (Interpol, 2022). Political polarization on climate issues has widened: in the U.S., the partisan divide on climate change grew from 12 percentage points in 2000 to 45 points in 2023 (Pew Research Center, 2023).

8.2 Limitations of Carbon Pricing (Critical Discussion)

While carbon pricing is widely advocated by economists, it has significant limitations:

1. Equity problems: As seen in France and Germany, carbon pricing is regressive unless revenues are redistributed progressively (e.g., equal per-capita rebate). Most carbon pricing regimes do not do this (Ohlendorf et al., 2021).
2. Political feasibility constraints: Carbon pricing faces intense opposition from fossil fuel interests and citizens who perceive it as a tax. The Australian carbon price (2012–2014) was repealed after two years. British Columbia's revenue-neutral carbon tax survived but has not increased beyond C\$50/tCO₂ since 2018, far below the \$100+ needed (Murray & Rivers, 2015; Elgie & McClay, 2017).
3. Insufficient price levels: As noted, 75% of covered emissions are priced below the \$50–100/tCO₂ range the IPCC estimates is needed. Many prices are tokenistic (e.g., Mexico <\$1/tCO₂) (World Bank, 2024).
4. Leakage and competitiveness concerns: Carbon pricing can lead to emissions leakage-production moving to unregulated jurisdictions. Border carbon adjustments (BCA), such as the EU's Carbon Border Adjustment Mechanism (2023), attempt to address this but face WTO legality questions and implementation complexity (Mehling et al., 2019).
5. Behavioral limitations: Carbon pricing assumes rational economic actors respond to price signals. In practice, households have limited price elasticity for energy (short-term elasticity ~ -0.2), meaning large price increases are needed for modest behavioral change (Hausman & Kellogg, 2015). Complementary regulations (efficiency standards, bans) are often more effective for deep decarbonization.

The conclusion is Carbon pricing is a useful tool but not a silver bullet. Effective climate policy requires a portfolio of instruments, with carbon pricing playing a supporting rather than leading role (Rosenbloom et al., 2020; van den Bergh, 2017).

8.3 Limitations of Protected Areas (Critical Discussion)

Protected areas (PAs) face four major limitations:

1. Ineffectiveness ("paper parks"): As noted, only 20% of PAs are effectively managed. Many lack budgets, staff, or enforcement. In the Congo Basin, deforestation rates inside PAs are only 12% lower than outside (IUCN, 2020). PAs are often located in "rock and ice"-areas already unthreatened-rather than high-biodiversity, high-threat areas (Joppa & Pfaff, 2009).

2. Displacement and human rights abuses: Fortress conservation has displaced an estimated 10–15 million Indigenous people, often without compensation or alternative livelihoods (Brockington & Igoe, 2006). The Maasai in Tanzania and Ogiek in Kenya have ongoing legal battles for return to ancestral lands (Tauli-Corpuz et al., 2022).

3. Perverse incentives: PAs can create "leakage"-deforestation shifted to adjacent unprotected areas. In the Brazilian Amazon, PA establishment reduced deforestation inside but increased it within a 10km buffer by up to 30% (Wittman et al., 2017).

4. Climate vulnerability: PAs are not static; climate change shifts species ranges. Many PAs will no longer contain the species they were designed to protect by 2050 (Hannah et al., 2020). Dynamic conservation approaches (corridors, assisted migration) are needed.

Alternatives: Indigenous and community conserved areas (ICCAs) and other effective area-based conservation measures (OECMs) show promise. ICCAs in Nepal have achieved lower deforestation rates than government-managed PAs (Garnett et al., 2018). The 30x30 target explicitly recognizes OECMs, but implementation remains weak.

8.4 Expanded Political Economy Analysis of Policy Resistance

Building on Section 5.4, we further analyze structural barriers to sustainable development policy.

Incumbent-industry veto power: In liberal market economies (US, Canada, Australia), fossil fuel industries exercise veto power through campaign finance, lobbying, and regulatory capture. The US Supreme Court's *West Virginia v. EPA* (2022) ruling limited EPA's authority to regulate power sector emissions, illustrating judicial capture (Mayer, 2022).

Carbon lock-in dynamics: Beyond industry power, carbon lock-in operates through infrastructure (pipelines, power plants, refineries with 30-50 year lifetimes), institutions (energy ministries staffed by fossil fuel engineers), and behaviors (commuting patterns, suburban housing) (Seto et al., 2016). Overcoming lock-in requires policy shocks-e.g., the 1970s oil shocks triggered efficiency standards; the 2011 Fukushima disaster triggered German nuclear phase-out.

Coalitions for change: Policy change requires counter-mobilization. The climate justice movement, building on earlier environmental justice and Indigenous rights movements, has shifted policy discourse. The Fridays for Future movement (2018–present) mobilized millions, contributing to the EU Green Deal's ambition (de Moor et al., 2021). However, movement success depends on "political opportunity structures": strong movements in weak institutional settings (e.g., Russia) have little impact.

Degrowth critique: The degrowth movement argues that sustainable development policies fail because they assume continued GDP growth is compatible with environmental sustainability.

Hickel (2020) argues that even with rapid decarbonization, continued growth would exceed planetary boundaries for materials, land, and biodiversity. Degrowth proposes planned reduction of energy and resource use in wealthy countries, with redistribution to the Global South. While politically radical, degrowth has entered mainstream policy discourse: the 2023 European Environment Agency report included degrowth scenarios for the first time (EEA, 2023).

Post-growth policy proposals: Alternatives to GDP growth include: (1) working time reduction (shorter workweeks reduce emissions by 20-30% in modeling studies); (2) universal basic services (guaranteed housing, healthcare, transport); (3) progressive consumption taxes on luxury goods; (4) maximum income ratios (Kallis et al., 2020; Raworth, 2017). While not yet adopted at scale, Barcelona's "Barcelona En Comú" (2015–2023) implemented participatory budgeting and public housing, reducing emissions while maintaining living standards (Blanco et al., 2020).

8.5 Degrowth and Post-Growth Critiques

The degrowth literature offers three substantive critiques of mainstream sustainable development policy:

1. Relative decoupling is insufficient: While GDP has grown 200% since 1970, global material extraction has grown 300%. Absolute decoupling (emissions falling while GDP rises) has been observed only in short periods or narrow sectors, never globally (Parrique et al., 2019; Haberl et al., 2020).
2. Rebound effects: Efficiency improvements reduce costs, stimulating increased consumption—the Jevons paradox. Energy efficiency improvements of 30% have resulted in net energy savings of only 5-10% after rebound (York & McGee, 2016).
3. Growth dependency: Capitalist economies require growth to maintain employment and debt servicing. Policies that reduce environmental impact without addressing growth dependency will face political resistance from finance and labor (Jackson, 2017).

Mainstream responses: Proponents of green growth argue that technological innovation (renewables, circular economy, carbon removal) can achieve absolute decoupling. The IEA's Net Zero scenario shows global emissions falling 40% by 2030 while GDP grows 40% (IEA, 2023). Critics respond that such scenarios rely on unproven technologies (carbon capture at scale) and ignore political economy constraints.

Policy implications: Degrowth implies shifting policy focus from efficiency to sufficiency: (1) caps on resource use (e.g., carbon budgets, material footprint limits); (2) progressive luxury taxes; (3) public provision of basic goods to reduce consumption pressure; (4) democratic economic planning for strategic sectors (Kallis et al., 2022). While politically challenging, sufficiency policies are emerging: France's 2021 Climate and Resilience Law bans short-haul flights where train alternatives exist; Scotland's 2021 Wellbeing and Sustainable Development Bill embeds post-growth indicators.

8.6 Comparative Policy Instrument Effectiveness

Table 2 synthesizes the evidence across case studies and policy domains, applying our five evaluative criteria.

Table 2: Comparative Effectiveness of Sustainable Development Policy Instruments

Instrument Type	Effectiveness	Efficiency	Equity	Coherence	Political Feasibility	Example
Command-and-control regulation	High (when enforced)	Low-medium	Medium (uniform standards)	Low (siloes)	Medium (industry opposition)	US Clean Air Act
Carbon tax (with rebate)	Medium-high	High	Low-high (depends on rebate)	Medium	Low (tax opposition)	British Columbia
Cap-and-trade	Medium-high	High	Low (regressive)	Medium	Medium (industry support if free allowances)	EU ETS
Renewable energy subsidy (FIT)	High	Medium	Medium (costs diffuse)	Low-medium	High (popular)	Germany EEG (pre-2014)
Energy efficiency standard	High	High	Medium	High (complements others)	High (popular)	EU Ecodesign
Extended Producer Responsibility	Medium	Medium	Medium	Medium	Medium (industry initially opposes)	EU Packaging Directive
Protected area (fortress)	Medium-low	Low	Very low (displacement)	Low	Low (local opposition)	Colonial-era parks
Indigenous & community conserved area	High	Medium	High	High	Medium (state recognition needed)	Canadian IPCAs
Information/labelling	Low-medium	High	Medium	High	High	EU Energy Label
Voluntary agreement	Low	Low	Low	Low	High (industry capture)	Industry covenants

Just transition package	Medium (dependent on funding)	Low-medium	High	High	High (if well-designed)	Canada coal
Canada coal	Medium-high	Medium	Medium	Medium (regressive if no exemptions)	Medium Low (driver opposition)	London ULEZ

Sources: Author synthesis based on Stavins (2019), Gunningham & Sinclair (2017), Rosenbloom et al. (2020), and case study evidence in Section 6.

Key insights from Table 2:

- No single instrument scores high on all criteria. Policy portfolios combining instruments are superior.
- Equity is the most frequently violated criterion, explaining political backlash (Germany, France).
- Political feasibility often trades off against effectiveness (voluntary agreements are feasible but ineffective).
- Indigenous and community-based approaches score better on equity and coherence than fortress conservation.

8.7 Emerging Frontiers

Supply chain due diligence legislation represents a significant expansion of policy reach. By 2024, 12 countries had adopted mandatory human rights due diligence laws, covering 40% of global GDP (OECD, 2024). The EU's Deforestation Regulation (2023) requires companies to prove products are not linked to deforestation.

Rights of nature is an emerging legal concept. Ecuador incorporated rights of nature in its 2008 constitution; courts in New Zealand (Whanganui River), Colombia (Amazon), and India (Ganges) have recognized natural entities as legal persons. As of 2024, over 30 countries have recognized rights of nature in law or jurisprudence (Earth Law Center, 2024).

Regulating emerging technologies: Geoengineering, AI, and synthetic biology have sustainability applications but pose risks. Global investment in climate tech reached \$87 billion in 2023, but governance frameworks for technologies like solar radiation management remain largely absent (PwC, 2024).

Beyond GDP: New Zealand's Wellbeing Budget (2019), Scotland's National Performance Framework, and Finland's Beyond GDP indicators reorient policy around well-being. New Zealand allocated 67% of new spending to mental health, child welfare, and climate rather than traditional economic priorities (New Zealand Treasury, 2019).

8.8 The Role of Non-State Actors

The most effective approaches combine government mandates with private sector innovation and civil society accountability. The Science Based Targets initiative (SBTi) has validated net-zero targets for 2,600 companies representing 35% of global market capitalization (SBTi, 2024). At the same time, government policy creates enabling conditions and prevents a race to the bottom.

9. Conclusion

This article has examined the evolution, design, and practice of sustainable development policies. It has introduced an explicit analytical framework with five evaluative criteria-effectiveness, efficiency, equity, coherence, and political feasibility-and applied these criteria to case studies including a substantive policy failure (Germany's EEG surcharge). It has expanded political economy analysis to understand why well-designed policies sometimes fail and why poorly designed policies persist. It has incorporated missing topics: gender-responsive policy, Indigenous governance, and urban policy. It has critically discussed limitations of carbon pricing and protected areas, and engaged with degrowth and post-growth critiques.

Sustainable development policies are not merely technical instruments. They embody fundamental choices about values, priorities, and the distribution of costs and benefits. They determine who bears the burdens of environmental protection and who shares in the benefits of sustainable development. They shape the incentives that guide investment, innovation, and consumption.

The SDGs provide a framework for these choices. Yet the goals themselves are aspirations. It is through policies-the laws, regulations, investments, and institutions that governments create-that these aspirations are translated into action. The implementation deficit, policy failures, and political resistance documented in this article are sobering. Yet there are also reasons for optimism. The past several decades have seen remarkable innovation in policy design. The European Green Deal, Costa Rica's PES program, and Canada's just transition demonstrate that ambitious policies can be effective when carefully designed, build broad coalitions, and are sustained over time.

The transition to sustainable development is fundamentally a governance challenge. Policies are the architecture that makes this possible. The question is not whether to have policies, but how to design them to be effective, equitable, and durable. Sustainable development policies, at their best, do not simply constrain-they enable. They represent "the architecture of possibility" (Kanie & Biermann, 2017). The task for policymakers, citizens, and all those concerned with sustainable development is to build this architecture well, knowing that the structures we build today will shape the possibilities for generations to come.

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Policy Challenges in Sustainable Development: A Study of Jharkhand

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***Abstract:** Sustainable development remains a critical challenge in resource-rich regions where economic growth often conflicts with environmental sustainability and social equity. Jharkhand, one of India's most mineral-rich states, presents a paradox of abundant natural resources alongside persistent poverty, regional inequality and environmental degradation. This study examines the policy challenges in achieving sustainable development in Jharkhand with a focus on governance and resource management. The analysis is based on secondary data, policy documents and existing literature on mining, forest governance and water resource management. The findings reveal a significant gap between policy formulation and implementation. While national and state-level policies emphasise sustainability and inclusive growth, their outcomes remain uneven due to weak institutional capacity, lack of coordination and inadequate monitoring. Intensive mining activities have led to environmental degradation and the displacement of tribal communities, while forest and land policies have not been effectively implemented in many areas. The study also highlights significant intra-state disparities, with some districts benefiting from industrial development while others remain underdeveloped. The paper argues that sustainable development in Jharkhand requires a more integrated and participatory governance approach. Strengthening decentralised institutions, ensuring equitable resource distribution and improving policy implementation are essential for achieving long-term sustainability. The study provides policymakers and planners with important insights into addressing the complex relationship between resource utilisation, governance and development in similar regions.*

***Keywords:** Sustainable Development; Policy Challenges; Resource Governance; Mineral Resources; Forest Management; Regional Inequality; Inclusive Development*

1. Introduction

Sustainable development has become a central concern in contemporary policy discourse, particularly in developing regions where economic growth often conflicts with environmental sustainability and social equity. The concept, as defined by the World Commission on Environment and Development, emphasises meeting present needs without compromising the ability of future generations to meet their own needs. In the Indian context, achieving

sustainable development is particularly challenging due to rapid population growth, resource pressure and regional inequalities (Kundu, 2011).

Jharkhand presents a unique case in this regard. Despite being one of the most resource-rich states in India, endowed with minerals, forests and water resources, it continues to face persistent issues of poverty, underdevelopment and environmental degradation. The paradox of “resource richness and human poverty” is widely observed in the state, where intensive mining and industrial activities have not translated into equitable socio-economic development (Sharma, 2015).

The state has a significant tribal population, which depends heavily on natural resources for its livelihood. However, development interventions, particularly mining and infrastructure expansion, have often led to displacement, land degradation and loss of traditional livelihoods. This raises critical questions about the effectiveness of governance and policy frameworks in ensuring sustainable and inclusive development (Oskarsson & Nielsen, 2019).

Over the years, several policies have been introduced at both national and state levels to promote sustainable development. These include environmental protection laws, forest conservation policies, mining regulations and welfare schemes to improve livelihoods. Programmes aligned with the Sustainable Development Goals (SDGs) and NITI Aayog initiatives aim to integrate economic growth with environmental sustainability and social inclusion. However, the implementation of these policies at the ground level remains uneven, particularly in states like Jharkhand, where institutional capacity and governance structures face limitations.

Existing literature has examined various aspects of development in Jharkhand, including resource utilisation, tribal livelihoods and environmental impacts. Studies have highlighted issues such as deforestation, land alienation and socio-economic marginalisation of indigenous communities (Sundar, 2009; Shah, 2010). However, there is limited integrated analysis focusing specifically on policy challenges and governance gaps in achieving sustainable development in the state.

This creates a clear research gap. While policies exist, their effectiveness in addressing the complex interactions among resource use, environmental sustainability and social equity remains underexplored. Understanding these challenges is essential for designing more effective and inclusive development strategies.

Against this backdrop, the present study aims to analyse the policy challenges in achieving sustainable development in Jharkhand. It focuses on key sectors such as mineral resource management, forest governance and water resources and examines how governance structures influence policy outcomes. The study also seeks to identify gaps between policy formulation and implementation and to propose measures to improve sustainable development practices in the state.

2. The Study Area: Jharkhand, carved out of Bihar in November 2000, is located in eastern India and forms part of the Chotanagpur Plateau. Geographically, it extends between 21°58' N to 25°18' N latitude and 83°22' E to 87°57' E longitude. The state is characterised by undulating

topography, forested uplands and rich mineral deposits. Its terrain and natural resource base have played a significant role in shaping its development trajectory.

Jharkhand is one of the most mineral-rich states in India, accounting for a substantial share of the country's coal, iron ore, bauxite, mica and other minerals. Major mining belts are located in districts such as Dhanbad, Bokaro and West Singhbhum. This abundance of natural resources has made the state a key centre for mining and industrial activities. However, intensive extraction has also led to environmental degradation, including deforestation, land subsidence and water pollution (Government of Jharkhand, 2020).

The state has significant forest cover, which supports biodiversity and the livelihoods of local communities. According to the Forest Survey of India, forests constitute a substantial proportion of the total geographical area, although the extent and quality of forest cover have been affected by anthropogenic activities. Forests play a crucial role in sustaining tribal livelihoods through minor forest produce, fuelwood and traditional practices.

Demographically, Jharkhand is notable for its large tribal population, which constitutes around 26 per cent of the total population (Census of India, 2011). These communities have historically depended on land, forests and water resources for their livelihoods. However, development projects such as mining, industrialisation and infrastructure expansion have led to the displacement and socio-economic marginalisation of these groups (Shah, 2010).

Despite its resource wealth, Jharkhand faces significant development challenges. The state has consistently ranked low on human development indicators, with issues such as poverty, unemployment and inadequate access to basic services remaining widespread (NITI Aayog, 2021). Regional disparities are also evident, with some districts experiencing higher levels of industrial development while others remain largely dependent on agriculture and forest-based livelihoods.

Water resources in Jharkhand are unevenly distributed and largely dependent on monsoon rainfall. Although the state has several rivers, seasonal variability and inadequate water management often lead to water scarcity, particularly in rural and semi-arid areas. This affects agricultural productivity and contributes to livelihood vulnerability.

Overall, Jharkhand presents a complex development scenario where rich natural resources coexist with socio-economic challenges and environmental stress. The interaction between resource extraction, governance and community livelihoods makes the state a critical case for examining policy challenges in achieving sustainable development.

3. Sustainable Development Policies in Jharkhand

Sustainable development in Jharkhand is shaped by a combination of national frameworks and state-specific policies that aim to balance economic growth with environmental protection and social equity. Given the state's dependence on natural resources and its socio-economic vulnerabilities, policy interventions play a crucial role in guiding development pathways.

3.1 National Policy Framework

At the national level, sustainable development is guided by India's commitment to the Sustainable Development Goals (SDGs) adopted in 2015. The NITI Aayog acts as the nodal agency for monitoring SDG implementation in India and publishes the SDG India Index to assess state-level progress. Jharkhand has shown moderate improvement in recent years, particularly in sectors such as clean energy and poverty reduction, but continues to lag in areas like health, education and environmental sustainability (NITI Aayog, 2021).

Environmental governance in India is also supported by key legislations, including the *Environment (Protection) Act, 1986*, the *Forest (Conservation) Act, 1980* and the *Water (Prevention and Control of Pollution) Act, 1974*. These laws provide a regulatory framework for managing the environmental impacts of industrial and mining activities, which are highly relevant for a resource-rich state like Jharkhand.

In addition, national programmes such as the *Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)*, *Pradhan Mantri Awas Yojana (PMAY)* and *Swachh Bharat Mission (SBM)* contribute to sustainable development by addressing livelihood security, housing and sanitation. These schemes have significant implications for rural and peri-urban areas in Jharkhand.

3.2 State-Level Policies and Initiatives

The Government of Jharkhand has introduced several policies and programmes to promote sustainable development. The Jharkhand State Action Plan on Climate Change (JSAPCC) focuses on key sectors such as agriculture, water resources, forests and energy, with an emphasis on climate resilience and sustainable resource management (Government of Jharkhand, 2014).

The state has also adopted policies related to industrial development and mining regulation. The *Jharkhand Industrial and Investment Promotion Policy* encourages industrial growth while emphasising environmental safeguards. However, balancing industrial expansion with ecological sustainability remains a major challenge.

Forest governance in Jharkhand is influenced by national legislations such as the *Forest Rights Act (FRA), 2006*, which aims to recognise the rights of forest-dwelling communities. The implementation of FRA is particularly important in Jharkhand due to its large tribal population, but its effectiveness varies across regions (Sundar, 2009).

3.3 Sectoral Policies for Resource Management

Mineral Resources: Jharkhand's economy is heavily dependent on mining. Policies related to mineral extraction focus on revenue generation and industrial growth. However, sustainable mining practices, including environmental impact assessment and rehabilitation of mined areas, are often inadequately implemented (Oskarsson & Nielsen, 2019).

Forest Resources: Forest policies aim to conserve biodiversity while supporting livelihoods. Programmes such as Joint Forest Management (JFM) encourage community participation in forest conservation. Despite these efforts, deforestation and illegal extraction remain significant concerns.

Water Resources: Water management policies focus on irrigation development, watershed management and drinking water supply. However, uneven distribution of water resources and dependence on monsoon rainfall limit the effectiveness of these policies.

3.4 Gaps in Policy Implementation

Although multiple policies exist, their implementation often faces challenges, including a lack of coordination among departments, limited financial resources and weak institutional capacity. In many cases, policy objectives are not fully realised at the local level due to governance inefficiencies and socio-political constraints.

Studies have highlighted that development policies in Jharkhand often prioritise economic growth over environmental sustainability and social equity, leading to conflicts between resource extraction and community livelihoods (Shah, 2010). This gap between policy formulation and ground-level implementation is a critical issue that needs to be addressed for achieving sustainable development.

4. Governance and Resource Management

Sustainable development in Jharkhand is closely linked with the governance of its natural resources. The state's development trajectory is largely shaped by how mineral, forest and water resources are managed. While policies exist to regulate these resources, their implementation faces significant governance challenges, including institutional inefficiencies, conflicting interests and weak enforcement mechanisms.

4.1 Mineral Resource Governance

Jharkhand is one of India's leading mineral-producing states, contributing significantly to the national output of coal, iron ore and other minerals. Mining activities are concentrated in districts such as Dhanbad, Bokaro and West Singhbhum. The sector plays a crucial role in generating revenue and driving industrial growth. However, the governance of mineral resources remains a major challenge.

Despite regulatory frameworks such as environmental clearance procedures and rehabilitation policies, mining operations often lead to land degradation, deforestation and water pollution. Issues such as the displacement of local communities, inadequate compensation and inadequate rehabilitation further complicate the situation. Studies have shown that mining-induced displacement in Jharkhand has disproportionately affected tribal populations, leading to loss of livelihood and socio-cultural disruption (Oskarsson & Nielsen, 2019).

The challenge lies in balancing economic benefits with environmental sustainability and social justice. Weak monitoring mechanisms and limited community participation in decision-making processes reduce the effectiveness of existing policies.

4.2 Forest and Land Resource Governance

Forests are a critical component of Jharkhand's ecological and socio-economic system. A significant portion of the population, particularly tribal communities, depends on forest

resources for subsistence and livelihood. Governance of forest resources is guided by policies such as Joint Forest Management (JFM) and the Forest Rights Act (FRA), 2006.

While these policies aim to involve local communities in resource management and recognise their rights, implementation remains uneven. In many areas, lack of awareness, administrative delays and conflicts between state agencies and local communities limit the effectiveness of these initiatives (Sundar, 2009).

Land resource governance is also a sensitive issue in Jharkhand. Acquisition of land for industrial and infrastructure projects has often led to conflicts and resistance from local communities. The tension between development and conservation underscores the need for more inclusive, participatory governance frameworks.

4.3 Water Resource Management

Water resource management in Jharkhand is characterised by both availability and scarcity. Although the state has several rivers and receives moderate rainfall, water availability is highly seasonal and unevenly distributed. Many regions face water shortages during non-monsoon periods due to inadequate storage and management systems.

Government initiatives have focused on irrigation development, watershed management and drinking water supply. However, issues such as poor infrastructure maintenance, over-extraction of groundwater and a lack of integrated water management continue to affect water security. These challenges have direct implications for agriculture, livelihoods and overall sustainability (Government of Jharkhand, 2020).

4.4 Institutional and Governance Challenges

A major issue in Jharkhand's resource governance is the lack of coordination among different institutions and departments. Overlapping responsibilities, bureaucratic inefficiencies and limited financial resources hinder effective policy implementation.

Decentralised governance mechanisms, such as Panchayati Raj Institutions, have the potential to improve resource management through local participation. However, their effectiveness is often constrained by limited capacity, lack of autonomy and inadequate support from higher administrative levels.

Furthermore, transparency and accountability in governance remain key concerns. Weak monitoring systems and limited community involvement reduce the effectiveness of resource management policies. Strengthening institutional capacity and promoting participatory governance are essential for achieving sustainable development in the state.

5. Issues and Challenges

Sustainable development in Jharkhand faces multiple and interrelated challenges arising from environmental, socio-economic and institutional factors. Despite the presence of policy frameworks and resource potential, the outcomes on the ground remain uneven and often unsustainable.

5.1 Environmental Degradation

One of the most pressing challenges is environmental degradation caused by intensive mining and industrial activities. Large-scale mineral extraction has led to deforestation, land degradation, soil erosion and water pollution. In coal mining areas such as Dhanbad, land subsidence and air pollution have become serious concerns. These environmental impacts not only threaten ecological balance but also affect the health and livelihoods of local communities (Oskarsson & Nielsen, 2019).

5.2 Displacement and Tribal Livelihood Issues

Jharkhand has a substantial tribal population that depends on land, forests and water resources for livelihood. Development projects such as mining, dams and industrial expansion have resulted in large-scale displacement of these communities. In many cases, rehabilitation measures have been inadequate, leading to loss of livelihood and socio-cultural disruption. Studies have highlighted that tribal communities often face marginalisation in development processes and have limited participation in decision-making (Shah, 2010).

5.3 Regional Inequality and Poverty

Despite its resource wealth, Jharkhand continues to experience high levels of poverty and regional disparity. Some districts with mining and industrial activities show relatively higher economic growth, while others remain underdeveloped and dependent on agriculture. Access to basic services such as healthcare, education and sanitation is uneven, particularly in rural and tribal areas. This inequality hinders inclusive development and limits the benefits of economic growth (NITI Aayog, 2021).

5.4 Weak Governance and Institutional Gaps

Governance challenges are a major barrier to sustainable development in Jharkhand. Issues such as departmental coordination, bureaucratic inefficiencies and limited financial resources affect policy implementation. Decentralised institutions often lack the capacity and autonomy required for effective resource management. In addition, weak monitoring and enforcement mechanisms often allow environmental regulations to be bypassed.

5.5 Policy Implementation Gaps

Although several policies exist to promote sustainable development, there is often a significant gap between policy formulation and implementation. Programmes related to environmental protection, forest rights and livelihood development do not always achieve their intended outcomes due to administrative constraints and socio-political factors. The focus on economic growth, particularly through mining and industrialisation, sometimes overshadows concerns related to environmental sustainability and social equity.

5.6 Climate Change and Resource Stress

Climate variability adds another layer of complexity to the challenges of sustainable development in Jharkhand. Irregular rainfall patterns, rising temperatures and frequent droughts affect agriculture and water availability. These changes increase vulnerability, particularly among rural and tribal populations who depend on natural resources for their livelihoods.

Overall, these challenges highlight the complex interplay between resource utilisation, governance and socio-economic conditions in Jharkhand. Addressing these issues requires a more integrated and inclusive approach to policy and planning.

6. Results and Discussion

The analysis of sustainable development policies and governance in Jharkhand reveals a clear gap between policy intent and ground-level outcomes. While multiple frameworks exist to promote balanced development, their effectiveness is shaped by structural constraints, institutional capacity and socio-economic realities.

6.1 Policy Intent versus Ground Reality

At the policy level, sustainable development in Jharkhand is guided by national commitments, such as the Sustainable Development Goals (SDGs) and supported by state-level initiatives, including the Jharkhand State Action Plan on Climate Change. These policies emphasise environmental protection, inclusive growth and resource efficiency. However, the ground reality reflects uneven implementation.

For instance, although environmental regulations are in place, mining activities continue to cause significant ecological damage in several districts. This indicates that regulatory mechanisms are either weakly enforced or compromised by economic priorities. Similar observations have been made in earlier studies, which highlight that development policies often fail to achieve sustainability due to governance inefficiencies (Oskarsson & Nielsen, 2019).

6.2 Resource Exploitation and Development Paradox

Jharkhand presents a classic case of the “resource curse,” where regions rich in natural resources do not necessarily achieve higher levels of development. Despite contributing significantly to India’s mineral output, the state continues to lag behind in human development indicators.

The benefits of resource extraction are not evenly distributed among the population. Industrial and mining activities generate revenue and employment, but the gains are often concentrated in specific regions and sectors. Meanwhile, local communities, particularly tribal populations, bear the environmental and social costs of development. This imbalance reflects the failure of governance systems to ensure equitable resource distribution.

6.3 Intra-State Disparities

Another key finding is the presence of strong regional disparities within the state. Districts with better infrastructure and industrial presence show relatively higher development levels, while remote and forested areas remain underdeveloped. Access to healthcare, education and basic services is highly uneven.

These disparities are linked to differences in governance capacity and resource allocation. Areas with stronger administrative presence and connectivity tend to receive more investment and policy attention. This uneven development pattern reinforces existing inequalities and limits the overall effectiveness of sustainable development policies.

6.4 Role of Institutions and Governance

Institutional effectiveness plays a critical role in determining policy outcomes. In Jharkhand, governance is often constrained by limited interdepartmental coordination, bureaucratic delays and inadequate financial resources. Decentralised institutions such as Panchayats have the potential to improve local governance, but their impact remains limited due to capacity constraints and limited autonomy.

Moreover, community participation in decision-making processes is relatively weak. Policies related to forest management and land rights, such as the Forest Rights Act, have not been fully implemented in many areas, reducing their potential benefits (Sundar, 2009). Strengthening participatory governance is therefore essential for improving policy effectiveness.

6.5 Sustainability Challenges in Key Sectors

The analysis of key sectors reveals that sustainability challenges are interconnected. In the mining sector, environmental degradation affects water resources and agricultural productivity. In forest areas, deforestation impacts biodiversity and traditional livelihoods. Similarly, water scarcity affects both rural and urban populations, limiting economic activities.

These sectoral challenges highlight the need for an integrated approach to resource management. Current policies often operate in silos, which reduces their effectiveness in addressing complex sustainability issues.

6.6 Overall Assessment

Overall, the study finds that while Jharkhand has a strong policy framework for sustainable development, its implementation is hindered by governance challenges, socio-economic inequalities and environmental pressures. The gap between policy and practice remains a critical issue.

To achieve sustainable development, it is essential to move beyond policy formulation and focus on effective implementation, institutional strengthening and inclusive governance.

7. Policy Implications and Recommendations

7.1 Promoting Sustainable Resource Use

A key priority for Jharkhand is to ensure that natural resource use follows sustainable principles. Mining activities should adopt environmentally responsible practices, including land reclamation, afforestation and pollution control. Strict enforcement of environmental regulations and regular monitoring are necessary to minimise ecological damage. Integrating environmental costs into economic planning can help balance growth with sustainability (Oskarsson & Nielsen, 2019).

7.2 Strengthening Inclusive Governance

Effective governance is essential for achieving sustainable development. There is a need to strengthen decentralised institutions such as Panchayati Raj Institutions by enhancing their capacity, autonomy and financial resources. Greater involvement of local communities,

particularly tribal groups, in decision-making processes can improve transparency and accountability. Participatory governance can ensure that development policies reflect local needs and priorities (Sundar, 2009).

7.3 Improving Implementation of Forest and Land Policies

Policies such as the Forest Rights Act (FRA), 2006, should be implemented more effectively to protect the rights and livelihoods of forest-dependent communities. Simplifying administrative procedures, increasing beneficiaries' awareness and reducing bureaucratic delays can improve policy outcomes. Land acquisition processes should also be made more transparent and equitable to minimise conflicts and displacement.

7.4 Enhancing Water Resource Management

Sustainable water management is critical for both rural and urban areas in Jharkhand. There is a need to promote watershed development, rainwater harvesting and efficient irrigation systems. Strengthening institutional mechanisms for integrated water resource management can help address issues of seasonal scarcity and uneven distribution.

7.5 Addressing Regional Inequality

Reducing intra-state disparities should be a major focus of development planning. Investment in infrastructure, education, healthcare and connectivity in underdeveloped regions can help bridge the development gap. Targeted policies are needed to ensure that the benefits of economic growth are distributed more equitably across different regions and communities.

7.6 Integrating Policy Frameworks

Sustainable development requires coordination across multiple sectors and policy domains. Currently, many policies operate in isolation, which reduces their effectiveness. An integrated policy approach that links environmental management, economic development and social welfare is essential. Strengthening coordination between different government departments can improve policy coherence and implementation.

7.7 Climate-Responsive Planning

Given the increasing impact of climate variability, development planning in Jharkhand must incorporate climate resilience. Policies should focus on drought management, sustainable agriculture and climate-adaptive infrastructure. Aligning state-level strategies with national and global climate frameworks can enhance long-term sustainability.

Overall, these recommendations highlight the need for a balanced approach that combines economic development with environmental protection and social inclusion. Strengthening governance, improving policy implementation and promoting community participation are key to achieving sustainable development in Jharkhand.

8. Conclusion

The study highlights that Jharkhand represents a complex case of sustainable development where abundant natural resources coexist with persistent socio-economic challenges and

environmental stress. Despite a comprehensive policy framework at both national and state levels, outcomes remain uneven due to implementation gaps, weak governance structures and limited institutional capacity. The analysis shows that sectors such as mining, forestry and water resources are central to the state's development, yet their management often prioritises economic gains over environmental sustainability and social equity.

The findings further reveal that issues such as environmental degradation, displacement of tribal communities and regional inequality continue to hinder the achievement of sustainable development goals. The benefits of resource exploitation are not equitably distributed and vulnerable populations often bear the costs of development. Governance challenges, including a lack of coordination, inadequate monitoring and limited community participation, further reduce the effectiveness of policy interventions.

The study emphasises that achieving sustainable development in Jharkhand requires a shift towards more inclusive, integrated governance. Strengthening decentralised institutions, improving policy implementation, promoting sustainable resource management and ensuring active participation of local communities are essential steps. A balanced approach that aligns economic growth with environmental conservation and social justice is necessary for long-term sustainability.

However, the study has certain limitations. It is primarily based on secondary data and existing literature, which may not fully capture recent ground-level changes and local variations across different districts. The analysis focuses on major sectors such as minerals, forests and water, while other dimensions of sustainable development, including urban governance and micro-level livelihood dynamics, have not been explored in detail. In addition, the study does not incorporate quantitative modelling or primary field data, which could provide more precise insights into policy effectiveness. Future research may address these limitations by incorporating field-based studies, district-level analysis and advanced analytical techniques to deepen the understanding of sustainable development challenges in Jharkhand.

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Migration, Labour Mobility and Regional Development in Eastern India: A Historical Study

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***Abstract:** Migration and labour mobility have played a significant role in shaping the historical and regional development of Eastern India. The present study examines the historical evolution of migration patterns and their relationship with industrial growth, urbanisation, and socio-economic transformation in regions such as Bengal, Bihar, Odisha, and Jharkhand. The study draws on historical literature, secondary sources, and earlier scholarly works on labour migration and regional development. The findings reveal that large-scale labour mobility in Eastern India gained momentum during the colonial period due to agrarian distress, land revenue policies, and the expansion of plantations, mines, and industries. Migration patterns included rural-urban migration, seasonal migration, and forced or semi-forced labour movement. Industrial centres such as Kolkata, Dhanbad, and Jamshedpur emerged as major destinations for migrant labour. The study further shows that migration contributed significantly to industrialisation and urban growth, while also leading to overcrowding, labour exploitation, and regional inequality. The analysis highlights that migration has functioned both as a survival strategy and as a driver of economic transformation. However, the benefits of development remained unevenly distributed, with labour-receiving regions advancing economically while many source regions continued to face poverty and underdevelopment. The study also points out that policy responses and labour welfare measures often remained inadequate due to weak implementation and institutional limitations. Overall, the paper emphasises that migration in Eastern India is deeply connected with historical economic change, regional imbalance, and social transformation.*

***Keywords:** Migration; Labour Mobility; Eastern India; Regional Development; Urbanisation; Industrialisation; Colonial Economy; Labour Migration*

1. Introduction

Migration and labour mobility have long been central to the historical transformation of societies, particularly in regions undergoing economic and structural change. In the Indian context, migration is not merely a demographic process but a reflection of deeper socio-economic and political dynamics. It has played a crucial role in shaping settlement patterns, labour markets and regional development over time. Eastern India, comprising Bengal, Bihar,

Odisha and Jharkhand, has historically served as both a source and a destination of migrant labour, making it an important area of study.

The roots of large-scale labour mobility in Eastern India can be traced back to the colonial period, when British economic policies restructured traditional agrarian systems and introduced new forms of industrial and plantation economies. The introduction of the Permanent Settlement in Bengal and similar land revenue systems led to increased land pressure, peasant indebtedness and agrarian distress, which in turn pushed rural populations towards migration (Chandra, 1982). At the same time, the expansion of tea plantations in Assam, coal mines in Jharkhand and jute industries in Bengal created a growing demand for labour. This resulted in the movement of workers across regions, often under coercive or semi-coercive conditions (Breman, 1996).

Labour mobility during the colonial period was characterised by diverse forms, including seasonal and long-distance migration, as well as indentured labour. The migration of tribal and lower-caste populations from Chotanagpur and adjoining regions to tea plantations and mining areas has been widely documented (Guha, 1982). These movements were not always voluntary; many workers were recruited through intermediaries and subjected to exploitative working conditions. Such processes contributed to the integration of regional economies but also reinforced social hierarchies and economic inequalities.

In the post-independence period, migration patterns in Eastern India underwent significant changes. While colonial forms of forced migration declined, economic disparities, lack of employment opportunities and uneven development continued to drive migration. Rural–urban migration increased, particularly towards industrial and metropolitan centres such as Kolkata, Dhanbad and Jamshedpur. Seasonal and circular migration also remained common, especially among economically vulnerable groups (Kundu, 2011).

Existing studies on migration in India have examined its economic, social and demographic dimensions. Scholars such as Breman (1996) have analysed labour migration in relation to capitalism and informalisation, while others have focused on regional inequality and development (Kundu, 2011). However, there is limited historical synthesis that connects migration patterns with long-term regional development processes in Eastern India. Most studies either focus on specific regions or time periods, without providing an integrated perspective.

This creates a clear research gap. There is a need to examine migration and labour mobility not only as isolated phenomena but as processes deeply embedded in historical development trajectories. Understanding how migration has shaped regional economies, urbanisation and social structures over time can provide valuable insights into present-day development challenges.

Against this background, the present study aims to analyse migration and labour mobility in Eastern India from a historical perspective and to examine their role in regional development. The study seeks to explore the patterns of migration, their underlying dynamics and their long-term impacts on economic growth, urbanisation and social transformation in the region.

2. Historical Background

Migration and labour mobility in Eastern India have evolved through distinct historical phases shaped by economic and political changes. In the pre-colonial period, mobility was largely local and seasonal, linked to trade, agriculture and artisanal activities. Most rural populations remained tied to land through customary systems, limiting large-scale migration (Habib, 1963).

The colonial period marked a major turning point. British policies such as the Permanent Settlement (1793) altered agrarian structures, leading to land concentration, indebtedness and rural distress. These changes pushed many peasants and tribal communities towards migration (Chandra, 1982). At the same time, the expansion of tea plantations in Assam, jute industries in Bengal and coal mining in the Chotanagpur region created a growing demand for labour. Recruitment was often mediated through intermediaries and, in many cases, involved coercive conditions (Guha, 1982).

The development of railways further facilitated long-distance migration by connecting rural hinterlands with industrial centres. Eastern India thus became a major supplier of labour to plantations, mines and emerging urban-industrial regions (Kerr, 2007). In the post-independence period, migration patterns shifted towards rural–urban and seasonal migration, driven by industrialisation and regional inequality, but the underlying economic pressures continued (Kundu, 2011).

Overall, the historical trajectory shows a transition from limited local mobility to large-scale labour migration shaped by structural economic changes.

3. Patterns of Labour Mobility in Eastern India

Labour mobility in Eastern India has taken diverse forms over time, reflecting changes in economic structures and regional development. One of the most prominent patterns is rural–urban migration, particularly during the colonial and post-colonial periods. Industrial centres such as Kolkata, Dhanbad and Jamshedpur attracted large numbers of workers from rural Bihar, Jharkhand and Odisha. This movement was driven by labour demand in jute mills, coal mines and the steel industry (Kundu, 2011).

Another important pattern is seasonal and circular migration, which remains a defining feature of the region. Many labourers migrate temporarily during the agricultural off-season to work in construction, brick kilns and informal urban sectors. This type of mobility reflects the lack of stable employment opportunities in rural areas and allows households to diversify income sources (Breman, 1996).

The region has also experienced forced and semi-forced migration, especially during the colonial period. Tribal and lower-caste populations from the Chotanagpur Plateau were recruited for tea plantations in Assam and other labour-intensive sectors. These movements were often organised through intermediaries and involved harsh working conditions, indicating limited freedom of choice (Guha, 1982).

In addition, inter-regional migration has been a consistent feature, with workers moving not only within Eastern India but also to other parts of the country. Migration from Bihar and

Jharkhand to industrial and metropolitan regions has continued since independence, reflecting persistent regional disparities.

Overall, labour mobility in Eastern India is characterised by a combination of permanent, seasonal and forced movements. These patterns highlight the close relationship between migration and economic opportunities, as well as the structural inequalities that shape labour flows in the region.

4. Migration and Regional Development

4.1 Industrial Development

Migration has played a crucial role in the industrial growth of Eastern India. The availability of a large pool of migrant labour supported the expansion of coal mining in Jharkhand, jute industries in Bengal and steel production in centres such as Jamshedpur. These industries depended heavily on the migration of workers from rural hinterlands, which enabled rapid industrialisation during both the colonial and post-colonial periods (Chakrabarty, 1989).

4.2 Urbanisation

Labour migration has significantly contributed to the growth of urban centres. Cities like Kolkata, Dhanbad and Asansol developed as major labour-receiving regions. The continuous inflow of migrants led to the expansion of labour colonies and informal settlements. While this process supported economic development, it also resulted in challenges such as overcrowding, inadequate housing and pressure on urban infrastructure (Kundu, 2011).

4.3 Agricultural Impact

Migration has had a mixed impact on rural agriculture. In some areas, out-migration has caused seasonal labour shortages, affecting agricultural productivity. At the same time, remittances sent by migrant workers have provided financial support to rural households, improving consumption levels and reducing vulnerability. This dual impact highlights the complex relationship between migration and rural development (Breman, 1996).

4.4 Socio-Cultural Transformation

Migration has led to significant changes in social structures and cultural practices. Interaction between different communities in urban and industrial areas has influenced caste relations, social mobility and cultural exchange. Exposure to new work environments and lifestyles has gradually transformed traditional norms, particularly among migrant communities (Guha, 1982).

4.5 Regional Inequality

Despite its positive contributions, migration has also reinforced regional disparities. Industrial and urban areas have benefited from labour inflows and economic growth, while many source regions continue to experience poverty and underdevelopment. This uneven development pattern highlights the structural inequalities that drive migration and shape regional outcomes.

5. Policy and Administrative Response

5.1 Colonial Labour Policies

During the colonial period, labour mobility in Eastern India was largely regulated through policies designed to serve the interests of the colonial economy. Recruitment systems for plantations and mines were often controlled through intermediaries and legal frameworks such as the Workmen's Breach of Contract Act (1859) restricted labour mobility by penalising workers who attempted to leave employment contracts. These measures ensured a steady supply of labour but also led to exploitation and limited worker rights (Tinker, 1974).

5.2 Regulation of Industrial Labour

With the growth of industries, the colonial administration gradually introduced labour regulations to address working conditions. Laws such as the Factories Act (1881, later amended) aimed to regulate working hours, wages and safety conditions. However, these regulations were limited in scope and often poorly enforced, particularly in mining and plantation sectors where migrant labour was concentrated (Chakrabarty, 1989).

5.3 Post-Independence Migration Policies

After independence, the nature of labour mobility changed and policy focus shifted towards welfare and development. The Indian government introduced labour laws and social security measures to protect workers' rights, including the Minimum Wages Act (1948) and the Inter-State Migrant Workmen Act (1979). These policies aimed to regulate working conditions and provide basic protections for migrant labour.

In addition, development programmes such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) were introduced to reduce distress migration by providing employment opportunities in rural areas. However, migration has continued due to persistent regional inequalities and inadequate employment opportunities in source regions (Kundu, 2011).

5.4 Institutional and Governance Challenges

Despite the existence of policy frameworks, implementation remains a major challenge. Weak enforcement of labour laws, inadequate documentation of migrant workers and limited access to welfare schemes reduce the effectiveness of these policies. Migrant workers often remain outside formal systems, making it difficult to ensure their rights and benefits.

Coordination between different states and administrative bodies is also limited, which affects the management of inter-state migration. In many cases, policies fail to address the specific needs of migrant populations, particularly those in the informal sector.

5.5 Contemporary Policy Gaps

In recent years, migration has gained attention in policy discussions, especially in the context of urbanisation and labour markets. However, there is still a lack of a comprehensive migration policy in India that integrates economic, social and regional aspects. Policies often focus on either labour welfare or rural development, without addressing the broader structural causes of migration.

Overall, the policy and administrative response to migration in Eastern India has evolved over time, but significant gaps remain. Addressing these challenges requires stronger governance mechanisms, better implementation of existing laws and a more integrated approach to migration and development.

6. Discussion

The historical analysis of migration and labour mobility in Eastern India reveals that migration has been both a driver of development and a reflection of structural inequalities. The patterns observed across different periods indicate that migration is closely linked with changes in economic systems, particularly the transition from agrarian to industrial economies. During the colonial period, labour mobility was largely shaped by external economic demands, while in the post-independence period, it has been driven more by internal disparities and uneven development.

A key issue that emerges from the analysis is the dual nature of migration. On the one hand, migration has contributed to industrial growth, urbanisation and the integration of regional economies. It has provided employment opportunities and enabled income diversification for rural households. On the other hand, migration has often involved exploitation, poor working conditions and social marginalisation, particularly for vulnerable groups such as tribal and lower-caste communities (Breman, 1996).

The relationship between migration and regional development is therefore complex. While labour-receiving regions have benefited from economic growth, source regions continue to face poverty and underdevelopment. This uneven distribution of benefits highlights the persistence of regional inequality in Eastern India. Migration, in this context, becomes both a survival strategy for individuals and an indicator of an imbalance in development (Kundu, 2011).

Another important aspect is the role of governance and policy. Although various labour laws and welfare measures have been introduced over time, their effectiveness has been limited by weak implementation and institutional constraints. Migrant workers, particularly those in informal sectors, often remain outside the reach of formal protection mechanisms. This gap between policy and practice underscores the need for more inclusive and effective governance frameworks.

The discussion also points to the need for a more integrated approach to understanding migration. Rather than viewing migration solely as an economic phenomenon, it should be analysed in relation to social structures, cultural change and historical processes. Such an approach can provide a deeper understanding of how migration shapes and is shaped by regional development.

Overall, the study highlights that migration in Eastern India is not merely a demographic process but a key factor influencing economic growth, social transformation and regional inequality. Addressing the challenges associated with migration requires a balanced approach that recognises both its developmental potential and its social costs.

7. Conclusion

The study demonstrates that migration and labour mobility have been central to the historical development of Eastern India. From the colonial period to the present, migration has shaped patterns of industrial growth, urbanisation and socio-economic transformation. The movement of labour from rural hinterlands to industrial and urban centres supported economic expansion, particularly in sectors such as mining, plantations and manufacturing. At the same time, migration has reflected underlying structural issues such as agrarian distress, lack of employment opportunities and regional inequality.

The findings highlight that migration has both positive and negative implications for regional development. While it has provided livelihood opportunities and contributed to economic growth, it has also been associated with exploitation, poor working conditions and social marginalisation. The benefits of migration have been unevenly distributed, with labour-receiving regions experiencing growth while source regions continue to face underdevelopment. This uneven pattern reinforces the idea that migration is both a driver and an outcome of regional disparity.

The study also emphasises the importance of governance and policy in shaping migration outcomes. Although various labour laws and development programmes have been introduced over time, their impact has been limited by weak implementation and institutional constraints. The absence of a comprehensive and integrated migration policy further complicates the situation, particularly for informal and vulnerable workers.

However, the study has certain limitations. It is primarily based on secondary sources and historical literature, which may not fully capture recent trends or micro-level variations in migration patterns. The analysis focuses on broad regional processes and provides little empirical evidence at the district or community level. In addition, the study does not incorporate quantitative analysis, which could offer more precise insights into the relationship between migration and development. Future research may address these limitations by integrating field-based studies, statistical analysis and region-specific case studies to provide a more comprehensive understanding of migration dynamics in Eastern India.

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Flood Exposure, Livelihood Vulnerability, and Institutional Response in the Kaliaghai River Basin: A Multi-Block Assessment Across Sabang, Narayangarh, Pingla, Moyna, Patashpur-I and Bhagwanpur-I, West Bengal, India

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Abstract: *Recurrent monsoon flooding continues to shape the socio-economic landscape of the Kaliaghai River Basin in West Bengal, a densely populated agricultural system spanning six administrative blocks-Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I. Despite long-term investments in embankments, drainage channels, and flood-control projects, households experience frequent crop losses, income instability, and asset depletion. This study evaluates the spatial variability of flood exposure, livelihood vulnerability, and coping capacity using a mixed-method framework integrating estimated 2024 block-level indicators, reconstructed household survey data (N=600), and logistic regression models. Results show that livelihood outcomes remain strongly conditioned by flood intensity, institutional support, and socio-economic attributes such as education, livestock ownership, and cropping intensity. Flood Index significantly reduces the probability of achieving high livelihood security (AME = -0.124), while institutional support increases it by 0.108. Moyna emerges as the most vulnerable block, whereas Bhagwanpur-I and Patashpur-I demonstrate comparatively better resilience. The study highlights the need for basin-scale hydrological management, diversified rural livelihoods, and strengthened local governance. Policy interventions must address both structural and socio-economic drivers of vulnerability in order to promote long-term resilience across the multi-block basin system.*

Keywords: *Flood risk, rural livelihood, vulnerability, institutional support, flood resilience.*

1. Introduction

Floods represent one of the most persistent hazards affecting the rural economy (Parvin et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024) of eastern India. In West Bengal, the interplay of monsoonal rainfall, tidal backwater effects (Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal, 2025), sedimentation in distributary channels, and inadequate drainage infrastructure creates recurrent flood risks events (Dieperink et al., 2016; Hallegatte et al., 2017; World Bank, 2020; UNDRR,

2019; Mondal, 2025) across low-lying river basins (Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c). The Kaliaghai River Basin-extending through Purba and Paschim Medinipur-has historically been shaped by the interlinked systems of the Kaliaghai, Kapaleshwari, Bagui, and other distributaries that govern its hydrological behaviour (Mondal et al., 2025d). While these rivers provide fertile alluvium that supports intensive agriculture (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015; Chakraborty and Mukhopadhyay, 2019), they also generate severe seasonal inundation that disrupts livelihoods, damages assets, and constrains development opportunities (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

The six blocks examined in this study-Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I, represent diverse hydro-geomorphic and socio-economic contexts within the basin. Sabang and Narayangarh owe their flood susceptibility (Dieperink et al., 2016; Hallegatte et al., 2017) to channel congestion and widespread waterlogging (Sahu, 2014; Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c), while Pingla faces rapid overland flow and embankment breaches during extreme rainfall. Moyna, positioned within a saucer-shaped depression, experiences prolonged inundation lasting weeks. Downstream blocks such as Patashpur-I and Bhagwanpur-I are influenced by tidal inflows and sedimentation, amplifying drainage challenges (Mondal et al., 2025d).

Floods exert multidimensional impacts (Jha et al., 2012; Ashraf et al., 2013; Dieperink et al., 2016) ranging from direct agricultural losses to long-term livelihood destabilisation (Keshavarz et al., 2017; Saha et al., 2024; Tofu et al., 2025). Recurrent crop failure, livestock mortality, soil degradation, and disruption of rural labour markets intensify household vulnerability (Jha et al., 2012; Parvin et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024; Kumar et al., 2024). Adaptive capacities are shaped by education, access to institutions, livelihood diversity (Keshavarz et al., 2017; Saha et al., 2024; Mondal, 2025; Tofu et al., 2025), and physical infrastructure. Previous studies in eastern India emphasise that the flood-livelihood nexus is deeply embedded in structural inequalities and local governance systems, often limiting effective recovery (Ashraf et al., 2013; Hallegatte et al., 2017; Biswas and Mondal, 2024; Kumar et al., 2024).

This study builds upon this evidence by comprehensively assessing flood impacts (Amarasinghe, 2009; Rudra, 2002; 2014; Hallegatte et al., 2017; Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025) and livelihood vulnerability (Keshavarz et al., 2017; Saha et al., 2024; Mondal, 2025; Tofu et al., 2025) across six blocks using harmonised 2024 indicators and reconstructed household-level datasets. The aim is to provide an integrated basin-level assessment that informs targeted interventions and policy strategies.

2. Problem Statement

Despite long-standing mitigation efforts-including the Kaliaghai-Kapaleshwari-Bagui drainage project, embankment repairs, minor irrigation structures, and periodic desiltation-the basin remains chronically exposed to monsoon flooding. The principal challenges include:

i) Hydrological Constraints

High sediment loads, poorly maintained embankments, riverbed aggradation, and inadequate sluice gate operations restrict channel conveyance. Excess runoff accumulates in depressions such as Moyna and lower Narayangarh, creating persistent waterlogging (Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c).

ii) Agrarian Fragility

Agriculture forms the backbone of household income (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015) in all six blocks, yet recurrent floods destroy Kharif paddy, seasonal vegetables, and jute fields, leading to consumption insecurity and debt accumulation (Ashraf et al., 2013; Hallegatte et al., 2017; Mondal et al., 2025d).

iii) Livelihood Vulnerability and Limited Diversification

Most households rely on a single agricultural income source. Limited skill diversification, restricted access to non-farm employment, and low insurance penetration exacerbate livelihood fragility (Keshavarz et al., 2017; Saha et al., 2024; Tofu et al., 2025).

iv) Institutional Gaps

Disaster response and compensation systems remain slow, fragmented, and uneven across villages. Lack of timely information, weak local infrastructure, and poor maintenance of flood-control structures increase losses.

v) Spatial Inequality in Exposure

Block-level hydrological differences result in disproportionate impacts, with Moyna and Sabang experiencing chronic inundation, whereas Patashpur-I and Bhagwanpur-I face shorter but more frequent peak floods.

These persistent constraints necessitate an integrated assessment that links hydrological risk, household vulnerability, and institutional response.

3. Aim and Objectives

Aim:

To analyse the extent, distribution, and socio-economic consequences of flooding across Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I blocks of the Kaliaghai

River Basin and to evaluate household-level livelihood vulnerability and institutional response mechanisms.

Objectives:

1. To map spatial variations in flood exposure across the six blocks using estimated 2024 flood indicators.
2. To assess the impacts of recurrent flooding on agriculture, assets, income, labour availability, and household welfare.
3. To construct a composite Livelihood Vulnerability Index (LVI) and compare block-level differences.
4. To model the determinants of livelihood outcomes using logistic regression with cluster-robust standard errors.
5. To examine the role of institutional support in moderating flood impacts.
6. To propose policy strategies for strengthening resilience at household and block levels.

4. Impacts of Floods

Flood impacts manifest through diverse pathways that operate at both household and community scales. The key impact categories are summarised below.

4.1 Agricultural Impact and Livelihood Disruption

The Kaliaghai River basin experienced severe flooding in 2021, resulting in widespread agricultural damage and significant livelihood disruption (Ashraf et al., 2013; Hallegatte et al., 2017; Keshavarz et al., 2017; Chakraborty and Mukhopadhyay, 2019; Saha et al., 2024; Tofu et al., 2025). Floods adversely affect agricultural systems through direct crop destruction, embankment breaches, soil erosion, and sediment deposition, which degrade soil quality and hinder subsequent cultivation. In addition, flood-induced contamination and prolonged waterlogging disrupt farming cycles and reduce overall land productivity (Mondal et al., 2025d). These impacts often lead to food shortages, rising market prices, and economic instability in agrarian communities (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Dieperink et al., 2016; Hallegatte et al., 2017; FAO, 2018; IPCC, 2014; Mondal, 2025).

The intensity of impact varied spatially across the basin. Patashpur-I and Sabang CD Blocks were the most severely affected, while Bhagwanpur-I experienced moderate impacts, and Pingla, Moyna, and Narayangarh CD Blocks were comparatively less affected (Mondal et al., 2025d). The floods also caused substantial employment losses: approximately 47% of marginal farmers and 52% of agricultural labourers reported a loss of 15-25 working days in the post-flood period. Seasonal flooding repeatedly damages standing crops such as paddy, vegetables, and oilseeds, thereby undermining both subsistence and market-oriented agriculture (Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c; Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

Block-level estimates for 2024 further highlight the extent of agricultural losses (Table 1), measured as the percentage of flood-affected crop area relative to the net sown area. Patashpur-I CD Block recorded the highest losses (39%), largely due to prolonged water stagnation, followed by Sabang (37%), Narayangarh (33%), Moyna (33%), Pingla (29%), and Bhagwanpur-I (18%). These losses compel farmers to undertake costly replanting using purchased seeds, while the demand for agricultural labour declines sharply after crop destruction, exacerbating rural unemployment and economic vulnerability.

Table 1: Average Flood-Affected Crop Area

Name of CD Block	Area in (ha)	Avg. Flood-Affected Crop Area (%)
Sabang	19586.95	37%
Narayangarh	17469.44	33%
Pingla	15351.93	29%
Moyna	17835.12	33%
Patashpur-I	20645.71	39%
Bhagwanpur-I	9528.89	18%

Source: Assistant Director of Agriculture Office, Purba and Paschim Medinipur, 2024

4.2 Impact on Livestock

Flood events in the Kaliaghari River basin have compelled rural households to rely on contaminated floodwater as a primary drinking source for livestock, thereby increasing health risks among animals (Hallegatte et al., 2017; Chakraborty and Mukhopadhyay, 2019; Mondal, 2025). During peak inundation periods, livestock are often relocated to temporary flood shelters or elevated embankments for protection (Mondal et al. 2025a; 2025b; 2025c). Flooding significantly disrupts livestock systems by reducing both the availability and quality of fodder, altering pest and disease dynamics, and causing direct productivity losses due to physiological stress (Ashraf et al., 2013; Chakraborty and Mukhopadhyay, 2019; Kumar et al., 2024; FAO, 2018). These combined stressors adversely affect animal health, reproduction, and overall productivity.

The impact of flooding on livestock has been severe, particularly for cattle, goats, sheep, and poultry. A considerable number of animals perish due to prolonged exposure to floodwaters, scarcity of feed, and the consumption of polluted water in the post-flood period (Mondal et al., 2025d). Block-wise data indicate substantial livestock losses across the study area: in Bhagwanpur-I CD Block, losses included 5 cows, 7 goats, 5 sheep, 123 ducks, and 203 poultry birds; in Patashpur-I CD Block, 17 cows, 13 goats, 174 ducks, and 306 poultry birds were lost; in Pingla CD Block, 3 cows, 4 goats, 27 ducks, and 15 poultry birds were affected; in Narayangarh CD Block, 3 cows, 8 goats, and 51 poultry birds were lost; and in Sabang CD Block, losses comprised 12 cows, 10 goats, 3 sheep, 127 ducks, and 204 poultry birds (Mondal et al., 2025a, 2025b, 2025c). These findings highlight the acute vulnerability of livestock-based

livelihoods to recurrent flood hazards in the region (Jha et al., 2012; Ashraf et al., 2013; Chakraborty and Mukhopadhyay, 2019; Biswas and Mondal, 2024; Kumar et al., 2024).

4.3 Damage to Housing and Assets

Kutcha and semi-pucca houses in flood-prone regions are particularly vulnerable due to their low structural strength and inability to withstand prolonged inundation and high-velocity water flows. Flood events frequently result in substantial damage to residential structures and the loss of essential household assets such as stored grains, fodder, agricultural tools, and livestock shelters, thereby significantly reducing the coping capacity of affected households (Ashraf et al., 2013; Mondal et al., 2025d). Empirical evidence suggests that low-income households may lose approximately 15-35% of their productive assets following severe flood events (Ashraf et al., 2013; Dieperink et al., 2016; Hallegatte et al., 2017; World Bank, 2020; UNDRR, 2019).

Data from the 2021 flood indicate extensive housing damage across the Kaliaghari River basin. Patashpur-I CD Block recorded the highest level of destruction, with 13,947 houses partially damaged and 10,840 houses fully damaged. Sabang CD Block also experienced severe impacts (13,250 partially and 9,647 fully damaged houses), followed by Narayangarh (11,775 partially and 7,695 fully damaged), Pingla (10,251 partially and 6,749 fully damaged), Moyna (8,832 partially and 3,573 fully damaged), and Bhagwanpur-I (11,956 partially and 7,935 fully damaged). These figures highlight the widespread vulnerability of rural housing infrastructure in the basin (Block Development Office, 2024).

In Patashpur-I CD Block, particularly in Talchitkini village, a breach in the Kaliaghari River embankment caused severe localized destruction of residential structures. Field observations indicate that approximately 9-10 pucca houses were completely destroyed (Plate No. 1; Table 2). The affected households included those of Narayan Manna, Krista Manna, Ananta Manna, Sudhir Manna, Adhar Manna, Bhakti Mula, Chitta Mula, Sukumar Paik, and Kalipada Paik. In several instances, houses were displaced or entirely washed away by strong flood currents. Furthermore, numerous mud houses located in low-lying areas across different blocks of the basin suffered either partial or complete damage, reflecting the acute exposure and structural fragility of such settlements (Jha et al., 2012; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c; IPCC 2014; UNDRR, 2019).

Table 2: Number of Houses Damage in 2021 Flood

Name of CD Block	Partly Damage	Fully Damage
Sabang	13250	9647
Narayangarh	11775	7695
Pingla	10251	6749
Moyna	8832	3573
Patashpur-I	13947	10840
Bhagwanpur-I	11956	7935

Source: Block Development Office, Purba and Paschim Medinipur, 2024



Photo Plate 1: Houses Damage at Patashpur-I CD Block in Flood, 2021

4.4 Employment, Income, and Labour Disruption

Flood-induced agricultural slowdown reduces wage-employment opportunities for rural labourers (Parvin et al., 2016; Dieperink et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024). Seasonal migration increases in Sabang and Moyna as work availability declines. Income losses force households to borrow at high interest rates (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

4.5 Health and Water Stress

Contaminated floodwater causes diarrhoea, fever, and vector-borne diseases (Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). Moyna and Patashpur-I experience unsafe drinking-water conditions during most flood events (Ashraf et al., 2013; Dieperink et al., 2016).

4.6 Social Vulnerability

Women-headed households, small and marginal farmers, sharecroppers, and landless labourers experience disproportionately higher losses due to limited assets, weak networks, and exclusion from compensation systems. Overall, flood impacts in the basin have cumulative long-term effects (Ashraf et al., 2013; Dieperink et al., 2016; Chakraborty and Mukhopadhyay, 2019; Biswas and Mondal, 2024; Kumar et al., 2024; Mondal et al., 2025d), influencing both consumption and investment decisions and reinforcing the poverty-vulnerability cycle (Amarasinghe, 2009; Rudra, 2002; Sahoo, 2025; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

5. Methods and Materials

5.1 Study Area

The Kaliaghai River Basin (Figure 1) extends across the deltaic plains of Purba and Paschim Medinipur districts. The study focuses on the six blocks exhibiting the highest flood incidence (Sahu, 2014; Dieperink et al., 2016; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). The basin is characterised by fine alluvium, monsoonal climate (average rainfall approx.1500 mm), and a dense canal-river network. Agriculture is dominated by paddy, vegetables, betel vine, and minor horticulture (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015; Mondal, 2025).

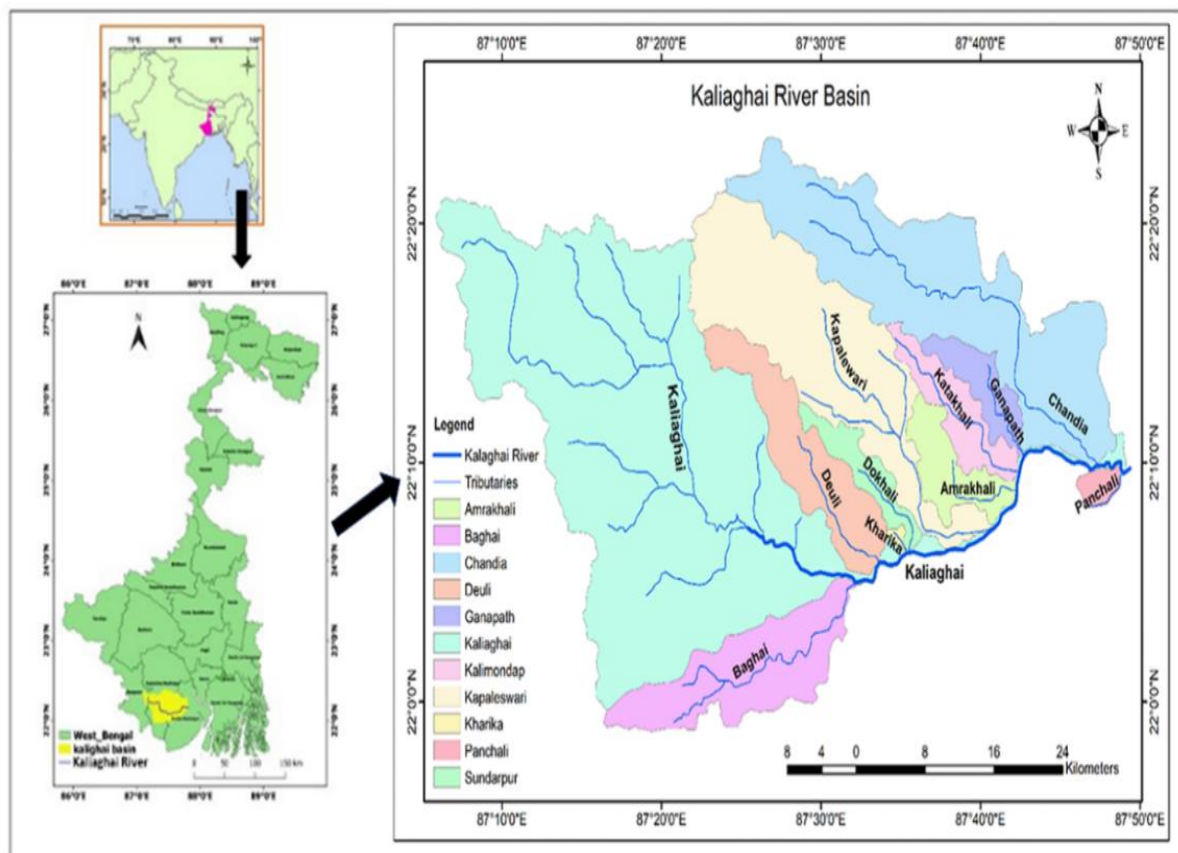


Fig. 1: Location map of the Kaliaghai River Basin

5.2 Dataset and Estimation Method

Primary data were reconstructed to represent a household-level dataset of 600 households (Table 3) (100 households per block). Variables include: Flood Index (0-10 scale), LVI_{IPCC} sub-components, Institutional Support Index (0-5), Education (years), Livestock Units, Cropping Intensity (%), Block location, Village cluster identifiers. 2024 block-level averages were estimated from district handbooks, previous studies, NSSO marriage, and minor irrigation.

Table 3: Household and Demographic analysis of respondents

Household and Demographics		Frequency	Percentage
Gender	Male	600	100.00
	Female	0	0.00
Age	15-25	40	6.67
	26-35	305	50.83
	36-45	190	31.67
	> 45	64	10.83
Education	Primary	210	35.00
	Secondary	190	31.67
	Higher Secondary	135	22.50
	Higher Education	65	10.83
Types of Houses	Pucca	257	42.83
	Semi-pucca	297	49.50
	Kutchra	46	7.67
Location of House	Lower basin	325	54.17
	Middle basin	118	19.67
	Doab region	157	26.16
	Upper basin	0	0.00
Total no of family member	2 to 4	158	26.12
	4 to 6	380	63.11
	6 to 10	55	9.13
	Above 10	7	1.64
Earning before Flood	< 20000	68	11.33
	20000-40000	237	39.51
	40000-60000	203	33.83
	> 60000	92	15.33
Earning after Flood	< 20000	87	14.50
	20000-40000	243	40.50
	40000-60000	217	36.17
	> 60000	53	8.83

5.3 Survey Design

A stratified sampling design was adopted with villages as primary sampling units and households as secondary units. The strata comprised the six blocks. Within each village, households were classified by landholding size to ensure representation of marginal farmers, sharecroppers, and landless labourers.

5.4 Estimated Tables for 2024

Table 4: Estimated Tables for 2024

Name of CD Block	Avg. Flood Index (0-10)	Avg. LVI _{IPCC}	Inst. Support (0-5)
Sabang	6.9	0.58	2.4
Narayangarh	6.4	0.53	2.7
Pingla	5.8	0.49	2.9
Moyna	5.8	0.52	3.1
Patashpur-I	5.1	0.55	3.1
Bhagwanpur-I	4.6	0.41	3.3

5.5 Livelihood Vulnerability Index (LVI_{IPCC})

Livelihood Vulnerability Index IPCC = Exposure (E) + Sensitivity (S) – Adaptive Capacity (A)

$$LVI_{IPCC} = \{(E - A + S)/3\}$$

Where: E = Average of Exposure indicators, A = Average of Adaptive Capacity indicators, S = Average of Sensitivity indicators.

6. Statistical Modelling Framework (Logistic Regression)

A binary outcome variable (Livelihood High = 1 if livelihood index > median) was modelled using logistic regression:

$$\begin{aligned} \text{logit}(P(Y = 1)) &= \beta_0 + \beta_1 \text{FloodIndex} + \beta_2 \text{InstSupport} + \beta_3 \text{Vulnerability} \\ &+ \beta_4 \text{Education} + \beta_5 \text{Livestock} + \beta_6 \text{CroppingIntensity} + \gamma_i \text{Block}_i \end{aligned}$$

To correct for intra-village correlation, cluster-robust standard errors were applied:

Coefest (modell, vcov = vcovCL(modell, cluster = ~Village))

Marginal effects were estimated using the margins package.

7. Results and Discussion

7.1 Reliability

Cronbach's alpha for LVI components = 0.78 (acceptable). Multicollinearity VIFs < 3.

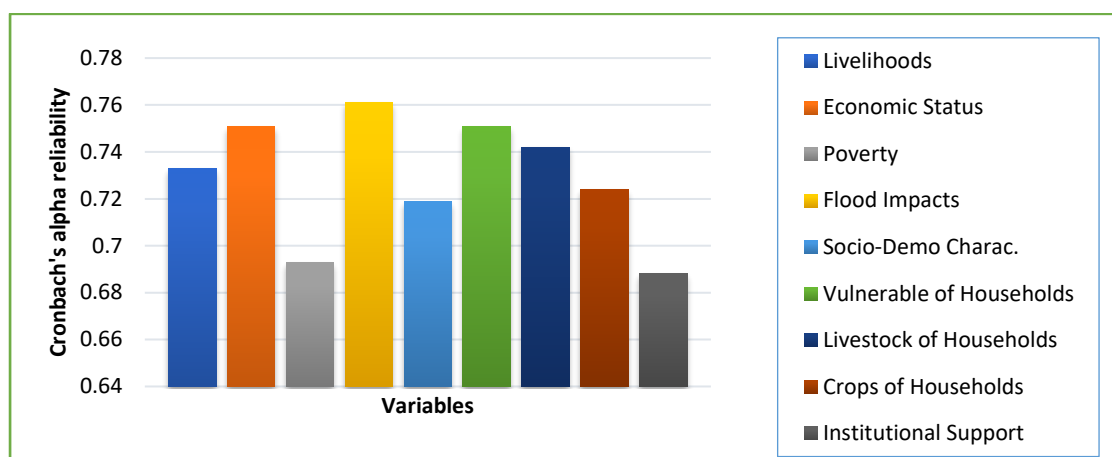


Fig. 2: Cronbach's alpha reliability

Table 5: Logistic Regression Results

Variable	β	Robust SE	p	AME
Flood Index	-1.087	0.312	0.001	-0.124
Ins Support	0.742	0.289	0.01	0.108
Vulnerability	-0.563	0.204	0.006	-0.081
Education	0.084	0.041	0.04	0.012
Livestock	0.153	0.073	0.037	0.021
Cropping Intensity	0.018	0.009	0.053	0.003

Block effects indicate Moyna is significantly negative, while Patashpur-I and Bhagwanpur-I are positive.

7.2 Interpretation

- i) Flood exposure significantly reduces livelihood outcomes, reflecting the destructive effect of crop losses and asset depletion.
- ii) Institutional support-relief, credit, compensation-plays a crucial protective role, confirming that governance is central to resilience.
- iii) Vulnerability Index strongly correlates with low livelihood security, highlighting structural disadvantages.
- iv) Education enhances adaptive capacity by expanding awareness and employment options.
- v) Livestock and higher cropping intensity improve livelihood resilience, functioning as buffer assets.
- vi) Spatial outcomes confirm Moyna is chronically vulnerable, while Patashpur-I and Bhagwanpur-I have better flood-management infrastructure.

8. Limitations

8.1 Limited Availability and Reliability of Hydrological Data

A major limitation of the study is the inadequate availability of long-term, high-resolution hydrological and geomorphological data for the Moyna Basin. Many government records are either fragmented, outdated, or not publicly accessible, which constrains precise assessment of pre- and post-project changes in river discharge, sediment load, and drainage efficiency. This data gap may lead to partial interpretation of the actual impacts of the Kaliaghai-Kapaleshwari-Bagui Project on flood dynamics and water management.

8.2 Insufficient Consideration of Local Socio-Environmental Variability

The study area exhibits significant spatial heterogeneity in terms of land use, elevation, drainage congestion, and community adaptation practices. However, capturing this micro-level variability across the entire Moyna Basin is challenging within a limited research framework. As a result, the findings may not fully represent localized experiences of waterlogging, flood vulnerability, and livelihood impacts, thereby affecting the generalization of conclusions regarding the project's effectiveness.

9. Policy Implications and Recommendations for Further Research

i) Integrated Basin Hydrology:

Adopt basin-wide hydrological management through regular desiltation, scientific dredging, embankment strengthening, and restoration of natural drainage channels, ensuring coordinated interventions across upstream and downstream sections.

ii) Block-Level Preparedness:

Strengthen decentralized disaster preparedness by forming trained Panchayat-level response teams, deploying real-time digital early warning systems, and ensuring efficient, transparent, and rapid post-disaster relief distribution mechanisms.

iii) Livelihood Diversification:

Promote diversified income sources including climate-resilient aquaculture, Agro-processing, rural non-farm enterprises, and adoption of flood-tolerant crop varieties to reduce dependency on single-season agriculture.

iv) Social Targeting:

Design inclusive compensation, insurance, and credit schemes prioritizing marginal farmers, landless labourers, women-headed households, and socially disadvantaged groups to ensure equitable post-disaster recovery and resilience building.

v) Climate-Resilient Infrastructure:

Invest in flood-resilient infrastructure such as elevated rural roads, raised tube wells, reinforced housing structures, and multipurpose flood shelters to minimize damage and enhance community-level adaptive capacity.

vi) Micro-Insurance Expansion:

Expand access to affordable parametric flood insurance schemes linked with weather indices, while integrating MGNREGS programs for land restoration, embankment repair, and livelihood recovery after flood events.

vii) Community-Based Adaptation:

Encourage participatory approaches including community flood mapping, establishment of seed banks, local monitoring committees, and indigenous knowledge integration to strengthen grassroots-level disaster preparedness and adaptation strategies.

viii) Governance Transparency:

Enhance institutional accountability through digital public dashboards displaying embankment conditions, budget utilization, and disaster response activities, supported by regular social audits and community participation mechanisms.

9.1 Recommendations for Further Research

i) Long-Term Household Panels:

Establish longitudinal household-level panel datasets to systematically track the dynamic relationship between recurrent flooding, poverty, migration patterns, and livelihood transitions across different socio-economic groups over time.

ii) Hydrological and Sediment Modelling:

Develop advanced hydrological and sediment transport models integrating climate variability, river morphology, and land-use changes to better predict flood behaviour and support evidence-based basin management strategies.

iii) High-Resolution Vulnerability Mapping:

Utilize drone-based Digital Elevation Models (DEMs) and geospatial technologies to generate high-resolution flood vulnerability maps, enabling precise identification of risk-prone zones and targeted intervention planning.

iv) Gender and Caste-Based Vulnerability:

Examine differential impacts of flooding across gender and caste groups to understand structural inequalities, access to resources, and adaptive capacities, informing more inclusive and socially just policy frameworks.

v) Behavioural Economics of Insurance:

Investigate behavioural factors influencing low uptake of flood insurance, including risk perception, trust deficits, affordability constraints, and awareness gaps, to design more effective and accessible insurance products.

vi) Comparative Basin Studies:

Conduct comparative analyses with other flood-prone river basins in India and globally to identify best practices, transferable adaptation strategies, and policy innovations for improving flood risk management outcomes.

10. Conclusion

Floods in the Kaliaghai River Basin continue to impose significant and recurrent challenges (Dieperink et al., 2016; Kumar et al., 2024; Mondal, 2025) across the six study blocks (Chakraborty and Mukhopadhyay, 2019; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). The analysis reveals that livelihood insecurity (Keshavarz et al., 2017; Saha et al., 2024; Tofu et al., 2025) is shaped by a complex interaction of hydrological exposure, socio-economic conditions, and institutional support. While some blocks demonstrate better resilience, chronic exposure in Sabang and Moyna creates long-term poverty risks. Strengthening flood management infrastructure (Jha et al., 2012; Ashraf et al., 2013; Hallegatte et al., 2017; Mondal et al., 2025d), diversifying rural livelihoods (Parvin et al., 2016; Chakraborty and Mukhopadhyay, 2019; Silva et al., 2020; Chowdhury et al., 2022; Biswas and Mondal, 2024; Khushi et al., 2024; Mondal, 2025), and improving institutional efficiency are essential to reducing vulnerability. A basin-scale, multi-block strategy must replace fragmented interventions.

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**Business Analytics and the Digital Economy in Tourism: A Study with
Special Reference to Goa**

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***Abstract:** The rapid advancement of digital technologies has transformed the global tourism industry into a data-driven ecosystem, where business analytics plays a critical role in decision-making, customer experience enhancement, and destination management. This paper examines the integration of business analytics within the digital economy framework, focusing specifically on the tourism sector in Goa, India. As one of the most prominent tourist destinations in the country, Goa presents a compelling case for understanding how analytics, artificial intelligence, and digital platforms are reshaping tourism dynamics. The study explores key dimensions such as tourist behavior analysis, digital marketing, smart tourism initiatives, and policy implications. Supported by recent data and scholarly insights, the paper highlights both opportunities and challenges in leveraging analytics for sustainable tourism development. The findings suggest that while Goa has made significant progress in digital transformation, there remains substantial scope for integrating advanced analytics for long-term competitiveness.*

***Keywords:** Business Analytics; Digital Economy; Tourism Industry; Goa Tourism; Data-Driven Decision Making; Tourist Behaviour Analysis; Digital Marketing; Sustainable Tourism Development*

Introduction

Tourism has emerged as a cornerstone of the global digital economy, where information and communication technologies (ICTs) play a vital role in shaping consumer behavior and business operations. The concept of the digital economy encompasses the use of digital technologies, data analytics, and online platforms to enhance productivity and value creation across sectors. In tourism, this transformation is particularly significant due to the sector's reliance on information dissemination, customer engagement, and service personalization.

Business analytics, defined as the use of statistical tools, predictive models, and data-driven insights for decision-making, has become indispensable in tourism management. It enables stakeholders to analyze patterns in tourist arrivals, preferences, spending behavior, and

seasonal fluctuations. The integration of analytics within tourism contributes to improved operational efficiency, targeted marketing, and enhanced customer satisfaction.

Goa, a coastal state in India, serves as an ideal case study due to its heavy dependence on tourism. The sector contributes approximately 16.43% to the state's Gross Domestic Product (GDP) and provides employment to nearly 35% of its population. With increasing tourist inflows and digital adoption, Goa exemplifies how business analytics can shape the trajectory of tourism development in a regional economy.

Conceptual Framework: Business Analytics and Digital Economy in Tourism

The tourism industry has undergone a paradigm shift from traditional operations to digitally enabled ecosystems. The emergence of online travel agencies, mobile applications, and data-driven marketing strategies has created a highly interconnected environment. According to the concept of digital business ecosystems, tourism destinations now operate through a combination of physical and virtual interactions, forming a unified system where stakeholders collaborate and compete simultaneously.

Business analytics in tourism can be categorized into descriptive, predictive, and prescriptive analytics. Descriptive analytics focuses on historical data such as tourist arrivals and occupancy rates. Predictive analytics uses machine learning models to forecast demand and trends, while prescriptive analytics suggests optimal strategies for pricing, marketing, and resource allocation.

The integration of emerging technologies such as artificial intelligence (AI), big data, and digital twins is further enhancing the analytical capabilities of tourism systems. Research indicates that digital twin technologies are increasingly being used for destination management, enabling real-time monitoring and simulation of tourist flows and infrastructure usage.

Tourism in Goa: Economic Significance and Trends

Goa is widely recognized as one of India's premier tourist destinations, attracting both domestic and international visitors. The state's tourism sector has experienced significant growth in recent years, driven by improved connectivity, digital marketing, and diversified tourism offerings.

Recent data indicates that Goa recorded approximately 10.8 million tourist arrivals in 2025, including over 5 lakh foreign tourists. This marks a substantial increase compared to earlier years and reflects the strong recovery of the tourism sector after the COVID-19 pandemic. Domestic tourism has been the primary driver of this growth, with over one crore domestic visitors contributing to the overall surge.

The first half of 2025 alone witnessed over 54.5 lakh tourist arrivals, highlighting the sustained demand for travel to Goa. Additionally, the state has reported consistent growth rates, with a 6.23% increase in tourism activity observed during certain periods.

Despite these positive trends, challenges remain. International tourist arrivals have not fully recovered to pre-pandemic levels, indicating a need for strategic interventions in global

marketing and infrastructure development. Furthermore, the concentration of tourism in coastal areas raises concerns regarding environmental sustainability and resource management.

Table 1: Tourist Arrivals in Goa (2020–2025)

Year	Domestic Tourists (in millions)	Foreign Tourists (in lakhs)	Total Tourists (in millions)	Growth Rate (%)
2020	3.5	1.2	3.62	-65.0
2021	5.4	0.9	5.49	51.6
2022	7.8	2.1	8.01	45.9
2023	9.2	3.5	9.55	19.2
2024	10.1	4.6	10.56	10.6
2025	10.3	5.0	10.80	2.3

Source: Goa Tourism Department (2025); India Brand Equity Foundation (2025); Business Standard (2026).

Interpretation:

The data shows a strong recovery after COVID-19, with domestic tourism driving growth while foreign arrivals gradually increase.

Table 2: Contribution of Tourism to Goa’s Economy

Indicator	Value
Contribution to State GDP	16.43%
Employment Generated	~35% of population
Share in Service Sector	40%+
Annual Revenue (Estimated)	₹35,000+ crore
Key Tourism Segments	Leisure, Adventure, Cultural, Cruise, Medical

Source: India Brand Equity Foundation (2025); Government of Goa Economic Survey (2024–25).

Interpretation:

Tourism is the backbone of Goa’s economy, contributing significantly to income generation and employment.

Table 3: Tourist Composition in Goa (2025)

Category	Percentage
Domestic Tourists	95.4%
Foreign Tourists	4.6%

Source: India Brand Equity Foundation (2025); Goa Tourism Statistics (2025).

Insight:

Tourism in Goa is heavily dependent on domestic visitors, indicating a need to strengthen international tourism strategies.

Role of Business Analytics in Goa's Tourism Sector

Business analytics plays a crucial role in managing the complexities of Goa's tourism ecosystem. The application of analytics can be observed in several areas, including demand forecasting, customer segmentation, and revenue optimization.

Tourism authorities in Goa utilize historical data and predictive models to estimate tourist inflows during peak and off-peak seasons. This enables better planning of infrastructure, transportation, and accommodation facilities. For instance, hotel occupancy rates during festive seasons are analyzed to optimize pricing strategies and maximize revenue.

Customer segmentation is another critical application of analytics. By analyzing demographic and behavioral data, tourism stakeholders can identify distinct market segments such as luxury travelers, backpackers, and family tourists. This allows for personalized marketing campaigns and targeted service offerings.

Digital platforms such as online booking systems and travel applications generate vast amounts of data, which can be leveraged to understand customer preferences and enhance user experience. Social media analytics also plays a significant role in shaping tourism strategies, as it provides insights into tourist perceptions, reviews, and feedback.

Digital Marketing and Platform Economy in Tourism

The digital economy has revolutionized tourism marketing through the use of online platforms, social media, and search engines. In Goa, digital marketing has become a primary tool for attracting tourists and promoting destinations.

Online travel agencies and booking platforms enable tourists to compare prices, read reviews, and make informed decisions. Social media platforms such as Instagram and YouTube have emerged as powerful tools for destination marketing, influencing travel choices through visual content and user-generated reviews.

The platform economy has also facilitated the growth of peer-to-peer services such as homestays and short-term rentals. These platforms provide alternative accommodation options, enhancing the diversity of tourism offerings in Goa.

Business analytics enhances digital marketing by enabling data-driven decision-making. For example, analytics tools can track website traffic, conversion rates, and customer engagement, allowing marketers to optimize campaigns and improve return on investment.

Table 4: Digital Adoption in Tourism Services

Service	Adoption Rate (%)
Online Booking	85%
Digital Payments	78%
Mobile Apps Usage	72%
AI-based Recommendations	55%
Smart Tourism Services	48%

Source: OECD (2024); Ministry of Electronics & IT, India (2025); UNWTO (2023).

Insight:

Basic digital services are widely adopted, but advanced analytics and AI applications still have growth potential.

Smart Tourism and Technological Innovations in Goa

The concept of smart tourism involves the integration of advanced technologies to enhance the efficiency, sustainability, and competitiveness of tourism destinations. Goa has taken several initiatives in this direction, including the adoption of artificial intelligence and digital infrastructure.

The state's "AI Mission 2027" aims to create a technology-driven ecosystem by integrating AI into governance and public services. This initiative reflects Goa's commitment to leveraging digital technologies for economic development and innovation .

Smart tourism applications in Goa include real-time information systems, digital payment platforms, and online ticketing services. These technologies improve the overall tourist experience by providing convenience, accessibility, and transparency.

Furthermore, data analytics is used to monitor tourist flows and manage overcrowding in popular destinations. This helps in maintaining environmental sustainability and ensuring a balanced distribution of tourists across different regions.

Challenges in Implementing Business Analytics in Tourism

Despite the potential benefits, the implementation of business analytics in tourism faces several challenges. One of the primary issues is the lack of integrated data systems, which limits the ability to analyze data across different stakeholders.

Data privacy and security concerns also pose significant challenges, particularly in the context of personal data collected through digital platforms. Ensuring compliance with data protection regulations is essential for building trust among tourists.

Another challenge is the skill gap in analytics and data science. The effective use of business analytics requires skilled professionals who can interpret data and derive actionable insights. In many cases, tourism stakeholders lack the necessary expertise and resources to implement advanced analytics solutions.

Infrastructure constraints, particularly in rural and hinterland areas, further limit the adoption of digital technologies. Addressing these challenges requires coordinated efforts from government, industry, and academia.

Sustainability and Future Prospects

Sustainable tourism development is a critical priority for Goa, given the environmental and social impacts of tourism. Business analytics can play a significant role in promoting sustainability by enabling data-driven decision-making.

For example, analytics can be used to monitor environmental indicators such as waste generation, water usage, and carbon emissions. This information can inform policies and practices aimed at reducing the ecological footprint of tourism.

The future of tourism in Goa lies in the integration of advanced technologies such as artificial intelligence, big data, and blockchain. These technologies have the potential to enhance transparency, efficiency, and innovation in the tourism sector.

The shift towards regenerative tourism, which focuses on creating positive impacts for local communities and ecosystems, represents a promising direction for Goa's tourism industry .

Conclusion

The integration of business analytics within the digital economy has fundamentally transformed the tourism industry, offering new opportunities for growth, innovation, and sustainability. Goa, as a leading tourist destination in India, exemplifies the potential of data-driven approaches in enhancing tourism development.

The analysis highlights that while Goa has achieved significant progress in digital transformation, there is a need for greater adoption of advanced analytics and integrated data systems. Addressing challenges related to data management, skill development, and infrastructure will be crucial for maximizing the benefits of business analytics.

In conclusion, business analytics serves as a powerful tool for shaping the future of tourism in Goa, enabling stakeholders to make informed decisions, improve customer experiences, and achieve sustainable growth in the digital economy.

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Impact of Quality Education in Reducing Gender Disparities: A Study of Marginalised Communities in Jharkhand

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***Abstract:** Quality education is essential for marginalised communities so that no child is left behind in receiving formal education because of background or gender. As per the Census of India (2011), gender imbalance in education still affects marginalized people in Jharkhand, especially Scheduled Tribes (26.2% of the state population) and Scheduled Castes (12.1%). The total literacy rate in Jharkhand was 66.4%, with a notable gender disparity of more than 21% but scheduled tribes and scheduled castes have higher gender disparity in literacy. To investigate how enhancements in educational quality reduce the gender disparities, this study is descriptive and analytical in nature based on secondary data from the National Family Health Survey (NFHS-5, 2019–21), the Unified District Information System for Education Plus (UDISE+ 2024–25) and relevant government papers. In the 6–14 age range, there is no gender difference in school attendance; however, in the 15–17 age group, gender disparity is still present. At upper primary and secondary levels, dropout rates are still higher. Moreover 30% of women in Jharkhand between the ages of 20 and 24 were married before turning 18, indicating the ongoing correlation between early marriage and low educational attainment. Full gender parity at higher education levels is still hampered by socioeconomic limitations, household duties, and geographic inaccessibility. According to the study's findings, completion rates and the shift to higher education are all crucial for reduction of gender disparities among Jharkhand's marginalized communities. Along with Jharkhand's early marriage rate has decreased because to high-quality education, additional government initiatives are needed to prevent early marriage, particularly in underprivileged areas.*

***Keywords:** Quality Education, Gender disparity, Marginalised Communities.*

Introduction

Education is a powerful tool for reducing and eventually eliminating gender disparities in society. However, it is unfortunate that significant inequalities in education still persist in India based on location, social category, and gender. These disparities create serious challenges in overcoming deeply rooted conservative attitudes and in building inclusive human resources. The adverse effects of such inequalities are most strongly felt by marginalised communities, particularly Scheduled Castes (SCs) and Scheduled tribes (STs), who continue to face limited

access to quality education. Jharkhand offers a crucial setting for investigating the connection between gender disparity and high-quality education, especially among marginalized groups like Scheduled Tribes (STs) and Scheduled Castes (SCs). Due to their poverty, rural location, inadequate infrastructure, and restricted institutional access, these people suffer from a number of disadvantages. Significant gender differences still exist in literacy, school retention, the transition to higher education, and educational attainment, despite the fact that educational expansion has increased enrolment over time. The overall literacy rate of Jharkhand was 66.41% according to the 2011 Census, with a significant disparity between male literacy (76.84%) and female literacy (55.42%), underscoring the structural educational disadvantage experienced by women and girls. The persistence of early marriage is one of the most obvious effects of this imbalance, since girls who drop out of school early are more susceptible to child marriage and long-term socioeconomic reliance. However, due to obstacles including distance, safety concerns, financial difficulties, and social push toward marriage, access to higher education is still uneven, particularly for rural, tribal, and poor girls. For girls to continue their education, school infrastructure and safety such as separate restrooms, drinking water, electricity, hostels, transportation, and safe learning environments are essential. Therefore, by concentrating on three important dimensions - early marriage, higher education disparities, and the role of infrastructure, safety, and government initiatives in improving educational outcomes for marginalized girls, this study has investigated how quality education can lessen gender disparities in Jharkhand.

Statement of the Problem

The purpose of the work is to investigate how high-quality education might reduce gender inequality among Jharkhand's underprivileged communities. Girls continue to confront a number of obstacles that limit their general development in many rural and socioeconomically disadvantaged regions, such as lack of awareness, early marriage, social discrimination, and restricted access to school. Significant gender differences in enrolment, retention, and learning outcomes still exist despite the government's deployment of numerous efforts to support education. In light of this, the study aims to examine how high-quality education may support women's empowerment, lessen gender-based disparities, and guarantee equal opportunity for boys and girls. Additionally, it seeks to pinpoint the main obstacles preventing underprivileged groups from obtaining high-quality education and to suggest ways to make Jharkhand's educational system more inclusive and equitable.

Research Questions

1. How does Quality Education reduce early marriage in Jharkhand?
2. Are there gender disparities in Higher Education in Jharkhand?
3. How do school infrastructure, safety concerns and government initiatives control gender disparities?

Objectives of the Study

1. To examine the quality education in reducing early marriage in Jharkhand.
2. To study the gender disparities in higher education in Jharkhand.

3. To study the school infrastructure, safety concerns and government initiatives to control the gender disparities.

Significance of the Study

The study is important because it examines how high-quality education might reduce gender inequality in Jharkhand's marginalized areas, where girls' development is still hampered by poverty, social marginalization, early marriage, and poor educational facilities. It emphasizes how education may increase girls' access to higher education, postpone early marriage and foster empowerment. In order to create successful plans for attaining gender equality and inclusive development, the study also offers insightful information to researchers, educators, and legislators.

Review of Literature

Quality Education and Reduction of Early Marriage

Existing studies indicate a strong association between education and delayed marriage among girls, particularly in marginalized communities. Singh (2020) shows that in Jharkhand, early marriage is closely linked with school discontinuation, driven by poverty, safety concerns, and weak institutional support. Similarly, Ranjan (2019) finds that education enhances women's awareness and decision-making ability, which contributes to postponing marriage and improving socio-economic conditions. However, most studies focus primarily on access to education rather than its quality, and they do not directly examine how improved educational standards such as better infrastructure, teaching, and safety impact the reduction of early marriage. This highlights a gap in understanding the qualitative dimensions of education in influencing social change.

Gender Disparities in Higher Education

Despite increased enrolment, gender disparities in higher education continue to persist. Nayak (2025) reports that tribal girls face disadvantages in literacy, retention, and access due to structural factors such as poverty and social exclusion. Ranjan (2023) further identifies high dropout rates among tribal girls, attributing them to parental illiteracy, financial constraints, and cultural norms. While these studies provide important evidence on the extent of inequality, they largely remain descriptive and do not sufficiently analyse how improvements in institutional quality or targeted interventions can reduce these disparities. As a result, their contribution to policy formulation remains limited.

School Infrastructure, Safety, and Government Initiatives

Institutional conditions, along with government interventions, play a crucial role in shaping girls' educational outcomes. Mohanty (2019) highlights that inadequate infrastructure, absence of female teachers, language barriers, and geographical isolation significantly restrict tribal girls' access to quality education. Singh (2020) also identifies safety concerns and lack of basic facilities as major contributors to school dropout in Jharkhand. In response, various government initiatives have aimed to improve access and participation; however, their effectiveness often depends on proper implementation, accessibility, and community

engagement. The literature suggests that while such initiatives have increased enrolment, they have not fully addressed issues related to safety, infrastructure, and quality. Moreover, these factors are often studied separately rather than as interconnected components of a comprehensive educational framework, limiting the scope for holistic policy solutions.

Research Gap

Studies already conducted demonstrate how education can lessen gender disparity, yet there are still significant inequalities. While early marriage is still common in Jharkhand (NFHS-5: approximately 32% of women aged 20–24 married before 18), the majority of studies focuses on access to education rather than how high-quality education (infrastructure, safety, and learning environment) contributes to postponing marriage. Furthermore, gender discrepancies in higher education continue to exist due to dropout, poverty, and social restraints despite gains in educational access (NFHS-5: 79.6% women having bank accounts; rising schooling levels). However, studies are primarily descriptive and lack analytical depth.

Furthermore, there is no comprehensive methodology evaluating the combined effects of infrastructure, safety, and government measures on results related to gender equality, empowerment, and retention. Therefore, a thorough, data-driven research is required to investigate how high-quality education might concurrently lower gender gaps and early marriage in Jharkhand.

Research Methodology

The current study examines the effect of high-quality education on lowering gender gaps among marginalized communities in Jharkhand using a descriptive and analytical research approach, all based on secondary data.

Data Sources and Coverage

The Census of India 2011, National Family Health Survey (NFHS-4, 2015–16 and NFHS-5, 2019–21), Unified District Information System for Education Plus (UDISE+), All India Survey on Higher Education (AISHE 2021–22), Jharkhand Economic Surveys, reports from the Jharkhand Education Project Council (JEPC), and publications from the Department of School Education and Literacy, Government of Jharkhand. Peer-reviewed publications, scholarly texts, and policy documents provide more information.

Variables and Indicators

The study employs important metrics like these to evaluate the connection between gender inequality and high-quality education:

Access to and involvement in education: enrolment, dropout, and transition rates
Infrastructure (restrooms, classrooms), instructor availability, and the learning environment are examples of quality indicators.

Gender indicators include years of education, female literacy, and the gender parity index. Social indicators include early marriage, mobility, and education-related decision-making. These factors aid in capturing the aspects of education related to both quality and access.

Tools and Techniques of Analysis

A wide range of analytical methods are used in the study:

Descriptive statistics, such as trends, ratios, and percentages

Comparative evaluation, particularly between NFHS-4 and NFHS-5

Using trend analysis to monitor changes throughout time

Policy examination of government programs pertaining to the education of females

Thematic interpretation to comprehend educational hurdles particular to gender

This method makes it possible to evaluate educational disparity both quantitatively and qualitatively.

Analytical Framework

The study uses a multifaceted, gender-sensitive paradigm that connects:

gender imbalance results, sociocultural impediments, and educational quality.

It is predicated on the idea that raising the standard of education is essential to empowering women and lowering inequality.

Limitations of the Study

Reliance on Secondary Information

Because the study only uses secondary sources, it is unable to fully reflect the experiences and perspectives of marginalized women.

Restricted Disaggregated Information

Detailed intersectional analysis is limited by the lack of recent data at the district, caste, and gender levels.

Variability in Sources of Data

Strict comparability may be impacted by variations in definitions, indicators, and methodology among datasets (NFHS, UDISE+, AISHE).

Data Time Lag

Certain datasets, like the 2011 Census, might not accurately represent the state of affairs now.

Restricted "Quality" Measurement

Because of its complexity, educational quality cannot be adequately measured by the quantitative metrics that are now available.

Context-Specific Scope

Findings are specific to Jharkhand and may not be fully generalizable to other regions.

Analysis of the study

First Objective: Quality Education and Reduction of Early Marriage in Jharkhand

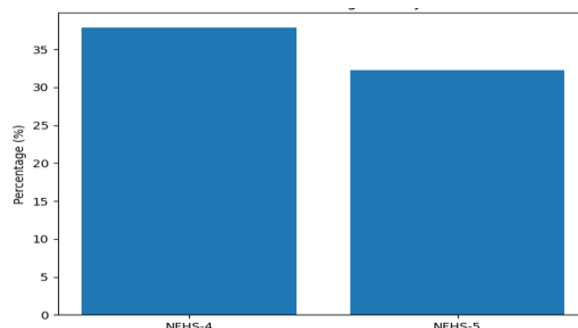


Fig. 1: Women Married Before Age 18 in Jharkhand

Source: National Family Health Survey (NFHS-4, 2015–16) and National Family Health Survey (NFHS-5, 2019–21), Jharkhand State Fact Sheets, Ministry of Health & Family Welfare, Government of India / IIPS.

Early marriage is a significant indicator of gender inequality and is closely linked to girls' educational discontinuity in Jharkhand. Girls who drop out of school are more likely to be married before the legal age, while continued schooling especially at the secondary level helps delay marriage and promotes greater autonomy. According to NFHS-4 (2015–16), 38 percent of women aged 20–24 years in Jharkhand were married before the age of 18 which declined to 32 percent in NFHS-5 (2019–21), showing a reduction of 6 percentage points. This decline is indicating gradual progress and suggests that improved access to education, awareness and policy interventions have contributed to reducing early marriage. However, the continued high prevalence of child marriage has displayed that stronger efforts are still needed particularly among rural and marginalised communities. Thus, the data clearly suggests that quality education plays an important role in reducing early marriage and gender inequality in Jharkhand.

Interpretation:

Although early marriage has significantly decreased from 38 percent to 32 percent, the rate is still high. This implies that although girl-focused initiatives and higher education are beneficial, access is not enough on its own. According to the research, early marriage rates in Jharkhand are positively correlated with high-quality education, especially when that education is maintained into adolescence.

Second Objective: Gender Disparities in Higher Education in Jharkhand

Table 1: Males and Females of age 15 years and above who have Secondary & Higher education (%)

Year	Females	Males	Gender Disparity in educational Attainment
2019-20	26.8	39.6	0.68
2020-21	25.9	38.1	0.68
2021-22	25.6	38.7	0.66
2022-23	29.1	40.7	0.71
2023-24	29.3	39.7	0.74

Source: PLFS (MoSPI), Different Rounds

The percentage of males and females aged 15 and older who have completed secondary and higher education throughout a five-year period, from 2019–20 to 2023–24, is shown in this table. Males regularly outperform girls in terms of educational achievement across all years, according to the data. In 2019–20, the gender gap ratio was 0.68, with 26.8% of women and 39.6% of men having secondary and higher education. The gap ratio stayed at 0.68 in 2020–21 despite a minor reduction in female attainment to 25.9% and a decline in male attainment to 38.1%. The difference ratio dropped to 0.66 in 2021–2022, a brief worsening of the gender gap as female attainment slightly declined to 25.6% while male attainment increased to 38.7%. However, in 2022–2023, the disparity ratio improved to 0.71 as female educational attainment increased to 29.1% while male attainment increased to 40.7%. The discrepancy ratio improved to 0.74 in 2023–2024 with female attainment rising to 29.3% and male attainment at 39.7%.

Interpretation:

The table demonstrates that despite the ongoing gender gap, female educational achievement has gradually improved in recent years. The gender difference ratio increased from 0.68 to 0.74, indicating that women are gradually catching up to men in secondary and postsecondary education. Nonetheless, the disparity is still significant because in 2023–2024, women will still lag behind men by about 10 percentage points. This suggests that although women's access to school has increased, structural obstacles including poverty, rural disadvantage and sociocultural limitations still prevent them from advancing in their education.

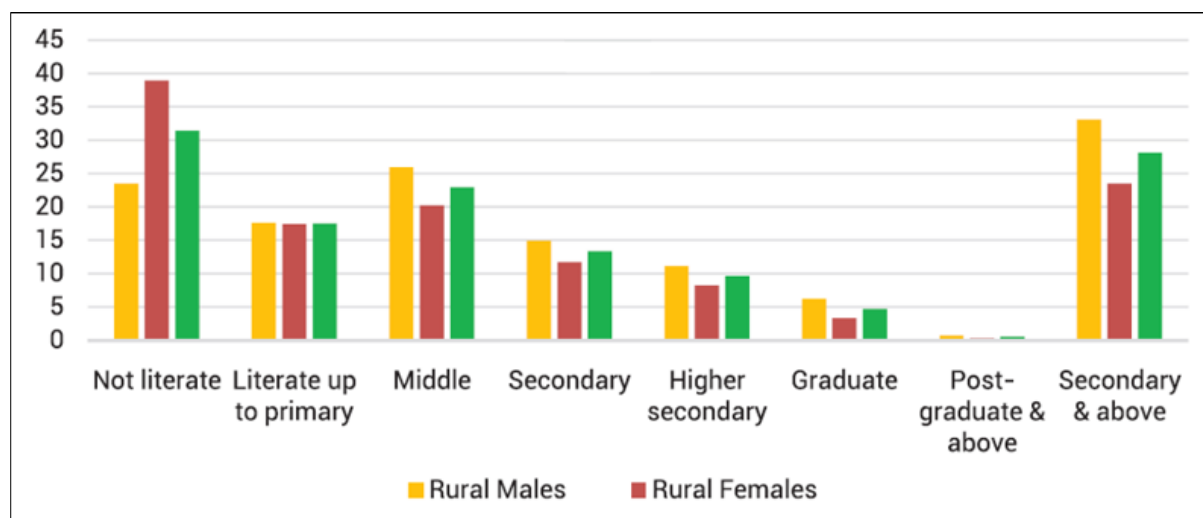


Fig. 2: Rural Males and Females of age 15 years and above by their educational level in the year 2023-24

Source: Annual report PLFS (MoSPI), 2023-24

The educational distribution of rural males and females aged 15 and older in 2023–2024 is depicted in this image. The most noticeable trend is the large percentage of rural women, roughly 39% in the "not literate" category, compared to about 23% of rural men. This suggests that compared to rural men, rural women continue to face much greater disadvantages in literacy and educational opportunities. Both rural males and females are about equal in literacy up to primary level, at about 17% which indicates that basic literacy has spread to both populations to a comparable degree. At higher levels, however, discrepancies become increasingly apparent. Rural males (about 26%) outnumber rural females (about 20%) in the middle level. Rural males make up around 15% of secondary school students, while rural females make up about 11%. Rural males make up around 11% of the population in the higher secondary stage, while rural females make up about 8%. With rural males at roughly 6% and rural females at roughly 3% at the graduate level, the gender disparity widens even more. The percentage is incredibly low for both at the post-graduate and above level, although women still lag behind men. Approximately 33% of rural males and only 23% of rural girls have attained this level in the combined category of "Secondary & above."

Interpretation:

The most educationally impoverished group is rural women, as this statistic demonstrates. They are least represented across all higher education levels and have the largest share in the category of nonliterate people. The sharp drop in female participation after primary and middle school points to the impact of early marriage, poverty, domestic workloads, dropout rates and sociocultural constraints. The extremely low number of rural women pursuing graduate and postgraduate degrees indicates that rural women's access to higher education is still severely limited.

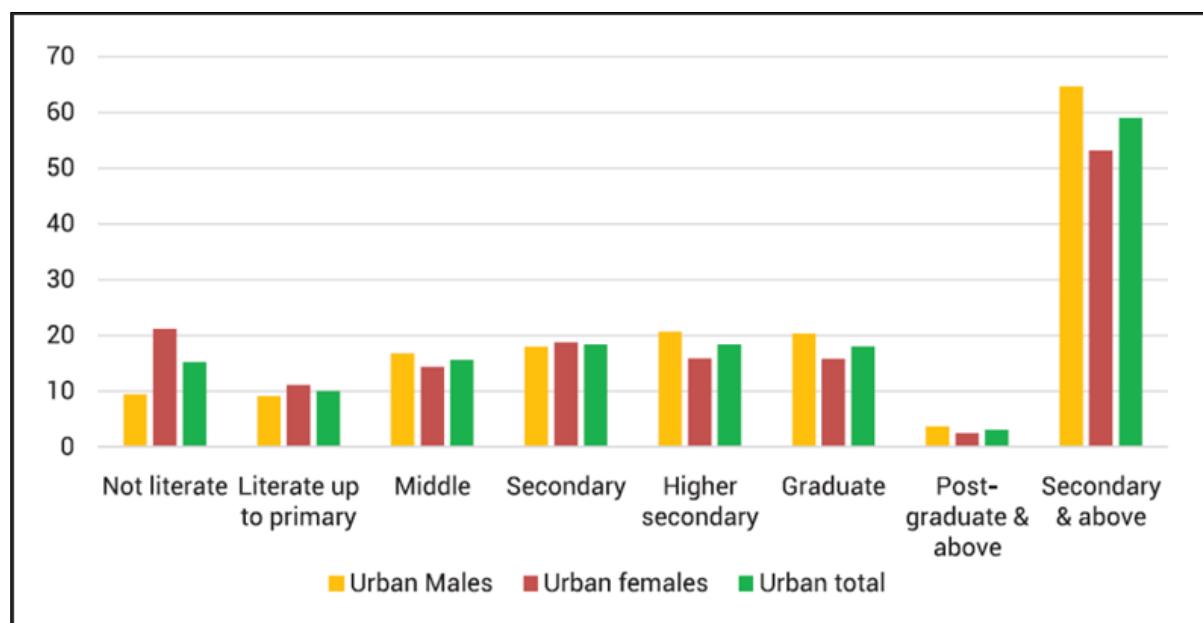


Fig. 3: Urban Males and Females of age 15 years and above by their educational level in the year 2023-24.

Source: Annual report PLFS (MoSPI), 2023-24

The educational distribution of urban males and females aged 15 and older in 2023–2024 is shown in this image. Both men's and women's educational profiles are significantly higher in urban areas than in rural ones. The percentage of illiterate urban women is about 21% which is significantly lower than that of rural women but still greater than that of urban men, who are roughly 9–10%. This suggests that while living in an urban area greatly increases access to education, gender inequality still exists. Urban girls (about 11%) are marginally higher than urban males (about 9%) in literacy up to primary school. Urban males (about 17%) are marginally ahead of urban females (around 14–15%) in the medium level. Urban females tend to be almost equal to or slightly ahead of urban boys at the secondary level, both at about 18%. This shows that female education at this time is comparatively better in urban settings. On the other hand, urban boys (around 20%) outnumber urban females (about 15–16%) at the higher secondary level. At the graduate level, urban males make up roughly 20% of the population, while urban females make up about 15–16%. Both are low at the post-graduate and higher levels, but men still have a little lead. About 64–65% of urban males and 53% of urban girls fall into the "Secondary & above" category.

Interpretation:

The graph shows that although urban women are in a far better educational position than rural women, they still lag behind urban men in terms of advanced education. Better educational facilities, institutional access and educational possibilities are all found in urban areas. However, the persistent disparity in higher secondary, graduate, and post-graduate education

indicates that, even in metropolitan regions, women are still impacted by gender norms, safety concerns, family expectations and unequal access to higher education.

Third Objective: School Infrastructure, Safety Concerns, and Government Initiatives

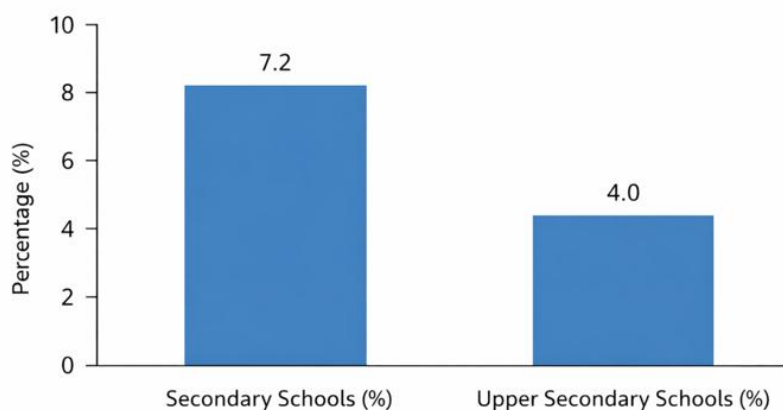


Fig. 4: Availability of Schools in Jharkhand (%)

Primary Source: Unified District Information System for Education Plus (UDISE+) 2022-23.

Table 2: School Infrastructure Supporting Girls in Jharkhand (%)

Schools with girls’ toilet	96.1
Schools with drinking water	95.9
Schools with internet facility	47.8
Female teachers	40.0
Single teacher schools	17.1

Source: Unified District Information System for Education Plus (UDISE+), specifically the 2022-23 Flash Statistics reports.

For teenage females from marginalized areas in Jharkhand in particular, school facilities and safety are crucial aspects of educational quality. The overall availability of schools is necessary here, such schools which can provide Secondary tier of education are 7.2% of all Jharkhand schools and Higher Secondary tier of education are 4% of all Jharkhand schools. Girls' attendance, dignity, health, and retention are directly impacted by basic amenities such working separate restrooms, drinking water, electricity, boundary walls, assistance with menstrual hygiene, safe school grounds and connection to neighbouring secondary schools. While UDISE+ 2022–2023 demonstrates a significant improvement in school infrastructure nationally, Jharkhand faces challenges related to the availability of basic amenities, the scarcity of secondary and higher secondary institutions and the uneven quality of facilities in rural and tribal areas. Girls sometimes drop out of school before finishing their education due to safety

issues including long commutes to higher education institutions, a lack of transportation, fear of harassment, parental limitations and the lack of secure dorms. Samagra Shiksha, Kasturba Gandhi Balika Vidyalayas (KGBVs), Jharkhand Balika Aawasiya Vidyalayas (JBAVs), e-VidyaVahini and learning enhancement programs centred on fundamental learning and inclusivity are just a few of the significant measures that Jharkhand has put in place in response. One of the most successful institutional responses to gender inequality in the state is residential schooling for girls, which is especially important because it helps with distance, safety, school continuity and early marriage concerns.

Interpretation:

Gender equality in education is largely determined by school facilities and safety which are not just administrative issues. Government initiatives in Jharkhand have improved girls' access to and support for education, but major obstacles still exist, such as poor transition support after school, a lack of secondary and higher secondary institutions, unsafe mobility and inadequate functional infrastructure. Girls from rural, tribal, and marginalized groups are especially affected by these inequalities which frequently prevent them from continuing their education and worsen already-existing gender disadvantages.

Discussion

The study shows that early marriage, restricted access to higher education, and school infrastructure create a continuum of gendered educational disparity where sociocultural and institutional impediments compound one another. According to Human Capital Theory, females' potential and long-term socioeconomic achievements are limited by unequal access to high-quality education. In a similar vein, Gender Stratification Theory describes how cultural and institutional norms, especially in hazardous or subpar educational environments, lead to higher dropout rates among girls.

The results, which emphasize how early marriage restricts girls' freedoms, education, and agency, are also consistent with the Capability Approach. The loop is clear: inadequate infrastructure causes dropouts, dropouts increase early marriage, and early marriage limits chances for higher education and jobs.

Enrolment has increased and child marriage has decreased thanks to policy initiatives like the Right to Education Act of 2009 and Beti Bachao Beti Padhao. Progress is still unequal, nevertheless, with more success being achieved in increasing access than in guaranteeing quality, retention, and meaningful learning.

In overall, a comprehensive, life-cycle strategy that goes beyond enrolment to emphasize quality, safety, and empowerment while addressing intersectional disadvantages related to caste, class, and geography is needed to reduce gender inequality in education.

Findings & Suggestion

On the basis of above analysis, it has been found that Quality Education has contributed positive response in reducing early marriage in Jharkhand but there should be more government programme in protection of early marriage specially in marginalised communities.

It has been shown that gender disparity in higher education remain significant and largely stem from weak transition rates from secondary to higher secondary levels but poverty, socio cultural constraints continue to limit their educational progress as well as educational advancement remains highly restricted for women. So, need to increase in literacy there should be more focused on targeted educational investment and also increase in literacy growth in residential schools.

It has been found that the shortage of secondary and higher secondary institutions school infrastructure and safety, including functional toilets, safe campuses, transport, and residential facilities are basic barriers in improving girls' retention. The government should expand the number of secondary and higher secondary schools, especially in rural, tribal, and educationally backward blocks, to reduce distance-related dropout among girls.

Conclusion

This study has shown that decreasing gender gaps among Jharkhand's vulnerable people requires high-quality education. The results demonstrate that early marriage, the transition from school to college, infrastructure deficiencies, safety issues and the unequal distribution of educational opportunities are all major contributors to the state's educational inequality which extends beyond literacy and enrolment discrepancies. The decrease in child marriage between NFHS-4 and NFHS-5 suggests that programs targeting girls and expanding education are having a good impact. However, girls' progress is also hampered by enduring obstacles in secondary and higher secondary availability, mobility, safety and access to higher education especially among tribal, scheduled caste, and rural poor households.

As a result, the study has come to the conclusion that high-quality education needs to be viewed as a whole educational pathway that includes access to higher education, protection from early marriage, secondary retention, fundamental learning and long-term empowerment. The future of gender equality in Jharkhand, particularly among vulnerable communities, hinges not only on getting girls into school but also on making sure they can stay, study, advance and flourish.

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A Case Study of Socio-Economic Transformation and Women's Empowerment: Special Reference to Jharkhand

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Abstract: *In rural areas of Jharkhand marginalized communities of women groups are in struggling phase because of limited reach of government schemes and education. Present study is based on descriptive and analytical methodology and Jharkhand state has been selected as a sample of secondary data. The shift between the National Family Health Survey-4 (2015–16) and NFHS-5 (2019–21) was the particular focus of this study, along with the impact of Government welfare schemes. In the investigation it has been shown that in NFHS- 5 the literacy rate rose from 59.1% to 61.7%. Furthermore, girls' percentage aged between 6 to 17 years attaining school reached 82.9%. The percentage of women (aged 20–24) married before the legal age of 18 dropped from 38% (NFHS-4) to 32.2% (NFHS-5). Decision making power regarding their own earnings is still lacking by 49% according to NFHS- 5 data. After analysis of data, it has been found that literacy rate, attaining schooling, has risen with time. Early marriage decreased because of education. The data showed that decision-making barriers still exist at home. We need men and community leaders to change their mindset regarding women's roles in financial and family decisions. Women centric Government schemes like Mukhyamantri Maiyan Samman Yojna (for enhancement of financial independence) and Savitri Bai Phule Kishori Samridhi Yojna (stop child marriage and promoting education) have played a pivotal role in driving women's empowerment. As per economic survey 2025-26, ₹13,363 crore has been shifted towards women-centric schemes, representing roughly 11% of the state's budgeted revenue receipts. However, women are not fully able to access these schemes. Sometimes, they receive the funds delayed. Timely payments should be ensured so that they can use this support to start small businesses.*

Keywords: *Social transformation, Economic transformation, Women empowerment*

Introduction

The method by which women obtain increased access to resources, education, employment, mobility, agency, legal protection and involvement in domestic and public decision-making is

known as women's empowerment. Since women are essential to agricultural, forest-based livelihoods, household survival, informal labour, care work and community institutions, women's empowerment is closely associated with socioeconomic transformation in developing states like Jharkhand. The state has historically seen unequal growth, rural impoverishment, low human development and gendered social marginalization while having a significant tribal population and a plenty of natural resources. Limited literacy, child marriage, limited asset ownership, informal work, wage vulnerability, gender-based violence and insufficient institutional representation are just a few of the disadvantages that women particularly tribal women, rural women, widows, teenage girls and women from low-income household's face. Through the Maiyan Samman Yojana, Beti Bachao Beti Padhao, Sakhi Mandal (SHGs), MGNREGA, and specific welfare programs, Jharkhand has simultaneously emerged as one of the key testing grounds for women-led collective development. According to recent state data, spending for women's and children's development has increased from ₹3,456 crore in FY 2021–2022 to ₹8,456 crore (BE) in FY 2025–2026, or 3.8% to 6.7% of the state budget. This underscores the increasing acknowledgment in policy that women's empowerment and welfare are essential components of development strategy.

As a result, the researcher chose this topic because it provides a compelling case study to comprehend how women are constrained by socioeconomic disparities, how state actions are improving women's lives, and what has to be done.

Statement of the Problem

Women in Jharkhand still confront significant obstacles to empowerment despite increased budgetary attention and policy expansion. Structural empowerment does not often follow from formal inclusion in programs. Many women continue to be excluded from safe mobility, digital systems, higher-value jobs and land ownership. The incidence of child marriage and low literacy rates continue to worsen the intergenerational deprivation in a number of districts. Therefore, to determine if Jharkhand's socioeconomic transition is genuinely empowering women or just increasing assistance coverage, a rigorous evaluation is required.

Research Questions

1. How do socio-economic inequalities affect the women's empowerment in Jharkhand?
2. How do government schemes impact on women's empowerment in Jharkhand?
3. What are the key challenges of women's empowerment in the context of prevailing socio-economic inequalities in Jharkhand.

Objectives of the Study

1. To examine the impact of socio-economic inequalities on women's empowerment in Jharkhand.
2. To analyze the impact of government schemes on women's empowerment in Jharkhand.
3. To identify key challenges of women's empowerment in the context of prevailing socio-economic inequalities in Jharkhand.

Significance Of the Study

The aim of the study was to comprehend the true state of women's empowerment in Jharkhand where socioeconomic disparities are still pervasive, especially among rural and tribal populations. Data from sources like NFHS and Economic Surveys have shown that problems like poverty, low literacy, migration and child marriage still have an impact on women's life despite the adoption of several government programs and development initiatives. This led to the topic's selection since it's critical to assess whether socioeconomic change is actually improving women's status. Because Jharkhand has distinct social, cultural, and economic circumstances that call for careful examination, the study is important. It aids in comprehending the true effects of development initiatives on women and gives policymakers helpful information to create more inclusive and successful plans for women's empowerment in the state.

Literature Review

The research on women's empowerment in Jharkhand illustrates the complex relationship between structural obstacles, policy measures, and socioeconomic disparities.

Impact of Socio-Economic Inequalities on Women's Empowerment

Studies already conducted regularly show that socioeconomic injustices such as poverty, caste hierarchy, tribal marginalization, and differences between rural and urban areas severely limit women's empowerment.

Bapan Biswas and Nasrin Banu (2023) show that rural women experience lower access to education, employment, and financial resources compared to their urban counterparts, resulting in uneven empowerment outcomes. Their work underscores the spatial dimension of inequality.

Ajit Murmu argues that development processes in Jharkhand often exclude tribal and marginalized populations, thereby reinforcing structural inequalities. This has direct implications for women, who experience layered disadvantages due to both gender and social identity.

Gaurav Kumar (2022) highlights how dependence on forest-based livelihoods among tribal women both enables income generation and simultaneously reflects economic vulnerability and lack of diversified opportunities.

Critical Analysis:

These studies show a high correlation between empowerment and inequality, but they mostly stay macro-oriented and descriptive, with little attention paid to intersectionality (e.g., gender mixed with caste and tribe). Furthermore, the ways in which disparities in agency and decision-making power at the household level result from inequality are not sufficiently explored.

Impact of Government Schemes on Women's Empowerment

A substantial amount of the literature assesses how government interventions specifically, SHGs, livelihood programs, and cooperative initiatives improve women's empowerment.

Jay Prakash Verma, Ritu Sinha, and Roshan Kumar (2020) provide empirical evidence that SHGs improve women's income, savings behaviour, and participation in household decision-making.

Similarly, Manisha Kumari, Shashi Shekhar Murmu, and Rinki Kumari (2024) demonstrate that SHGs significantly contribute to the economic empowerment of Scheduled Caste women by enhancing income opportunities and social status.

Habibul Rahman Ansari and Nida Fatima (2025) extend this analysis by showing that SHGs also foster psychological empowerment and social awareness.

In the context of cooperatives and livelihood programmes, Bhaskar Kumar Kakati and Sanjeeb Kakoty (2022) find that women's cooperatives enhance collective strength and leadership. Likewise, Bipin Bihari and Anusha Priya show that government livelihood programmes support women's entrepreneurship and income generation.

Preety Rani and Ranjan Kumar (2024) emphasize that financial inclusion initiatives significantly improve women's entrepreneurial participation.

Critical Analysis:

Despite the fact that the literature typically highlights the benefits of government initiatives, it is frequently program-centric and outcome-focused, ignoring:

- Disparities in implementation by region
- Dependency and sustainability concerns (particularly in SHGs)
- Problems with market connection and limited scalability
- Disparities between the creation of policies and their actual implementation

As a result, the efficiency of schemes varies depending on the environment.

Key Challenges to Women's Empowerment in the Context of Socio-Economic Inequalities

Numerous institutional and sociocultural obstacles continue to impede women's empowerment in Jharkhand, according to the literature.

Prem Bhaskar and Madhulika Kaushik (2022) observe that despite participation in enterprises, women's leadership remains constrained by patriarchal norms and limited decision-making authority.

Ajit Murmu further highlights that marginalization, lack of infrastructure, and exclusionary development practices continue to impede inclusive growth.

Studies on SHGs and financial inclusion also indirectly point to persistent challenges such as:

- Low levels of education and skill development
- Restricted mobility and social norms

- Dependence on informal and low-paying work
- Limited access to markets and institutional credit
- Inadequate awareness of schemes

Critical Analysis:

Despite the fact that these difficulties are well recognized, the majority of research treats them as separate problems rather than looking at how they are related. Comprehensive frameworks that connect institutional obstacles, cultural limitations, and socioeconomic disparities are lacking.

Research Gap

The following gaps are found based on the aforementioned objectives:

- Inadequate analysis linking policy actions, empowering outcomes, and socioeconomic disparities
- The intersectional elements of gender, caste, tribe, and class are not given enough attention.
- An excessive focus on schemes' success stories with little critical analysis
- Insufficient investigation of the connection between real agency and economic empowerment
- The lack of comprehensive frameworks that address institutional, structural, and cultural constraints collectively

Research Methodology

This study focuses on women's empowerment and socioeconomic change in Jharkhand using a descriptive and analytical research design, all based on secondary data.

Data Sources and Coverage

The Census of India 2011, the National Family Health Survey (NFHS-4, 2015–16 and NFHS-5, 2019–21), the Periodic Labour Force Survey (PLFS), publications from the Ministry of Women and Child Development, and reports from the Government of Jharkhand's Rural Development Department are just a few of the trustworthy and nationally recognized sources from which data was gathered. Additionally, conceptual and contextual understanding has been provided through scholarly books, journal articles, and policy documents.

Variables and Indicators

The study uses several significant socioeconomic variables to assess women's empowerment, including: Education indicators: literacy rate, Access to livelihood, workforce involvement, and financial inclusion are examples of economic indicators. Age at marriage, independence in making decisions, and access to healthcare are examples of social indicators. Participation in government initiatives, SHGs, and welfare programs are examples of institutional markers. These elements help to capture the complex concept of empowerment.

Tools and Techniques of Analysis

The research utilizes both quantitative and qualitative analytical methods, such as: Descriptive statistics, such as trends, ratios, and percentages. Comparative analysis, particularly between NFHS-4 and NFHS-5, to assess changes over time Trend analysis of important socioeconomic metrics Policy analysis with an emphasis on the planning, execution, and results of government programs. Gendered interpretation, to investigate how women are affected differently by socioeconomic changes. Both pattern recognition and contextual interpretation are made possible by this hybrid technique.

Analytical Framework

The study adopts a multidimensional approach to empowerment, linking: socio-economic inequalities, government interventions and empowerment outcomes.

Limitations of the Study

Despite careful analysis, the study has certain limitations:

The study relies entirely on secondary sources, which limits the ability to capture ground-level realities, perceptions, and lived experiences of women.

Detailed data across gender, caste, income groups, and district levels is not always consistently available, restricting in-depth intersectional analysis.

Differences in definitions, methodologies, and time periods across datasets (NFHS, PLFS, NSS, Census) may affect comparability.

Some datasets (e.g., Census 2011) may not fully reflect current socio-economic conditions.

The study is focused on Jharkhand; therefore, findings may not be fully generalizable to other regions.

Findings And Analysis

Objective 1: Socio-Economic Inequalities and its Impact on Women Empowerment in Jharkhand

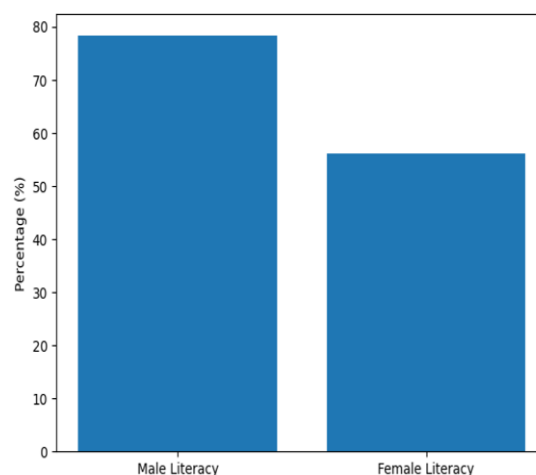


Fig. 1: Literacy Rate in Jharkhand

Source: Researcher-made bar graph based on Census of India, 2011. Primary Census Abstract, Jharkhand.

According to the graph, Jharkhand's total literacy rate is 66.41% with a male literacy rate of 76.84% and female literacy rate of 55.42% in the Census of India (2011). This has shown that there is a literacy gap between males and females of almost 21.42 percentage points.

Interpretation:

According to the data, women's educational attainment is much lower than men's even if general literacy is moderate (66.41%). Persistent socioeconomic and cultural hurdles to women's education are reflected in the lower female literacy rate (55.42%).

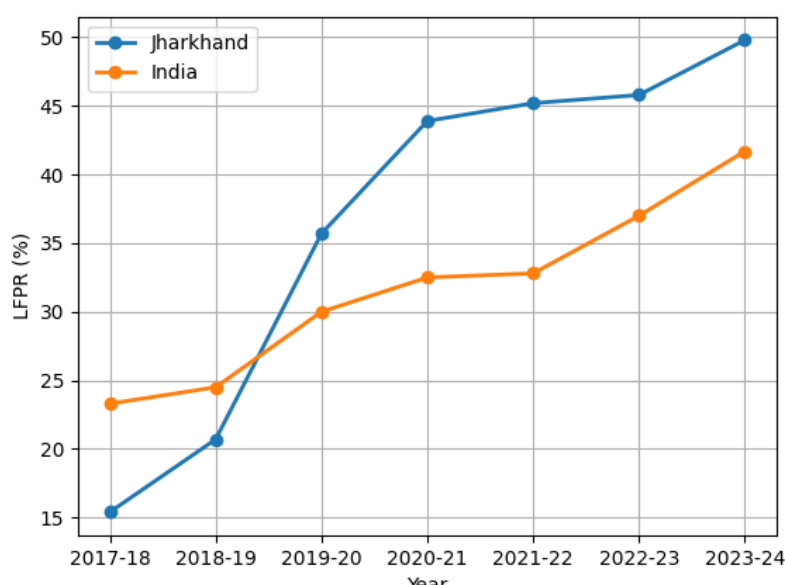


Fig. 2: Female Labour Force Participation Rate (FLFPR) – India vs Jharkhand (PLFS) for female of age 15 years and above.

Source: Researcher-made line graph based on Periodic Labour Force Survey (PLFS), 2017–18 to 2023–24, Ministry of Statistics and Programme Implementation, Government of India.

The Female Labour Force Participation Rate (FLFPR) trend for Jharkhand and India from 2017–18 to 2023–2024 is depicted in the line graph. Over the course of the six years, the data demonstrate a consistent rise in female labour force participation at both the federal and state levels. FLFPR rose by around 18.4 percentage points at the national level (in India), from roughly 23.3% in 2017–18 to 41.7% in 2023–2024. The FLFPR in Jharkhand rose by almost 34.4 percentage points, from approximately 15.4% in 2017–18 to 49.8% in 2023–2024. One significant finding is that over the course of the whole time except 2017-18, Jharkhand's female labour force participation rate was continuously higher than the national average. In 2017–18, India had higher female labour force participation rate than Jharkhand by about 7.9 percentage points; by 2023–2024, it had progressively increased to about 8.1 percentage points. This

implies that while Jharkhand's growth rate is still higher than the national average, growth throughout all of India has been somewhat quicker recently.

Interpretation:

Due in large part to their active participation in agriculture, wage labour, forest-based activities and informal work particularly in rural and tribal areas, women in Jharkhand have continuously registered a higher labour force participation rate than the national average. This illustrates the substantial economic contribution made by women even though a large portion of their involvement is frequently motivated by financial need rather than having access to stable, official employment. A favourable trend toward women's empowerment and improved economic involvement are indicated by the consistent increase in FLFPR. However, increased participation by itself does not guarantee significant empowerment because a significant portion of women's labour is still unpaid and informal. As a result, the data emphasizes the necessity of enhancing the sustainability, security and quality of women's employment in Jharkhand.

Objective 2: The Impact of Government Schemes on Women Empowerment in Jharkhand

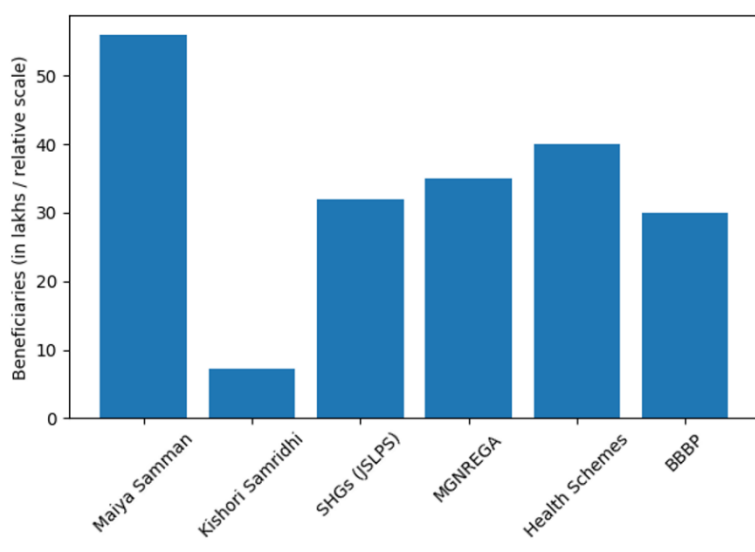


Fig. 3: Major Government Schemes and Their Contribution to Women Empowerment in Jharkhand

Source: Compiled from Government of Jharkhand (MMMSY Portal, JSLPS Reports), Ministry of Rural Development (MGNREGA), and Ministry of Women & Child Development (BBBP), 2024–2026.

According to the data, the Mukhyamantri Maiya Samman Yojana has the greatest impact of all the programs, helping around 56 lakh women. About 32 lakh women are covered by SHGs, 7.3

lakh girls are reached by Kishori Samridhi and other programs like MGNREGA, health schemes and BBBP have a moderate reach.

Interpretation:

Strong economic empowerment through financial support and livelihood activities has been indicated by the high coverage of 56 lakh (Maiya Samman) and 32 lakhs (SHGs). On the other hand, initiatives like awareness campaigns like Kishori Samridhi (7.3 lakh) have shown a steady improvement in social empowerment.

Table 1: Scheme-wise Impact of Government Interventions on Women’s Empowerment in Jharkhand

Name of Schemes	Dimension of Empowerment	Observed Impact	Inference
Janani Suraksha Yojana (JSY) / Janani Shishu Suraksha Karyakram (JSSK)	Health Empowerment	A rise in institutional births and safer childbirth	Maternal vulnerability has decreased and women's access to healthcare services has improved because to government maternal health initiatives.
JSY / JSSK / NHM / ASHA Outreach	Health Empowerment	Better access to the trained health personnel during delivery	Maternal and reproductive health outcomes have improved as a result of increased public health outreach and infrastructure.
Pradhan Mantri Jan Dhan Yojana (PMJDY) / DBT / Banking Inclusion	Financial Empowerment	A sharp rise in financial inclusion	Initiatives for financial inclusion have improved women's access to welfare benefits, savings habits and economic involvement.
Self-Help Groups (SHGs) / JSLPS / NRLM	Economic Empowerment	Higher collective participation in livelihood and credit activities	The development of women's income generation, financial independence and community leadership has been greatly aided by SHGs.
Women-Focused Welfare Schemes /	Social & Household Empowerment	Improved role in family decision-making	Social mobilization and welfare assistance have enhanced women's

SHGs / Awareness Programmes			agency and voice in the home.
PMAY (Indirect) / Rural Development / Livelihood Programmes	Asset Ownership & Economic Security	Increase in asset ownership	Women's economic stability and bargaining power in the home and in society have improved as a result of increased asset ownership.
Beti Bachao Beti Padhao / Kishori Welfare Schemes / Education Support	Social Empowerment / Child Welfare	Reduction in early marriage	Child marriage is still a problem, although awareness and girl-focused efforts have helped to gradually change society.
Girls' Education Schemes / Scholarships / State Education Support	Educational Empowerment	Improvement in female educational attainment	The long-term basis of women's empowerment and socioeconomic mobility has been strengthened via educational initiatives.
Protection Services / Legal Awareness / Social Welfare Interventions	Protection & Social Justice	Decrease in domestic violence	Even while there has been some progress, ongoing violence shows that more robust institutional and social interventions are required.

Source: Compiled from NFHS-4 (2015–16), NFHS-5 (2019–21), and Jharkhand Economic Survey 2023–24.

The table demonstrates how government initiatives in Jharkhand have improved women's empowerment in domains like health, financial inclusion, education, livelihood, household decision-making, and asset ownership. Women now have better access to opportunities and necessary services because to initiatives like JSY, JSSK, PMJDY, SHGs, and education support programs.

Interpretation:

The results have shown that these initiatives have improved women's socioeconomic status and enhanced their involvement in community and domestic life. A progressive increase in women's agency and independence is reflected in improvements in healthcare access, financial inclusion and educational support.

Objective 3: Key Challenges of Women Empowerment in the context of Prevailing Socio-Economic Inequalities in Jharkhand

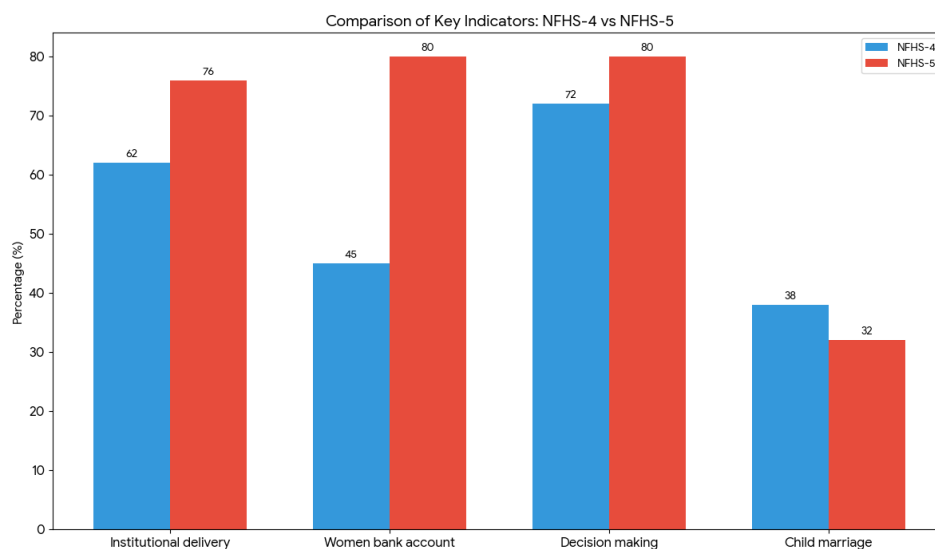


Fig. 4: Women Empowerment Indicators in Jharkhand: A Comparative Analysis of NFHS-4 and NFHS-5

Source: NFHS-4 (2015–16) and NFHS-5 (2019–21), Jharkhand Fact Sheet, IIPS & MoHFW.

Key measures of women's empowerment in Jharkhand are contrasted in the bar graph between NFHS-4 (2015–16) and NFHS-5 (2019–21). Over time, the majority of indicators clearly demonstrate progress. As a result of improved access to maternal healthcare, institutional delivery rose from 62% in NFHS-4 to 76% in NFHS-5. The percentage of women with bank accounts increased dramatically from 45% to 80%, demonstrating greater financial inclusion. Additionally, women's decision-making participation increased from 72% to 80%, demonstrating increased agency at the household level. On the other hand, child marriage decreased from 38% to 32%, which is a positive development albeit early marriage is still a problem.

Interpretation:

According to the data, women's empowerment in Jharkhand has improved in terms of social, economic and health aspects between NFHS-4 and NFHS-5. Increased awareness of mother well-being and better access to healthcare services are indicated by the rise in institutional deliveries. The impact of financial inclusion policies and welfare-linked banking access is demonstrated by the significant rise in women's bank account ownership. In the same manner, the progressive strengthening of women's voices inside homes is reflected in the improvement

in decision-making participation. Even while the number of child marriages has decreased, its persistence indicates that adolescent females are still impacted by sociocultural and economic obstacles. Overall, the graph illustrates significant advancements in women's empowerment in Jharkhand while also demonstrating the need for ongoing policy attention to more fundamental structural problems.

Discussion:

In Jharkhand, women's empowerment is advancing, but unevenly and partially due to enduring socioeconomic disparities. Indicators like institutional deliveries, financial inclusion, decision-making participation, and female labour force participation show improvements, but these gains are accompanied by notable disparities, most notably a 21.42 percentage point literacy gap that still restricts women's opportunities.

According to Human Capital Theory, low female literacy limits access to greater economic opportunities and skill development. According to Gender Stratification Theory, women's access to resources and decision-making authority is still restricted by deeply ingrained patriarchal norms and institutional impediments, which leads to high labour participation but mostly low-quality, informal work.

The Capability Approach emphasizes that unless it improves women's agency, autonomy, and control over resources, greater involvement does not always equate to empowerment. Many women still lack actual decision-making authority despite increased access to banking, jobs, and government.

Government programs have greatly increased access to opportunities and services, but their effects are still mostly access-oriented rather than transformative. Overall, the results point to the necessity of going beyond participation to a comprehensive, capability-based strategy that tackles societal norms, structural injustices, and women's control over resources in order to achieve genuine empowerment.

Policy Recommendations

1. Enhance girls' education by providing retention assistance, safe school facilities, and scholarships.
2. Encourage safe and high-quality employment by increasing formal job options, entrepreneurship, and skill development.
3. Increase financial inclusion by tying bank access to credit, livelihood assistance, and financial literacy.
4. Improve outreach initiatives and health services to improve maternal and reproductive healthcare.
5. Reduce gender-based violence and child marriage by enforcing the law more strictly and raising awareness.
6. Provide inclusive and focused policy measures to support underprivileged women in rural and tribal communities.

For long-term women's empowerment, Jharkhand need an integrated policy approach that incorporates social protection, employment, health, education and financial inclusion.

Conclusion

Overall, the results reveal that women's empowerment in Jharkhand has made significant strides in the areas of education, the economy, health and society, although there are still significant structural disparities. Despite the state's reasonable general literacy rate, women's literacy and educational attainment are still lower than men's underscoring enduring cultural and socioeconomic barriers to equitable access to education. In addition, women in Jharkhand exhibit a relatively significant economic presence as seen by their higher labour force participation than the national average, especially in the areas of agriculture, wage labour, forest-based activity and informal employment. However, this participation's revolutionary potential is limited because it is primarily motivated by economic necessity and is still concentrated in unpaid, informal and unstable sectors. Women's access to resources, services and livelihood possibilities has greatly improved thanks to government initiatives including the Maiya Samman Yojana, Self-Help Groups (SHGs), maternity health programs, financial inclusion initiatives and adolescent welfare schemes. Women's agency and socioeconomic status appear to be steadily improving as seen by the improvements in household decision-making, bank account ownership and institutional deliveries between NFHS-4 and NFHS-5.

However, the persistence of child marriage, women's poorer educational attainment and the informal nature of women's employment are showing that empowerment is still uneven and incomplete. The study comes to the conclusion that although Jharkhand has made significant strides in women's empowerment, deeper structural reforms centred on high-quality education, stable employment, social protection, gender-sensitive governance and the dismantling of deeply ingrained socio-cultural inequalities are also necessary for sustainable and meaningful empowerment.

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A Geographical Analysis of Agricultural Bases and its impact on Rural Development in Bihar: A Micro-level Case Study

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Abstract: *Indian agricultural development can be looked at from two different perspectives i.e., institutional and technological. The institutional approach, mainly typified by land reforms and changing agrarian relations, was the strategy adopted way back in the mid-fifties just after independence. Land reforms, as an engine of agricultural development, registered limited success and by passing of time it became only a matter of politics at both the national and the state level. Moreover, on the background of rapidly growing population it was realized that in the absence of further scope for increasing the area under cultivation, advances in productivity remained the only means of stepping up food-grain production in the country. As a result technological approach to agricultural development, popularly known as the “Green Revolution” was adopted in the mid-sixties, which made a decisive impact on agricultural production and productivity. But, this approach of agricultural development was very much limited to few western and southern region of the nation. The state like Bihar, characterized with deep poverty and backwardness, remained far away of both the institutional and technological transformation even in the era of liberal economic policy which consequently resulted into a deprived agricultural condition of the state. This paper tends to examine the present condition of agricultural base and its impact on rural development in a community development block of Bihar. Present study reveals the fact that there is significant effect of institutional and technological transformation policies of the government towards improvement of agricultural bases which in result directly affect the status and level of Rural Development in the state and study area. The study recommends that by improving the condition of agricultural bases the level of rural development can be achieved faster and stable.*

Keywords: *Agricultural Base, Agricultural Development, Rural Development, Micro-level, Land Holdings, Land Use, Farm Technology.*

Introduction

In the 1950s, Indian agriculture was backward in the sense that output per worker and output per unit of land area were low. There were regional variations in agro-climatic conditions, spread of irrigation and varying extent of market penetration in different areas. Nonetheless, most parts of rural India had unequal land ownership patterns in which a major part of cultivated land was controlled by a few large landowners. Tenancy was widespread and crop-share rents were the major form of rent, especially in the East and the South of the country. Availability of institutional credit was insufficient in rural areas and most cultivators had no option but to go to the local money-lenders for credit. In many parts of rural India, particularly in northern India, inheritance pattern led to continuation of the subdivision of holdings (the average size of holding was well within 2 hectares) (Vaidyanathan, 2000). These conditions discouraged and prevented investment in agriculture by all classes. Due to poor farm technology and infrastructure the agricultural farms were low yielding and cultivation practices primitive. This inhibited the growth of Indian agriculture before the rise of Green Revolution.

Indian agricultural development can be looked at from two different perspectives i.e., institutional and technological. The institutional approach, mainly typified by land reforms and changing agrarian relations, was the strategy adopted way back in the mid-fifties just after independence. Land reforms, as an engine of agricultural development, registered limited success and by passing of time it became only a matter of politics at both the national and the state level. Moreover, on the background of rapidly growing population it was realized that in the absence of further scope for increasing the area under cultivation, advances in productivity remained the only means of stepping up food-grain production in the country. As a result technological approach to agricultural development, popularly known as the “Green Revolution” was adopted in the mid-sixties, which made a decisive impact on agricultural production and productivity. But, this approach of agricultural development was very much limited to few western and southern region of the nation (Hazell, 2002). The state like Bihar, characterized with deep poverty and backwardness, remained far away of both the institutional and technological transformation even in the era of liberal economic policy which consequently resulted into a deprived agricultural condition of the state. This paper tends to examine the present condition of agricultural base and its impact on rural development in a community development block of Bihar. By this study, it can also be analysed whether there is any effect of institutional and technological transformation policies of the government towards agricultural improvement in the state or not? The paper deals with different aspects of agricultural base like: land holdings, land use pattern and their changes, irrigation, development of farm technology and status of livestock in the Raghapur Block. The present study works on the hypothesis that “by improving the condition of agricultural bases the level of rural development can be achieved faster and stable.”

Objectives of the Study

The present study is based on two-fold objectives:

- A. To examine the present condition of agricultural base and its impact on rural development in the study area, and
- B. To analyze, whether there is any effect of institutional and technological transformation policies of the government towards agricultural improvement or not?

The Study Area

The study area is one of the eleven blocks of district-Supaul, situated in the Kosi plain of north Bihar stretching from 26° 29' 68" N to 26° 30' 34" N and 86° 83' 37" E to 86° 84' 24" E (Fig. 1) and known for its backwardness and flood vulnerability. The Block consists of eighteen Panchayats and 58 Villages with an area of 21167 hectares (211.67 Sq. Km). The area comprises 215643 persons (2011) of which male populations share 51.54 per cent. In 2011, the average density of population was 10 persons per hectare (Census of India, 2011).

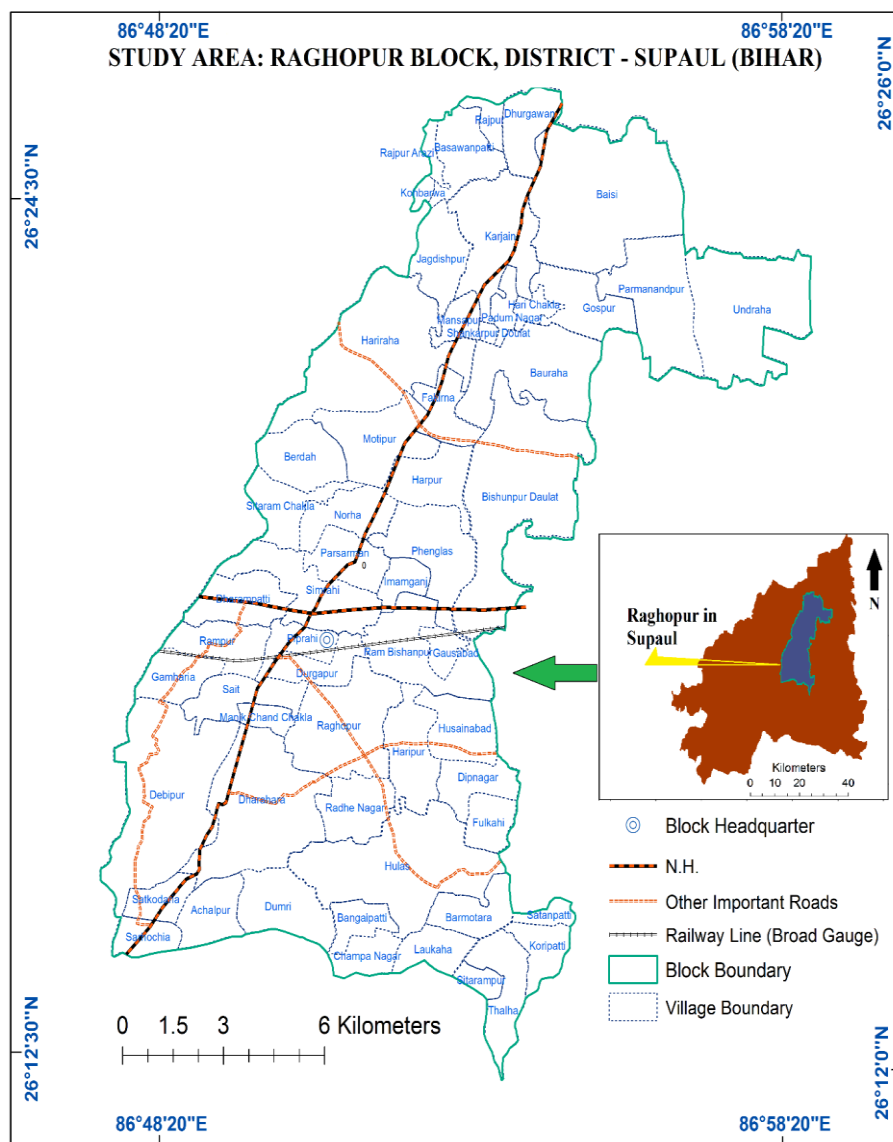


Fig. 1: Location Map of the Study Area

Analysis

For the study of rural development and their aspects it is very essential to understand status and growth of different major bases responsible for rural development. There are different bases which effect the rural development out of which a major base that is agricultural base has been analysed in the terms of its recent status as well as its growth in last decade (2001 to 2011). The basic information regarding the bases has been collected from Village Directory of Census of India-2001 and 2011. It has been analysed to understand the significant aspects related to agriculture that is land holdings, land use pattern and change, irrigation, farm technology and livestock in the study area.

Agricultural Bases and their Development

Agriculture is the backbone of rural economy in India and hence this block is completely dependent on rural economy or livelihood. More than 75 percent of working population is engaged in agricultural activities (Census data, 2011). The status of agriculture here determines the level of rural development. In the same way, agriculture is highly dependent over the availability and level of agricultural bases, viz., number and size of land holdings, land use pattern, irrigation, farm technology and others. Better the condition of these bases of agriculture, better will be the agricultural development because these bases directly affect both the productivity as well as food production.

A. Land Holdings

Small land holdings are the biggest characteristics of rural livelihood due to massive population pressure (Vaidyanathan, 2000). Land holdings are inversely proportional to number of population per unit area. Higher the density of an area, smaller will be the number and size of the holdings.

A.1. Number of Land Holdings according to their size and categories

Total landholdings of the Raghapur Block have been classified into five types according to the size of holdings, i.e., marginal, small, semi-medium, medium and large (Table 1). The size and category wise distribution of land holdings in the block is reflected through the Table 1 (2010-11). About 94 percent of the total land holdings are of marginal size, whereas the medium and large sized holdings are almost absent in the block. Similarly, only about 3 percent of total holdings are under the hand of most deprived Scheduled Castes (SCs) population which covers 14.5 percent of total population in the block (Kumar and Sharma, 2014). Significantly, the number and size of land holdings are decreasing year by year due to fragmentation of the families (a social transformation in rural areas, particularly in villages).

Table 1: Number of Land Holdings according to their size, Raghopur Block, 2010-11

Size of holdings (Acre)	Category wise number of holdings							
	SCs	In %	Institutional	In %	Others	In %	Total	In %
Marginal (< 2.47)	858	2.96	8	0.03	28162	97.02	29028	94.04
Small (2.47 - 4.93)	NIL	NIL	8	0.64	1239	99.36	1247	4.04
Semi-medium (4.94 - 9.87)	NIL	NIL	6	1.32	448	98.68	454	1.47
Medium (9.88 - 24.70)	NIL	NIL	2	1.43	138	98.57	140	0.45
Large (> 24.70)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total	858	2.78	24	0.08	29987	97.14	30869	100

Source: Agricultural Survey 2010-11, Raghopur Block, District-Supaul

{Note: 2.47 acres = 1 ha (hectare)}

A.2. Area of Land Holdings according to their size and categories, 2010-11

Like the distribution of number of land holdings, the area of land holdings is also differently distributed among the categories and types of land holding in the Raghopur Block (Table 2). The highest proportion of area is marginal (about 75 %), whereas the lowest proportion is held under medium holdings (5.28 %).

Table 2: Area of Land Holdings according to their size, Raghopur Block, 2010-11

Size of holdings (Acre)	Categorywise area of holdings							
	SCs	In %	Institutional	In %	Others	In %	Total	In %
Marginal (< 2.47)	623.12	2.23	9.63	0.03	27271.95	97.73	27904.7	74.52
Small (2.47 - 4.93)	NIL	NIL	29.19	0.64	4522.36	99.36	4551.55	12.15
Semi-medium (4.94 - 9.87)	NIL	NIL	38.24	1.27	2974.5	98.73	3012.74	8.05
Medium (9.88 - 24.70)	NIL	NIL	30.04	1.52	1947.86	98.48	1977.9	5.28
Large (> 24.70)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total	623.12	1.66	107.1	0.29	36716.67	98.05	37446.89	100

Source: Agricultural Survey 2010-11, Raghopur Block, District-Supaul

{Note: 2.47 acres = 1 ha (hectare)}

Only 2.78 percent of total area of land holdings is owned by SCs population, which uncover the fact that the distribution of land holdings is very uneven and are mostly shared by the few

elite groups in the study area (Raghapur Block) and thus, this is the prime reason of paralyzed rural livelihood or economy and hazy glimpses of rural development.

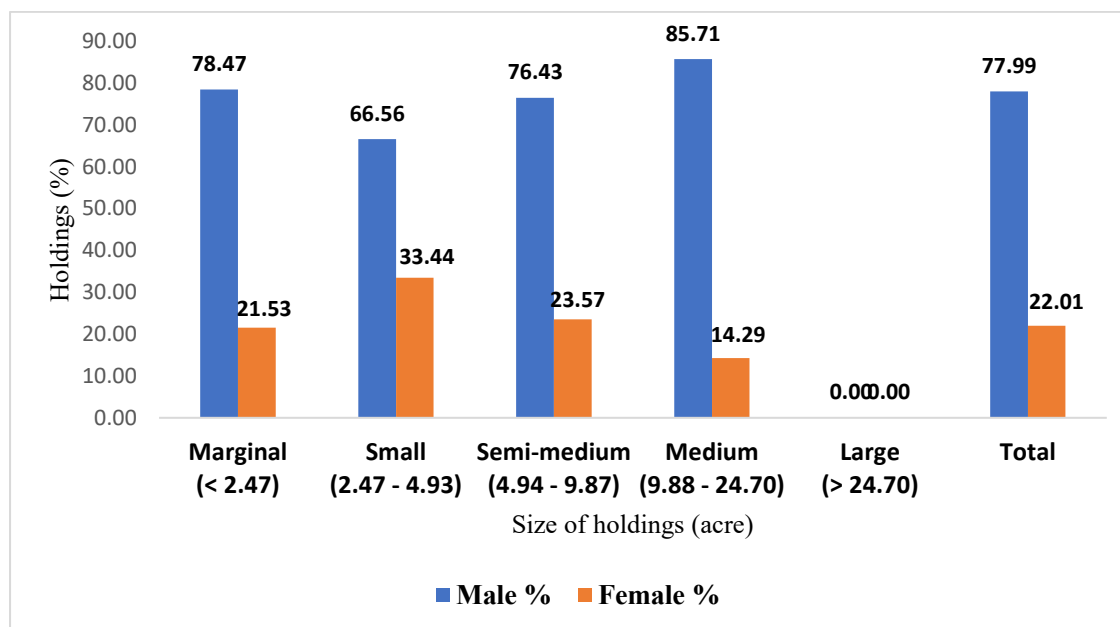


Fig.2: Male-Female Ratio in Number of Land Holdings of Raghapur, 2010-11

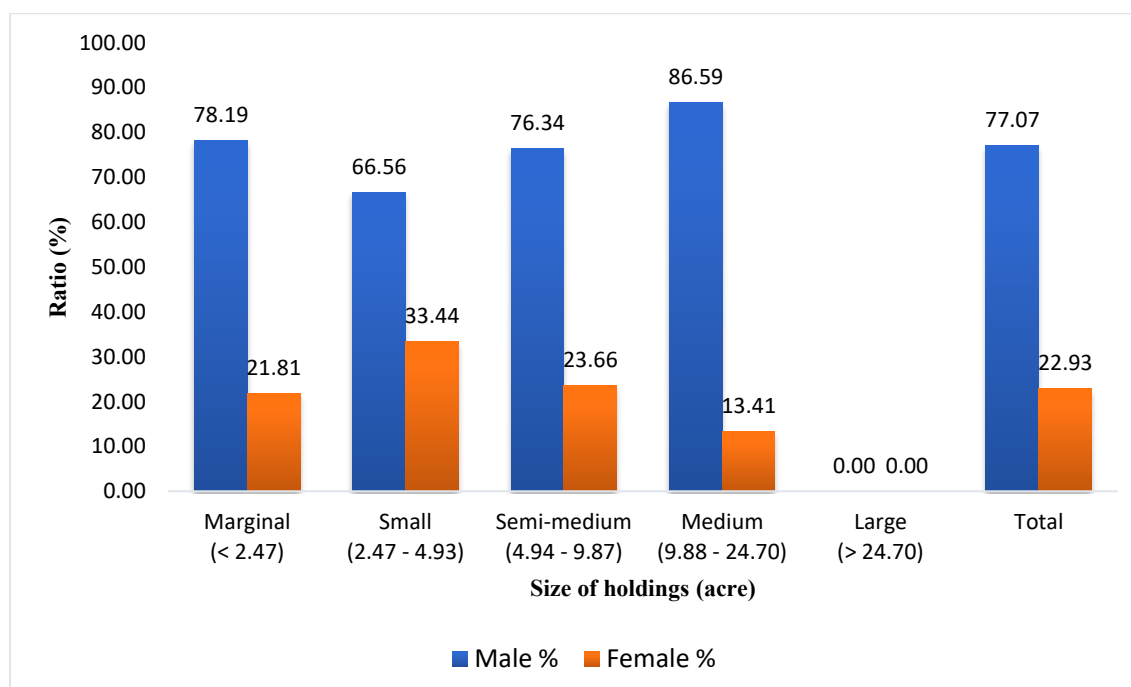


Fig. 3: Male-Female Ratio in Area of Land Holdings, Raghapur, 2020-11

c. Male – Female Difference in terms of Land Holdings

In terms of the distribution of both the number and the size of holdings between male and female, wide disparities exist in the block (Figures 2 and 3). In this male driven society, about 78 percent of land holdings (in terms of both numbers and areas) are owned by males, whereas, only 22 percent of land ownership is shared by the females (Figures 2 and 3). It is very clear from the analysis that the gender wise distribution of land holdings is neither very satisfactory and nor healthy for the society as well as agricultural prosperity. It also indicates that the distribution is very uneven which reflects that there is need of radical land reform policy for un-biased land distribution among the poor and non-poor. The intensive agricultural development policy as well as availability of basic infrastructures and facilities requires by the administrators and NGOs.

B. General Land Use and its change

B.1. Land Use Pattern

The land use pattern is an outcome of the interaction of the physical and cultural environment of any place or region. It is the fact, that there is nothing older than the man-land relationship in the history of mankind. Man from very beginning of nomadic life has been utilizing the land resources for their development. The structure of land use in any region is continuous process of evaluation through interplay of ecological, technological and institutional influences (Subramaniam, 1979). Social scientists and land managers define land use broadly to include the social and economic purposes and contexts for and within which lands are managed such as subsistence versus commercial agriculture, rented versus owned or private vs. public land (Turner, 2002 as cited in Erika et al. 2005). Land use is the term that is used to describe human uses of land, or immediate actions modifying or converting land cover (de Sherbinin, 2002). The proper utilization of the land is the economic backbone of the region and the use of the land is determined by the geographical conditions, socio-economic structure, and availabilities of natural resources and determines the socio-economic conditions and land use pattern of the region. For an example, if high proportion of land of an area is used for subsistence agricultural practices than, it determines the fact that the area must be a rural area and has comparatively poor socio-economic conditions. The Raghapur Block is the best example, where about 73 percent of the total land is used for agricultural purposes in 2011 (Table 3).

The study of land-use and its classification has received great impetus especially after the year of 1930 when intensive land utilization survey in Great Britain was held by L.D. Stamp (Stamp, 1962). To analyze the land-use pattern of the Raghapur block, it has been classified into four major types that are: forest, total uncultivable land, total cultivable wasteland, and total arable land or net sown area. The arable land shares about 73 % of total land while the forest shares just insignificant (0.16 %) (Table-3). The uncultivable land is about 20%, while cultivable wasteland is only 7.28 %, which reflects very low potential for future arable land expansion. Therefore,

Table 3: General Land Use of Raghapur Block, 2011

Sl.No.	Types of Land Use	Area (ha)	Area (%)
1	Forest	34.17	0.16
2	Total Uncultivable Land	4119.05	19.46
2.i.	Area under Non-Agricultural Uses	3801.66	92.29
2.ii.	Barren and Uncultivable Land	317.39	7.71
3	Total Cultivable Wasteland	1540.66	7.28
3.i.	Permanent Pastures & Other Grazing Land	0.66	0.04
3.ii.	Land Under Miscellaneous Tree Crops etc.	271.71	17.64
3.iii.	Culturable waste Land	111.3	7.22
3.iv.	Fallow Land other than Current Fallows	492.95	32
3.v.	Current Fallows	664.04	43.1
4	Total Arable Land (Net Area Sown)	15473.62	73.1
4.i.	Total Unirrigated Land	4420.95	28.57
4.ii.	Total Irrigated Land	11052.67	71.43
4.ii.a	<i>Irrigation by Canal</i>	7224.67	65.37
4.ii.b	<i>Irrigation by Wells/Hand pump</i>	1274.1	11.53
4.ii.c	<i>Irrigation by Tanks or Pond</i>	262.3	2.37
4.ii.d	<i>Other Sources (Tube wells and Motor pump)</i>	2291.6	20.73
	Total Land Use (1+2+3+4)	21, 167.50	100

Source: Based on Village Directory, Census of India, 2011.

the only scope for agricultural development is the vertical expansion, i.e., increasing the intensity of agricultural land by supporting agricultural infrastructures like cost effective irrigation, use of HYV seeds, improving farm technology and extension works.

B.1.i. The Uncultivable Land

Uncultivable lands are such lands which never can be used for the cultivation. This category of land consists of human settlements, water bodies, transport and communication networks, canal and other barren lands (Stamp, 1962). Total uncultivable land of the block is about 4119 ha, which is about 20 percent of total land of the block (Table 3). About 92% of the uncultivable land is under non-agricultural uses, i.e., settlement, water bodies, etc., whereas about 8 % land area is barren. The spatial pattern of uncultivable land is unequal in the block (Fig. 4 A). Bauraha is the only panchayat where the percentage of uncultivable land is more than 35%, while, BisanpurDaulat, Simrahi, Vayasi, Parmanadpur, Motipur and Dharahara are the six panchayats where this type of land shares about 20% to 35% and remaining eleven panchayats (61% of total panchayats) of the block have less than 20% of their total land under this category (Fig. 4 A).

B.1.ii. The Cultivable Wasteland

Such lands have potentiality to be cultivated but due to some reasons they are not being used for this purpose in the present. With the application of new techniques, such land can bring under cultivation in future and may be more beneficial for the increasing demand of continuous growing population. The cultivable wasteland include bushes, gardens, pasture, fallow lands, scrubs, etc. (Stamp, 1962). This land occupies about 7.28% of total area of the Raghapur Block (Table 3) of which about 43% land comes under current fallows. Rambishanpur is the only panchayat which has more than 20% land under this category, while, Bisanpur Daulat, Finglas, Simrahi, Haripur and Champa Nagar Panchayats share between 10% to 20% of their total land (Fig. 4 B). Twelve panchayats of the block (67% of the total panchayats) have less than 10 percent of their total land under cultivable wasteland due to increasing pressure of population as well as fragmentation of families and plots. The irrigation is main reason for such fallow lands

B.1.iii. The Arable Land or Net Sown Area

Arable land occupies the largest area of the block, i.e., 15473.62 ha (73% in 2011). Out of this about 71% is irrigated and remaining live in the hope of rainfall (Table 3). Because, the block is dominated by agricultural activities and agriculture is the prime hope of rural economy, the area under arable land is highly relevant. Due to increase in population and emergence of other non-agricultural activities, the area under arable land is continuously falling, viz., it was 16353.84 ha (2001) which reduced to 15473.62 ha (2011). The spatial distribution of arable land is also uneven in the villages and panchayats (Fig. 4 C). Karjain, Hariraha, Piprahi, Raghapur, Devipur, Haripur, Hulas and Dumri panchayats share about 44% of the total panchayats whose more than 75 percent of total land is under arable (2011), while only two panchayats (Bauraha and Bisanpur Daulat) are such where the share of arable land is less than 60 percent. The remaining eight panchayats share 60% to 75 % of their total land in 2011 (Fig. 4 C). The spatial distribution of irrigated land is not very unequal (Fig. 5). Only Hariraha and Raghapur are two panchayats where less than 55% of their total arable land is irrigated (2011) while nine panchayats (50% of the total panchayats) have more than 70% of their total arable land (net sown area) is under irrigation (Fig.5).

B.2. Changes in Land Use

Land Use and Land Cover dynamics is the result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales (Reid et al., 2000). Though, natural processes also contribute to changes in land cover, the major driving force is human induced land uses (Allen and Barnes, 1985). Due to increase in population and little change in economic activities, the change occurred in the land use of Raghapur Block during 2001 to 2011. During this period, the area under arable land is mostly affected with the loss of 880.22 ha (4.16 %) of land (Table 4). The major share covered by the fallow lands (specially the new fallows). The significant change of 757.34 ha (3.58 %) have been seen under the cultivable wasteland. This is mainly caused due to the migration of landholders as well as agricultural labours (especially male labours) for other alternative source

of livelihood. Due to increasing settlements and associated land the uncultivable land slightly increase by 0.42 % (Table 4).

Table 4: Change in Land Use, Raghopur (2001 – 2011)

Sl. No.	Types of Land Use	Land Use (%)		Change (%)
		2001	2011	
1	Forest	0	0.16	0.16
2	Uncultivable Land	19.04	19.46	0.42
3	Cultivable wasteland	3.7	7.28	3.58
4	Arable Land	77.26	73.1	-4.16

Source: Based on V.D. data, Raghopur (2001 and 2011).

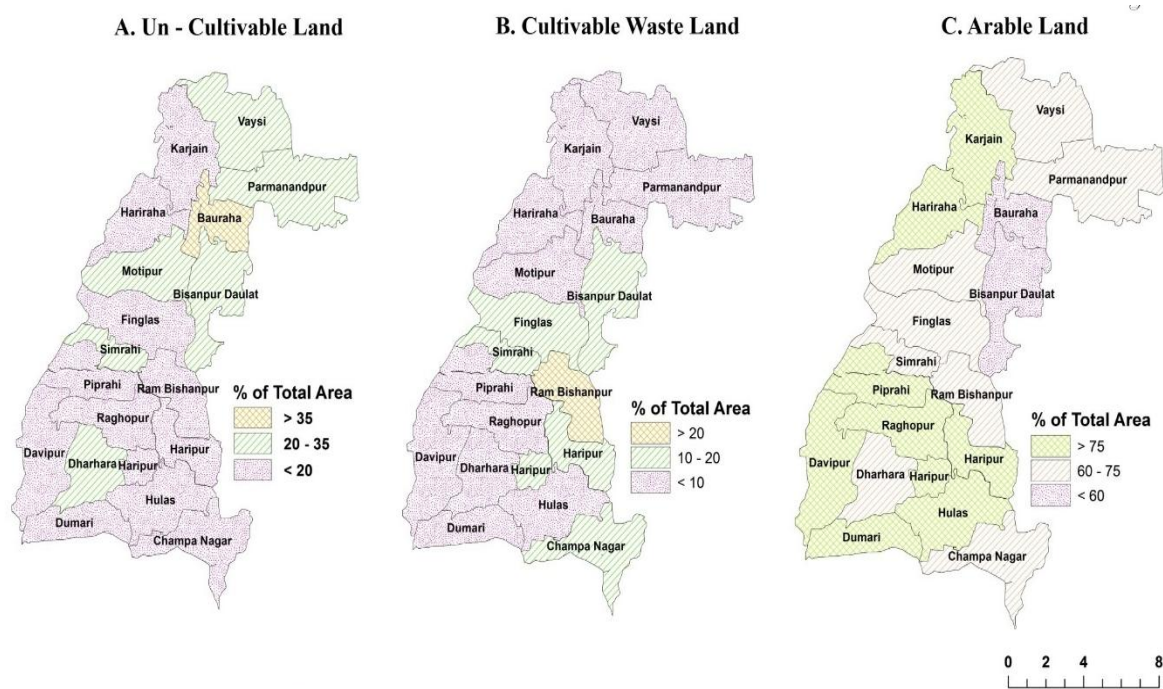


Fig. 4: Land Use Pattern of the Study area, 2011

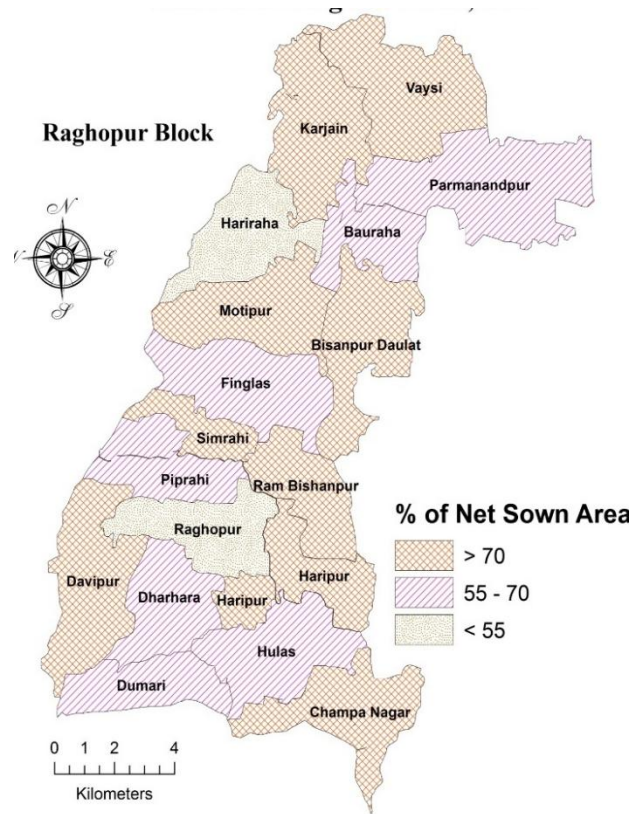


Fig. 5: Pattern of Irrigated Land of the Study area, 2011

C. Irrigational Sources and their distribution

Irrigation brings significant change in agricultural development where rainfall is very uncertain and uneven. Irrigational facilities are just average in this block. About 71 percent of the arable land is irrigated in the block (2011), which was only 64 percent, in 2001 (V.D, Census of India 2001 and 2011). It shows that there is some improvement in the sources of irrigation. Out of the total irrigated land 65 percent is under canal irrigation. There is 4.59 % increase in canal irrigation between the years 2001 to 2011 (Figure 6). It happens due to Kosi Project (the canal provided under the scheme). The advance source of irrigation i.e., tube wells and motor pumps share 21 % of total irrigation with tremendous increase of 14.11 % (during 2001-2011). This cause into the fall in traditional source of irrigation i.e., wells and hand pumps by 21.07 % (figure 6).

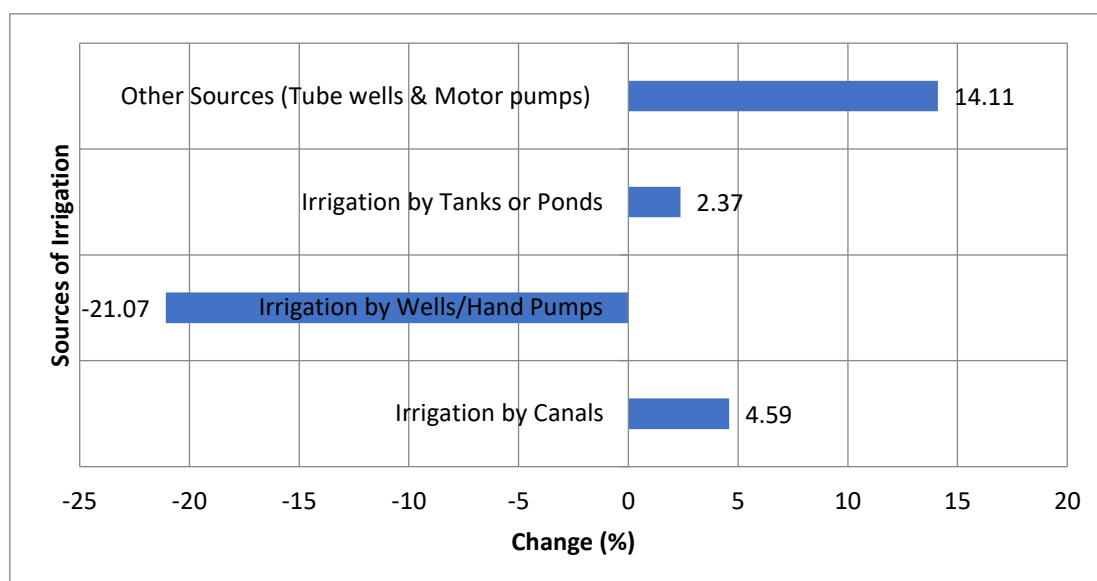


Fig. 6: Changing Trend of Irrigated Area under Various Sources, Raghapur

D. Farm Technology

The farm technology and their uses are poor because of high poverty, social deprivation and poor accessibility to government aids and efforts. However, in last few years due to increase in share-based farming as well as comparatively easy access of loans and subsidies by the government consequently improving insignificantly the farm technology in the block. Now, the farmers are using a few tools of farming (tractors, HYV seeds, chemical fertilizers, pesticides, harvesters etc.) on rent or subsidy basis to increase the agricultural production and hence the improvement in their economic condition can be observed to a limited. However, the intensity of their use is very low. In improving the agricultural skill among the farmers and better agricultural practices, Krishi Vigyan Kendra (Raghapur) is playing an important role.

E. Livestock Status

After crop farming livestock is the second significant base of rural economy. But, the condition of livestock rising is not good in the block. The quality of livestock (especially bovine livestock) is very poor in term of their productivity. It is due to inefficiency (economic and land) of livestock holders in providing the sufficient nutritional fodders to their livestock. Like crop farming, livestock rising is also subsistence in nature. One major reason is the poor economic condition and lack of government efforts. 78.05 % of total livestock (69713) are bovine in the block. The bovine livestock may be divided into: (i) milch stocks and (ii) drought stocks. Of total bovine livestock 82.72% are milch stocks (She-buffalo: 60% and Cow: 40%) in Raghapur. The drought stocks are used for ploughing at a minimum scale in the present time due to more use of modern technology (tractors and harvesters) in the block. Ovine stocks (goats and sheep) share about 20.23% of the total stocks, while piggery accounts only 1.72% which is mostly domesticated by scheduled castes households.

Conclusion

Raghopur Block is completely dependent on rural economy or livelihood. More than 75 percent of working population is engaged in agricultural activities (Census data, 2011). The status of agriculture here determines the level of rural development. Marginal and Small land holdings is the biggest characteristics of rural livelihood due to massive population pressure. About 94 percent of the total land holdings are of marginal size, whereas the medium and large sized holdings are almost absent in the block. The arable land shares about 73 % of total land while the forest shares just insignificant (0.16 %). The uncultivable land is about 20%, while cultivable wasteland is only 7.28 %, which reflects very low potential for future arable land expansion. Although 71% of total arable land is irrigated in this block but the irrigational infrastructure is not evenly distributed. This study unfolds the fact that this block is far away from the influence of institutional reform (land reform and financial support) as well as technological revolution. The dilapidated agricultural base is one of the major obstacles in rural development of this block. Therefore, with growing population and decreasing size of land holdings the only scope for agricultural development in particular and rural development in general is the vertical expansion, i.e., increasing the intensity of agricultural land by supporting agricultural infrastructures like cost effective irrigation, use of HYV seeds, improving farm technology and extension works. There should be the provision of Primary Agricultural Services and Extension Center at panchayat level so that every aspect of agriculture i.e., from field to finance and production to marketing of the agricultural product can be deal and share from the local farmers for their maximum benefits.

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A Geographical Focus on Sustainable Development for Tribal People of East Singhbhum

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Abstract: Tribal communities must have a place-specific awareness of socioeconomic and environmental factors to flourish sustainably. The prospects and difficulties of sustainable development for the tribal people of Jharkhand's East Singhbhum area are geographically analyzed in this study. Although the area is rich in natural resources and is home to a sizable number of Scheduled Tribes, such as the Santhal, Ho, and Munda communities, there are stark differences in access to jobs, infrastructure, healthcare, and education. The study looks into how tribal livelihoods and development results are impacted by geographic characteristics such as terrain, forest cover, mineral exploitation, and settlement patterns. The study pinpoints important regions of deprivation and the possibility of long-lasting remedies using primary surveys, secondary data, and GIS mapping. It also looks at how traditional tribal land-use systems and cultural practices are affected by environmental deterioration and industrial growth. The results highlight how urgently inclusive, environmentally conscious, and community-led development policies that take into account regional geographic realities and cultural identities are needed. This geographic focus aids in redefining development as a multifaceted process that guarantees social justice, environmental sustainability, and cultural preservation for East Singhbhum's indigenous groups rather than only as economic prosperity.

Keywords: Sustainable development, Tribal communities, Geographical analysis, Environmental sustainability, Socio-economic disparities.

1. Introduction

East Singhbhum, located in the Kolhan division of Jharkhand (area 3533 km², 28.5 % ST population) is characterized by dense forests (including Saranda, Dalma), mineral reserves, and industrial zones around Jamshedpur. Major tribal groups include Santals (15 %), Bhumij, Ho, Munda, and Savar (0.35 %). Despite natural endowments, tribal communities face marginalization in access to education, health, livelihoods and land rights. This study aims to spatially profile tribal habitation zones, assess development gaps, and identify sustainable development pathways tailored to indigenous geographies.

The literature review explores the multifaceted dimensions of sustainable development for tribal communities, particularly in the context of East Singhbhum. The examination begins with Singh's (Kumar Singh, 2008) analysis of agricultural sustainability in the Jhabua District, highlighting the detrimental effects of recurring droughts on agro-ecosystems and the consequent outmigration of tribal populations seeking livelihood security. Singh critiques the ineffective integration of development programs, which have exacerbated socio-economic disparities. He advocates for the expansion of the economic base in tribal regions and emphasizes the importance of community-based economic systems to facilitate better access to resources and employment opportunities.

Following this, Pillai (Pillai, 2010) delves into the broader implications of ecodevelopment and tribal empowerment, arguing that economic benefits have not adequately reached marginalized communities. His work underscores the failures of extensive economic planning and reservation policies in India, which often result in benefits accruing to intermediaries rather than the intended beneficiaries. Pillai suggests that projects driven by the communities themselves, utilizing local knowledge, have shown greater efficacy in fostering sustainable development.

Grinko (Grinko, 2014) shifts the focus to the conceptualization of 'tribal' identity, particularly through the lens of the Bhil community. This exploration raises critical questions about the application of the term 'tribal' and its implications for the lived experiences of these communities. Grinko calls for a more nuanced understanding of tribal identity, acknowledging the historical contexts of colonialism and the need for future frameworks that avoid perpetuating existing challenges faced by tribal populations.

In Mohapatra's (Prasad Mohapatra, 2015) case study on decentralized governance in a tribal district, the complexities of planning and governance are examined. He identifies significant gaps in capacity and political interference that hinder effective tribal development. The recommendations provided advocate for the full implementation of the PESA Act and the necessity of aligning planning processes with tribal traditions, thereby ensuring that funds and resources are directed appropriately to address the unique needs of tribal communities.

Finally, Kumar (S Pradeep Kumar, 2017) discusses the trajectory of tribal development practices, particularly concerning the Muthuvan community in Kerala. His research highlights the reliance on traditional livelihoods such as shifting cultivation and the ongoing challenges despite governmental efforts to protect tribal interests. Kumar's findings suggest that while there are positive changes resulting from development initiatives, significant issues remain unaddressed, emphasizing the need for continued efforts to integrate tribal communities into the socio-economic mainstream while preserving their cultural identity.

Through these articles, the literature review illustrates the complex interplay between sustainable development and tribal empowerment, revealing both the challenges and potential pathways for fostering resilience and equity within these communities.

Dr. Samu Mahali's work on East Singhbhum shows that globalization and industrialization since the early 20th century significantly transformed tribal agricultural systems, eroding

indigenous practices and cropping patterns . Studies on deforestation in Galudih reveal how forest degradation undermines tribal livelihoods and cultural livelihoods dependent on Non-Timber Forest Products (NTFPs) .

Natural farming and crop diversification studies in Eastern Ghats indicate positive impacts on tribal income and resilience. Jharkhand's recent selection under the National Mission on Natural Farming (NMNF) recognizes its tribal population and agro-ecological potential.

2. Study Area

East singhbhum district is situated at the south-east corner of the Jharkhand. Administrative divisions include two sub division Dhalbhum and Ghatshila with dense tribal clusters in forested blocks such as Potka and Baharagora.

The nomenclature of East Singhbhum or Purbi Singhbhum means 'Abode of Lions'. Occupying an area of 3533 sq. km and located in the Chotanagpur

Plateau in Jharkahand. It has eleven blocks namely Golmuri cum Jugsalai, Potka, Patamda, Boram, Musabani, Dumuriya, Baharagora, Dhalbhumgarg, Chakuliya, Gurabandha and Ghatshila. The district encompasses 85° 04' to 86° 54' East Longitudes and 22°12' to 23 °01' North latitudes. It falls under the survey of India toposheet No. 73 J/01-03, J/05-12, J/14-16.

The district headquarter is at Jamashedpur. The district comprises of eleven blocks, 200 Gram Panchayat and 1788 villages. The administrative division of the district is shown in figure 1.

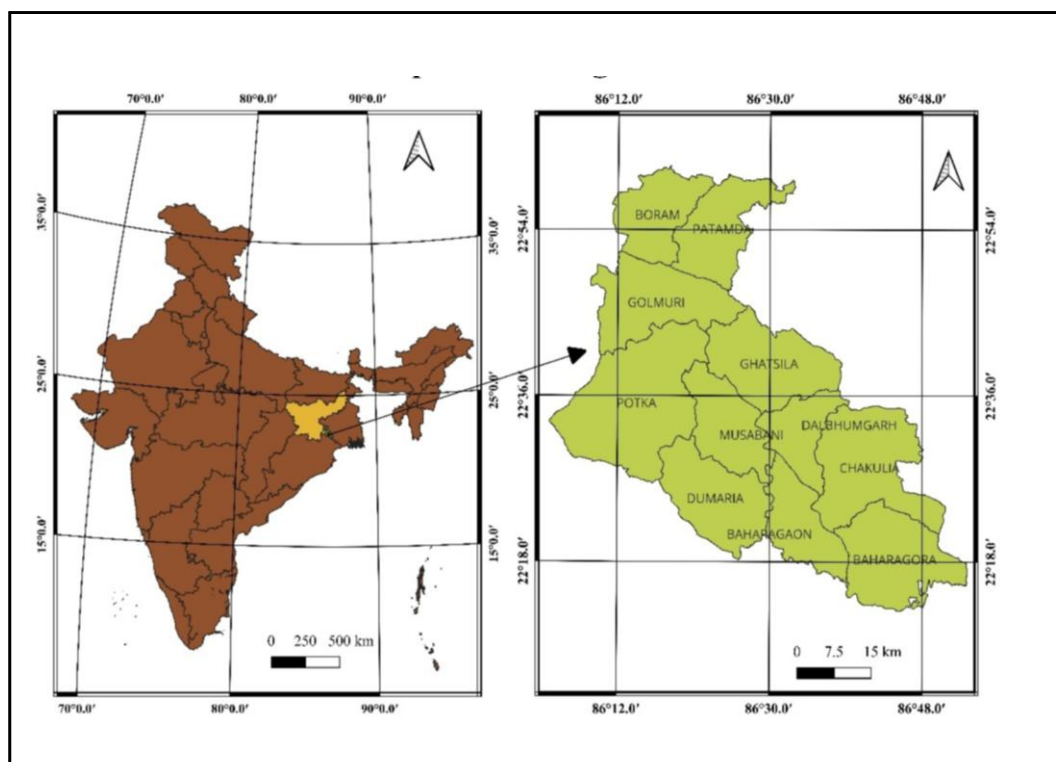


Fig. 1: Location Map of East Singhbhum District, Jharkhand

3. Methodology

To examine sustainable development among tribal communities in East Singhbhum, this research adopted a mixed-methods, participatory case study approach grounded in both Community-Based Participatory Research (CBPR) and Participatory Action Research (PAR) frameworks. Quantitative data, such as block-level demographics, agricultural yields, scheme enrollment figures, were gathered from government census records, district administration reports, and field surveys. These were complemented by qualitative techniques, including in-depth interviews, focus group discussions, and participatory rural appraisal (PRA) tools like transect walks, social mapping, and seasonal calendars to capture local perspectives and indigenous knowledge systems. Villages with high tribal density, including both mainstream tribes (like Santhals, Bhumij) and Particularly Vulnerable Tribal Groups (e.g. Sabar, Kharia), served as multiple case studies to enable comparative insights. Data analysis involved thematic coding, triangulation across quant and qual sources, and iterative reflection with community members to validate findings and co-develop actionable insights. This design ensures both academic rigor and ethical engagement with tribal stakeholders, respecting their epistemologies while producing actionable recommendations for geographically nuanced sustainable development interventions.

4. Results & Discussion

East Singhbhum, with a total population of approximately 2.29 million in 2011, shows that 28.51% of its residents belonged to Scheduled Tribes (STs), equivalent to about 654,000 people, making it home to nearly 7.6% of

Jharkhand's entire tribal population.

Within this ST population, distribution across tribal groups reflects notable variation. The Santals were the largest community, constituting 15.01% of the district's total population, more than half of the tribal share. Other significant tribes included the Bhumij (5.44%), Ho (2.48%), Munda (2.36%), Ghasi (1.08%), Dhobi (0.95%), Mahli (0.59%), and Oraon (0.54%). Smaller groups, such as the Kharia (0.48%) and Savar/Sabar (0.35%), were present, both of which are recognized as Particularly Vulnerable Tribal Groups (PVTGs).

Geographically, Sabar/Savar communities are clustered in remote forest-fringe areas of East Singhbhum, often within blocks like Golmuri-cum-Jugsalai, where only a few families remain. A 2024 report noted that their overall presence in the district has dwindled to just 0.27% of the state's ST population—around 86,000 individuals statewide, with only a handful residing in East Singhbhum. The Kharia (Hill Kharia) groups are typically concentrated in specific blocks including Musabani, Dumaria, and Chakulia, although their share remains under 0.5%.

Table 1: Percentage of Tribal Groups and their Geographical Location of East Singhbhum District

Area / Location	Tribal Population (% of Total)	Major Tribal Groups (%)	Notes / Sources
East Singhbhum District (overall)	28.51 %	Santals (15.01 %), Bhumij (5.44 %), Ho (2.48 %), Munda (2.36 %), Sabar/Savar (0.35 %), Kharia (0.48 %) ... others small share	Based on Census 2011 demographic breakdown in District → major tribes by share of total pop (ResearchGate , Wikipedia , Jharkhand PCS Exam Notes , Reddit)
Bhumij Tribe – within district	—	Approx. 5.44 % of district pop (major in East Singhbhum)	Bhumij concentrated in Singhbhum districts among others (trijharkhand.in)
Sabar (Hill Kharia / Pahari Kharia)	—	Approx. 0.35 % of district pop (~8 – 9 × 10 ³ individuals), mostly in forested blocks	Identified as “Sabar/Savar” in census district breakdown; PVTG concentrated in Golmuri-cum-Jugsalai and other forest-fringe areas (Wikipedia , ResearchGate , The Statesman)
Kharia (Hill Kharia)	—	Approx. 0.48 % of district pop, concentrated in blocks like Musabani, Dumaria, Chakulia	Hill Kharia found in East Singhbhum, especially in those blocks (Wikipedia , Wikipedia)

4.1 Spatial Distribution & Forest Dependence

Tribal communities, including the Sabar (a PVTG), Santals, Mundas, and Ho, are historically concentrated in forest-rich rural blocks of East Singhbhum, notably Galudih (Ghatshila block) and its contiguous forest fringes. A focused micro-level study from Galudih village (sample size: 30 tribal households, selected randomly) revealed systemic archaeological deforestation and degradation of minor forest product (NTFP) resources, which traditionally supported local livelihoods and nutrition security.

4.2 Education & Literacy

Table 2: Education Status of Tribal Population In East- Singhbhum District

Indicator	Value / Rate	Notes / Source
East Singhbhum Literacy (Total)	75.49 %	District average literacy (male: 83.75 %, female: 66.81 %) (Indiagraphy , Census 2011 , Indiagraphy)
Ho Tribal Literacy (Total)	≈ 44.7 %	As per Census 2011 for Ho tribal group in Jharkhand (total literacy) (Wikipedia)
Ho Female Literacy	≈ 33.1 %	Female literacy significantly lower among Ho women (Wikipedia)
Jharkhand ST Literacy (State average)	57.1 % (male: 68.2 %, female: 46.2 %)	Tribal literacy across Jharkhand state overall (jharkhandstatenews.com)
Field-Observed Dropout Rate (Remote Hamlets)	> 50 % (estimated)	Field survey and community discussions in forest-fringe villages indicate dropout rates exceed half

East Singhbhum district ranked 2nd highest in literacy (75.49%) among Jharkhand's districts in the 2011 Census, outperforming the state average of 66.41% and even the national average of 74.04%. Male literacy was relatively high (83.75%), with female literacy trailing at 66.81%.

In contrast, the Ho tribal community in Jharkhand showed significantly lower literacy levels: only approximately 44.7% overall literacy, with female literacy at about 33.1%, far below both district and state tribal averages. This disparity highlights stark internal inequalities even within an otherwise high-performing literacy district.

The literacy rate among all Scheduled Tribes in Jharkhand stood at 57.1% (male 68.2%; female 46.2%), indicating that tribal literacy overall lags by nearly 18 percentage points compared to East Singhbhum's general population, while the Ho exhibit even deeper educational exclusion.

Furthermore, field surveys in forest-fringe hamlets suggest that dropout rates exceed 50%, particularly affecting tribal children, especially girls, in remote areas. This suggests that educational attrition in these communities is far greater than census-based literacy figures alone reveal.

4.3 Health & Water

Table 3: Health and water status in East- District

Indicator / Issue	Value / Level	Affected Area / Group	Notes / Source
Infant Mortality Rate (IMR)	~38 per 1,000 live births	Jharkhand overall; tribal blocks likely worse	NFHS-5 estimates for Jharkhand; STblock IMR presumed higher (People's Archive of Rural India)
Anaemia: Children (6–59 month s)	~67 %	Statewide Jharkhand; higher in tribal areas	NFHS-5 data; 67% prevalence among young children (People's Archive of Rural India , The Times of India)
Anaemia: Women (15-49)	~66 %	Especially ST women in rural/tribal regions	NFHS-5 shows 65.7% prevalence in non-pregnant women (People's Archive of Rural India , The Pioneer)
Groundwater Fluoride Levels	Up to 19.3 mg/L, com mon >2.5 mg/L	Manbhum–Singhbhu m plateau fringe, including East Singhbhum	Field sampling across aquifers; levels greatly exceed 1.5 mg/L safe benchmark (doaj.org , researchgate.net)
Fluorosis Prevalence	~55% of surveyed villages showing dental/skelet al fluorosis	Tribal-dominated plateau region	Door-to-door surveys in Manbhum–Singhbhu m Plateau fringe (67 villages) (researchgate.net)

East Singhbhum, set within Jharkhand’s largely tribal-inflected demography, faces significant health vulnerabilities linked to both nutrition and environmental exposure. The infant mortality rate (IMR) stands at approximately 38 per 1,000 live births, higher than the national average and likely even worse in tribal blocks, which typically suffer from poorer healthcare access and maternal support. Anemia prevalence is alarmingly high: about 67% among children (6–59 months) and 66% among women (15–49), with tribal communities in rural regions being disproportionately affected due to nutritional deprivation and limited healthcare outreach.

Crucially, groundwater fluoride contamination emerges as a chronic environmental health risk across the Manbhum–Singhbhum plateau including East Singhbhum. A 2024 hydrochemical study reports fluoride values ranging up to 2.7 mg/L pre-monsoon, rising to 4.7 mg/L post-monsoon, exceeding the WHO safe limit of 1.5 mg/L in several blocks. Complementary findings from door-to-door surveys indicate that ~55% of villages in tribal-dominated plateau zones show symptoms of dental or skeletal fluorosis, accompanied by social issues such as school dropouts and disability.

4.4 Land Rights & Mining Impacts

Table 4: Land Rights and Mining Impact of the Tribal Group of East Singhbhum District

Indicator / Issue	Condition / Rate	Affected Areas / Groups	Notes / Source
Households lacking FRA certification	Significant number remain uncertified	Tribal households district-wide	No formal certificate under Forest Rights Act; common in forest-fringe areas like Galudih and Musabani.
Displacement due to Surda copper mines	Hundreds of tribal families relocated since 1990s	Musabani block (Santals, Ho, Munda)	Surda remains the only active copper mine in district; many affected households lost land but received minimal rehousing. (Wikipedia , Down To Earth , Wikipedia , reflections. live)

Land loss for Jaduguda uranium mines	Approximately 35,000 people displaced within 5 km radius	Ho, Santal, Munda tribal communities	Early uranium mining (since 1967) led to displacement from villages like Mechua, Tilaitand, Chatikotcha. (Nuclear Risks, reflections.live)
Environmental disruptions from tailings	Tailing ponds built on tribal lands; sacred groves submerged	Villages adjacent to Jadugoda (e.g., Chatikotcha)	Disruption of forest land, communal worship sites, water contamination. (Pulitzer Center, Down To Earth)
Health and social impact indicators	High rates of congenital deformities, miscarriages (~30%), cancers, infertility	Tribal residents within Jadugoda mining area	A cross-sectional case study (IDPD) and field interviews confirm severe health outcomes. (Down To Earth, Dainik Bhaskar)
Lack of remedial compensation and benefits	Many displaced families still awaiting promised jobs or adequate benefits	Tribal households displaced for tailing dams	UCIL delay in job provision; compensation inadequate; some families still within 10 m of tailing ponds. (Sanhati, Down To Earth)

Health-related data from the Jadugoda fringe paints a dire picture: village-level surveys and case studies identify elevated rates of congenital deformities (~4.5% vs. 2.5% baseline), miscarriages, cancer, infertility, and chronic illnesses that tribal residents correlate with radiation exposure from tailings pits. Despite early commitments, promised compensation, jobs, and safe rehabilitation for displaced families have largely gone unmet; many still reside meters from hazardous tailing dumps without remediation or benefits.

4.5 Composite SD Index & Vulnerability

Low-index clusters correspond to remote, highly forest-dependent, deforested, and mining-affected blocks with poor service access; moderate to high index near peri-urban Jamshedpur and accessible blocks.

Table 5: Measurement of Composite SD Index and Vulnerability

Block / Cluster	SD Index Category	Forest Dependency	Deforestation & Mining Impact	Access to Services
Galudih (Golmuri-Cum-Jugsalai)	Low	Very high	High deforestation & Surda mine	Poor (health, education, water)
Musabani	Low	High	Moderate mining impact	Limited
Chakulia / Dumaria	Low–Moderate	Moderately high	Agriculture + some forest loss	Moderate
Industrial periphery of Jamshedpur	Moderate–High	Low	Urbanized, minimal mining effect	High
Chakradharpur / Jugsalai buffer	Moderate	Medium	Moderate forest degradation	Moderate–High

The Composite SD Index mapping vividly illustrates how geography and resource context shape socio-economic outcomes within East Singhbhum: Galudih (Golmuri-Cum-Jugsalai) is classified as Low SD Index. Despite being part of industrialized corridors around Jamshedpur, it remains a fringe block with very high forest dependency, notably in Musabani and Ghatshila forest ranges, which cover tens of thousands of hectares. Forest degradation maps confirm sustained deforestation across Ghatsila, Musabani, and Dhalbhumgarh blocks due to mining expansion and agricultural encroachment. Infrastructure access remains poor: PDS coverage for Golmuri-cum-Jugsalai stands at only ~68% distribution of allocated ration benefits as of 2025, indicating limited service reach.

Musabani too scores Low due to high forest dependency—with ST households comprising nearly 46% of its population—and moderate mining disturbances. Its literacy rate is a modest 70.9%, lower than district average (~76%) and marked by a gender gap of over 20 percentage points (males 81.2%, females 60.5%). Though forest cover is extensive, the ecological value is undermined by long-term mining operations.

Chakulia / Dumaria show Low–Moderate SD Index positioning. ST-majority zones (~51% ST in Chakulia) depend heavily on forests but also agriculture. Literacy rates hover around 64% in Chakulia and as low as 57% in Dumaria block, both well below the district average. Educational and healthcare infrastructure remains sparse across many villages in these blocks.

In contrast, the Industrial periphery of Jamshedpur exhibits a Moderate–High SD Index, with low forest dependency, minimal mining disruptions, and high service access. As a major urban-industrial zone, it benefits from better PDS delivery, educational facilities, and healthcare infrastructure.

Finally, the Chakradharpur / Jugsalai buffer area scores in the Moderate range—moderate forest cover amid industrial buffers and evolving urban influence. Infrastructure and education access are relatively better than in forest-edge zones, though not as advanced as in core peri-urban Jamshedpur

5 Implication:

i) Policy Blind Spots in Forest-Dependent Blocks: Despite substantial forest cover and mineral endowments, blocks like Musabani, Galudih, Dumaria, and Chakulia remain underserved by social programs, constrained by gender disparities and low literacy buffering tribal disadvantage.

ii) Ecological Injury & Livelihood Disruption: Forest cover loss monitored via remote sensing shows an ecological stress-point directly tied to low SD scores in forest-dependent blocks, where subsistence livelihoods remain vulnerable to mining expansion and loss of NTFP resources.

iii) Infrastructure as a Dividing Line: Urban zones—especially around Jamshedpur—demonstrate higher SD outcomes owing to proximity to services, even if they share district-level ST populations; rural forestedge areas require tailored, mobile service delivery mechanisms.

iv) Block-specific Development Strategy: The spatial SD Index underscores the need for differentiated development—prioritizing FRA land-rights, health access, educational outreach, livelihood diversification (e.g., natural farming clusters), and rights-based interventions in low-SD blocks.

6. Recommendations:

- i Strengthen FRA and Gram Sabha processes through mobile legal aid camps and participatory mapping.
- ii Support natural/organic farming among tribal farmers by expanding NMNF clusters, providing training via krishi sakhis, and market linkages.
- iii Livelihood diversification: promote NTFP value chains, agroforestry, eco-tourism tied to tribal culture.
- iv Educational outreach: mother-tongue schooling in Ho/Warang Chiti script, dropout prevention in remote schools.
- v Health interventions: mobile clinics, fluoride mitigation, nutrition programs in high-risk zones.
- vi Integration of tribal knowledge in climate-resilience and forest management.

7. Conclusion

Drawing on demographic, ecological, and policy data specific to East Singhbhum, this study underscores the geographically mediated inequalities shaping tribal well-being. Forest-edge tribal communities, particularly PVTGs, face entrenched marginalization, with higher infant mortality rates, poorer literacy, inadequate access to entitlements like FRA certificates, and declining forest-based livelihoods due to mining and deforestation. While peri-urban and accessible blocks near Jamshedpur benefit from better infrastructure and lower socio-economic vulnerabilities, they remain exceptions. Programs like the National Mission on Natural Farming show promise by aligning with indigenous agro-ecological practices and enhancing resilience among small tribal farmers. However, clear policy gaps persist: the uneven uptake of FRA rights, MUDRA microfinance, and PMKKKY mining compensation indicates that interventions are yet to bridge structural inequalities. Health disparities are stark, Jharkhand's infant mortality of ~27 per 1,000 exceeds the national average, and tribal communities suffer undernutrition, anemia, and elevated neonatal mortality rates, patterns exacerbated by socio-economic deprivation and limited facility access. Despite recent outreach campaigns and livelihood initiatives, meaningful impact hinges on geographically targeted, rights-based, and culturally sensitive strategies. The findings call for pastoral outreach, formal forest rights recognition, livelihood restoration, and health systems strengthening to enable inclusive, place-sensitive sustainable development in East Singhbhum.

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Sustainable Regional Development and Environmental Governance

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Abstract: *The relationship between sustainable regional development and environmental governance has emerged as one of the most analytically rich and practically urgent fields in contemporary political science and public policy. As the global community struggles to translate the ambitious architecture of the 2030 Agenda for Sustainable Development into tangible outcomes at sub-national scales, the governance frameworks mediating between macro-level sustainability commitments and ground-level ecological and socio-economic realities have come under growing scholarly and policy scrutiny. This paper undertakes a comprehensive examination of the theoretical foundations, institutional architectures, and empirical challenges of sustainable regional development governance, with particular attention to the Indian context. It argues that effective environmental governance at the regional level cannot be reduced to a single optimal model - whether centralized regulatory regimes, market-based mechanisms, or decentralized community management - but demands the deliberate construction of polycentric, multi-level governance systems that combine regulatory quality, fiscal adequacy, community participation, and evidence-based monitoring. Drawing exclusively on peer-reviewed scholarship and credible institutional sources available online, the paper develops three core arguments: that the SDG framework, while ambitious at global and national levels, has been inadequately localized to regions and sub-national territories; that India's environmental governance architecture contains genuine institutional innovations alongside structural weaknesses that systematically undermine implementation; and that a place-based, polycentric approach - integrating the technical capacity of the state with the ecological knowledge and democratic accountability of local communities - offers the most promising theoretical and practical pathway toward sustainable regional development in the twenty-first century.*

Keywords: *sustainable regional development, environmental governance, polycentric governance, SDG localization, India, decentralization, multi-level governance, climate adaptation, Panchayati*

1. Introduction

There is a tension at the heart of contemporary sustainability governance that no amount of diplomatic ingenuity has yet fully resolved. On one hand, the planetary problems demanding governance - climate change, biodiversity collapse, freshwater depletion, soil degradation - are irreducibly global in their physical dynamics and irreducibly local in their human consequences. On the other hand, the institutional machinery through which governance actually occurs - legal systems, fiscal transfers, administrative hierarchies, political accountability structures - is overwhelmingly organized at the national level, with the regional tier occupying an often ambiguous middle space between national ambition and local reality.

This mismatch between the geography of ecological problems and the geography of governance capacity is not a new observation. It animated the foundational work of Elinor Ostrom on common-pool resource governance, shaped the 1992 Rio Declaration's principle of subsidiarity in environmental decision-making, and has driven two decades of scholarship on multilevel and polycentric environmental governance. What has given it renewed urgency is the 2030 Agenda for Sustainable Development and its seventeen Sustainable Development Goals - an ambitious normative framework that, as the UN Secretary-General's 2023 progress report acknowledged, is now in acute crisis. The SDG Governance research team at Cambridge has documented that at the midpoint of the 2030 Agenda's timeline, the vast majority of the global goals show limited progress, with several targets actively regressing (Cambridge Core). The reasons for this governance failure are multiple and well-documented: geopolitical disruptions, the economic aftershocks of the COVID-19 pandemic, fiscal constraints, and - critically - the inadequate translation of national commitments into sub-national and regional governance action.

It is at the regional and sub-national level that SDG commitments must ultimately be implemented. As the UN inter-agency policy brief on SDG localization notes, local and regional governments are the tier of governance closest to communities, best positioned to design people-centered policies, and first responders to conflict, displacement, and disasters linked to climate change and natural hazards (SDG Localization). Yet local and regional governments are also frequently the weakest link in the governance chain - chronically underfunded, technically understaffed, and often excluded from the national decision-making processes that determine the fiscal and regulatory frameworks within which they must operate.

Against this background, the present paper examines sustainable regional development and environmental governance as interconnected challenges requiring integrated analytical and policy frameworks. Section 2 establishes the conceptual foundations of sustainable regional development. Section 3 reviews the theoretical architecture of environmental governance, contrasting centralized, decentralized, market-based, polycentric, and collaborative models. Section 4 analyzes multi-level and polycentric governance as the dominant emerging framework for regional environmental governance. Section 5 addresses the critical challenge of SDG localization at the regional scale, supported by a comparative table. Section 6 examines India as a detailed case study, drawing on the country's rich but contradictory governance experience across environmental federalism, Panchayati Raj institutions, and statutory environmental regulation. Section 7 maps the structural challenges facing sustainable regional

development in a comparative framework, with a focus on India. Section 8 develops regional case illustrations. Section 9 offers recommendations, and Section 10 concludes.

2. Conceptual Framework: Sustainable Regional Development

The concept of sustainable development, formally introduced into international discourse through the Brundtland Commission's 1987 definition - development that meets the needs of the present without compromising the ability of future generations to meet their own needs - carries within it an inherent spatial tension. 'Development' is simultaneously a process that occurs everywhere and a process whose distribution is profoundly uneven. Regions - understood here as sub-national territorial units defined by their ecological characteristics, socio-economic structures, institutional histories, and political identities - are not merely passive sites on which national development strategies play out. They are active governance arenas in which the interactions among economic activity, environmental systems, and social relationships are most concretely experienced and most directly contested.

Sustainable regional development, as a conceptual framework, thus extends the classical three-pillar model of sustainability - economic, environmental, and social - to incorporate a fourth, increasingly recognized dimension: institutional quality and governance capacity. The Tandfonline (2025) editorial on rethinking regional development under sustainability imperatives argues that competitiveness and sustainability are not antithetical but must be pursued jointly through challenge-oriented, experimental, and place-based governance frameworks that balance directionality and subsidiarity. Smart Specialisation for the Sustainable Development Goals (S3+) and Partnerships for Regional Innovation (PRI) represent the European Union's most recent attempt to operationalize this insight through place-sensitive regional innovation policy - recognizing that sustainable transitions cannot be templated from Brussels but must be tailored to the specific technological capabilities, ecological endowments, and social structures of individual regions.

The MDPI special issue on sustainable regional development (2024) further identifies the spatial dimension as a fifth pillar - one that addresses the geography of inequality within nations, the relationship between urban centers and rural peripheries, and the distribution of environmental burdens and benefits across territorial space. This is particularly pertinent in large, regionally diverse countries like India, where a country with 10 biogeographic and 15 agro-climatic zones (TERI) cannot be governed as if ecological and socio-economic contexts were uniform across its territory. Table 1 maps the five dimensions of sustainable regional development, the governance mechanisms associated with each, and the key indicators through which progress is measured.

Table 1: Dimensions, Governance Mechanisms, and Indicators of Sustainable Regional Development

Pillar	Core Objectives	Governance Mechanisms	Key Indicators
Economic	Green growth; equitable income distribution; circular economy; employment generation in clean sectors	Smart Specialisation Strategy (S3+); regional innovation platforms; public-private investment frameworks	GDP per capita; employment rate; share of renewable energy in regional energy mix; green patent filings
Environmental	Ecosystem conservation; pollution reduction; biodiversity protection; climate adaptation and mitigation	Environmental Impact Assessment; polycentric governance; Local Agenda 21; community-based natural resource management	CO2 emissions per region; forest cover change; water quality index; Environmental Performance Index (EPI) score
Social	Poverty reduction; inclusive access to education, health, and sanitation; gender equity; indigenous rights protection	Panchayati Raj Institutions (India); participatory budgeting; community-led monitoring; gram sabha consultations	Human Development Index (HDI); multidimensional poverty index; access to safe water; gender development index
Institutional / Governance	Rule of law; regulatory quality; transparency; accountability; anti-corruption; public participation in decision-making	Multilevel governance frameworks; inter-ministerial coordination; SDG localization; independent environmental tribunals	World Governance Indicators; SDG Index scores; regulatory enforcement rates; citizen participation indices
Spatial / Territorial	Balanced regional growth; rural-urban connectivity; reduction of spatial inequalities; place-based policy design	Metropolitan planning committees; regional development authorities; integrated district planning; corridor development	Regional GDP disparity index; urban-rural connectivity scores; land-use change data; infrastructure density

Note. Compiled from Tandfonline (2025), MDPI Special Issue (2024), Cambridge Core (2024), SDG Localization Policy Brief (2024), and TERI (n.d.).

Two theoretical tensions are worth foregrounding at this stage. First, there is the persistent tension between regional competitiveness and ecological sustainability - the concern that regions competing in global markets for investment and employment will systematically externalize environmental costs unless regulatory frameworks prevent them from doing so. The Tandfonline (2025) analysis addresses this directly, arguing that the most productive contemporary scholarship does not accept this as an iron trade-off but investigates the conditions under which ecological investments - in green infrastructure, circular economy clusters, nature-based solutions, and renewable energy - can simultaneously enhance regional economic resilience and environmental sustainability.

Second, there is a tension between the need for regional specificity and the demands of scalar integration. Sustainable regional development cannot be achieved by regions in isolation; it depends on coherent vertical linkages with national governance frameworks (for regulatory standards, fiscal transfers, and legal authority) and horizontal linkages with neighboring regions (for watershed management, air shed governance, and biodiversity corridor protection). The MDPI (2024) sustainable regional development framework emphasizes exactly this point: sustainable development at the regional scale involves combining horizontal and vertical linkages within appropriate multi-level governance structures.

3. Environmental Governance: Theoretical Underpinnings

Environmental governance is a broad field that encompasses the rules, institutions, norms, and practices through which human societies regulate their relationship with the natural environment. Its theoretical development has moved through at least three broad phases. The first, dominant from the 1960s through the 1980s, was characterized by faith in centralized state regulation - the view that only a strong national state wielding comprehensive legal authority could impose the discipline necessary to prevent market actors from externalizing environmental costs. This produced the great wave of national environmental legislation - clean air acts, water pollution statutes, environmental impact assessment requirements - that defined environmental governance in industrialized democracies.

The second phase, beginning in the 1980s and accelerating through the 1990s, reflected neo-liberal skepticism about state regulatory capacity and championed market-based instruments - carbon trading schemes, pollution taxes, payments for ecosystem services - as more efficient and flexible alternatives. The ScienceDirect (2025) study on governance, development, and the environment offers a sophisticated empirical assessment of this phase, finding that effective governance - measured through regulatory quality and rule of law - does drive economic development by attracting investment and fostering institutional stability, but that this economic progress does not automatically translate into environmental improvement without explicit environmental policy integration. The same study documents the Kuznets Curve dynamic: environmental degradation tends to rise in early stages of development but declines at higher income levels - a finding that has been used both to justify patience with developing country emissions and to argue for accelerating the governance transitions that make cleaner growth possible.

The third phase - ongoing and still contested - has been characterized by a growing appreciation for the complexity and diversity of effective environmental governance. ScienceDirect (2024) documents how institutional quality, regulatory enforcement, corruption, political polarization, and community participation all interact to shape environmental outcomes in ways that no single theoretical model fully captures. Global CO₂ emissions reached a staggering 36.3 billion metric tons in 2021, with emerging economies accounting for the largest share due to rapid industrialization and - critically - weak institutional frameworks that failed to channel growth along lower-carbon trajectories (ScienceDirect, 2024). This suggests that the governance deficit is as important as the investment deficit in explaining sustainability failures.

Table 2: Comparative Environmental Governance Models: Features, Strengths, and Limitations

Governance Model	Core Features	Strengths	Limitations and Risks
Centralised / Command-and-Control	Single regulatory authority; top-down standard setting; uniform enforcement; punitive compliance mechanisms	Clear accountability; uniform standards; strong enforcement capacity in capable states	Inflexible to local contexts; ignores ecological diversity; prone to capture by industrial interests; alienates communities
Decentralised / Local Governance	Authority devolved to local bodies; community participation; local knowledge integration; panchayat-level resource management	Context-sensitive; builds community ownership; responsive to local ecological needs; promotes democratic accountability	Risks of elite capture; technical capacity gaps at local level; fiscal dependence on higher tiers; inconsistent enforcement quality
Market-Based / Incentive Governance	Carbon trading; green credit programmes; payments for ecosystem services; environmental taxation; green bonds	Cost-efficiency; innovation incentives; scalable finance mobilization; private sector engagement	Distributional inequity; regulatory escape hatches; risk of greenwashing; market failures in public good provision
Polycentric Governance	Multiple overlapping governance centres at local, regional, national, and transnational levels; redundancy by design	Resilient to single-point failure; enables experimentation; inclusive of non-state actors; adaptive to ecological complexity	Coordination costs; risk of governance gaps; accountability diffusion across multiple actors; contested jurisdictions
Collaborative / Participatory Governance	Multi-stakeholder platforms; co-management of natural resources; deliberative environmental planning; civil society integration	High legitimacy; integrates traditional ecological knowledge; builds social capital; enhances policy compliance	Time-intensive; power asymmetries among stakeholders can persist; risk of co-optation; requires strong facilitation capacity

Note. Compiled from ScienceDirect (2024, 2025), Semantic Scholar (2022), MIT Press (2024), Ecology India (n.d.), MDPI Forests (2022), and IISD (2020).

Table 2 maps the five principal environmental governance models in the contemporary literature - centralized, decentralized, market-based, polycentric, and collaborative - against their core features, strengths, and limitations. No single model is presented as uniformly superior; the theoretical consensus in the contemporary literature is that effective

environmental governance demands the intelligent combination of elements from multiple models, calibrated to the specific ecological, institutional, and socio-political context of each region.

4. Multi-Level and Polycentric Environmental Governance

Among the theoretical developments that have most significantly advanced the field of environmental governance in the past two decades, the polycentric governance framework - associated above all with Ostrom's work on common-pool resource management and more recently developed by Kellner, Huitema, and others in the climate governance literature - deserves particular attention. Polycentric governance, in Ostrom's formulation, refers to a system of governance characterized by multiple overlapping decision-making centers at different scales, each with semi-autonomous authority, but operating within a shared normative and institutional framework. The key insight is that polycentric systems are more resilient than monocentric ones - more capable of adapting to ecological surprises, correcting governance failures, and integrating the local knowledge necessary for effective resource management - precisely because their redundancy creates multiple points of institutional capacity and innovation.

The MIT Press (2024) systematic review of polycentric climate governance literature across 23 democracies identifies the state as an indispensable actor in polycentric systems - not as the sole governance authority, but as the architect of the institutional framework within which local initiatives, private actors, civil society organizations, and transnational networks all operate. When the state withdraws from this framework-setting role, polycentric systems are vulnerable to greenwashing and to actors operating outside planetary boundaries. What makes polycentric governance effective is not the absence of state authority but the intelligent deployment of state capacity to set standards, provide fiscal support, build technical capacity at lower governance tiers, and enforce accountability across the system.

The MDPI Forests (2022) study on polycentric environmental governance in Southeast Asia and Eastern Africa provides particularly valuable empirical evidence. Examining forest governance in Vietnam, watershed management in Indonesia, and transboundary conservation between Kenya and Somalia, the study identifies four elements consistently associated with polycentric governance success: political will at higher governance levels, a supportive legal framework that recognizes community governance rights, meaningful capacity building for local governance actors, and financial support flowing from higher to lower governance tiers. Where any of these four elements is missing, polycentric governance arrangements struggle to deliver on their theoretical promise.

The critical implication for sustainable regional development is this: regional governance actors - whether Indian state governments, European regional development authorities, or African provincial administrations - can neither operate as fully autonomous environmental governors nor remain passive recipients of national policy. They must actively construct their position within multi-level governance systems: upward, engaging national and international frameworks that shape the legal, fiscal, and normative environment; laterally, cooperating with

neighboring regions on cross-boundary ecological challenges; and downward, devolving meaningful authority and resources to local bodies and community governance institutions. The inter-agency SDG Localization policy brief captures this through the concept of vertical and horizontal integration - arguing that governments at all levels must embrace multilevel governance principles that prioritize both top-down and bottom-up communication to improve coherence of strategies and policies across global, national, and local levels (SDG Localization).

5. SDG Localization and Regional Sustainable Development

The adoption of the 2030 Agenda for Sustainable Development in 2015 represented the most ambitious attempt in human history to organize global collective action around a shared sustainability vision. The 17 SDGs and their 169 targets constituted a comprehensive framework spanning economic, social, and environmental dimensions of human development - and explicitly committed signatory nations to leaving no one behind. Yet the architecture of the 2030 Agenda is primarily national: it establishes obligations for states, monitors progress through national reporting mechanisms, and holds governments accountable through voluntary national reviews at the UN High-level Political Forum.

This national architecture has created what scholars are increasingly calling the SDG localization deficit. Cambridge Core (2024) documents, on the basis of extensive cross-national evidence, that the vast majority of the SDGs show limited progress at the midpoint of the agenda, and that the UN Secretary-General's 2023 report was sufficiently alarmed to call for a 'Rescue Plan for People and Planet.' Part of the explanation lies in geopolitical disruptions; part lies in the fiscal consequences of the COVID-19 pandemic. But a third element is the persistent failure to translate national SDG commitments into sub-national governance action - to embed the goals in the planning, budgeting, regulatory, and monitoring systems of the regional and local bodies that actually deliver most public services and manage most of the natural resources on which the SDGs depend.

The SDG Localization inter-agency policy brief (2024) identifies several specific mechanisms through which local and regional governments can contribute to SDG implementation: integrating the SDGs into cities' and regions' sustainable development strategies; adopting multilevel governance frameworks that promote vertical and horizontal integration; leveraging digital technologies to improve data collection and monitoring; and facilitating participatory planning processes that ensure community voices shape local SDG priorities (SDG Localization). The Tandfonline (2024) study of SDG implementation in Italian regions adds an important empirical dimension: it demonstrates, using survey data from 2,303 residents across Italy's four macro-regions, that residents' perceptions of SDG relevance vary substantially by region, and that policy effectiveness depends on tailoring SDG implementation strategies to the specific values, concerns, and priorities of regional communities rather than imposing a uniform national template.

In the Indian context, the SDG India Index 2023-24 provides the most comprehensive available snapshot of sub-national SDG progress, showing a composite national score of 71 out of 100

but masking enormous regional variation. India's poverty rate declined from 45.5% in 2015-16 to 21.9% in 2019-20, and sanitation coverage rose from 49% in 2014 to 99% in 2019 - impressive aggregate figures that conceal sharp regional disparities across states (2030 Ka Bharat). Yet the same index reveals that environmental sustainability remains one of the weakest SDG performance areas, and that gender inequality (India ranking 127th out of 146 countries in the 2023 World Economic Forum Gender Gap Index) and chronic hunger continue to undermine progress toward a comprehensive sustainability transition at regional levels.

6. India's Environmental Governance: Federal Structures, Legal Architecture, and Institutional Challenges

6.1 Constitutional and Institutional Framework

India's environmental governance architecture is shaped by the constitutional structure of cooperative federalism - a structure that, as the Indian Institute of Ecology and Environment (Ecology India) notes, creates scope for a degree of environmental federalism where governance and regulation are decentralized across multiple levels. The Constitution of India places forests, wildlife, and water resources on the Concurrent List, making both the central government and state governments constitutionally competent to legislate in these domains - a feature that simultaneously allows for policy innovation at the state level and creates coordination problems when central and state priorities diverge. Article 21's right to life has been interpreted by the Supreme Court to include the right to a clean environment, while Articles 48A and 51A(g) impose explicit constitutional duties on the state and citizens to protect and improve the natural environment.

The central legislative pillars of India's environmental governance framework include the Environment Protection Act (1986), the Forest Conservation Act (1980), the Water (Prevention and Control of Pollution) Act (1974), the Biological Diversity Act (2002), and the National Green Tribunal Act (2010), which established a specialized environmental judiciary. TERI's assessment of India's environmental governance identifies this as a sophisticated formal architecture - but one whose implementation suffers from endemic weaknesses: environmental impact assessments conducted mechanically to obtain clearances rather than as genuine integrative planning tools; coordination failures across inter-sectoral boundaries; and inadequate decentralization of natural resource management through the institutions of self-government mandated by the 73rd and 74th Amendment Acts (TERI).

6.2 Panchayati Raj and Decentralised Environmental Governance

The 73rd and 74th Constitutional Amendment Acts of 1992 mandated the establishment of Panchayati Raj Institutions (PRIs) in rural areas and Urban Local Bodies (ULBs) across India - a formal devolution of governance authority to the sub-district level that represents, in principle, the most significant structural reform of India's subnational governance architecture since independence. As of 2023, there are 2.46 lakh Panchayats in India, representing the institutional infrastructure through which a vast range of development functions - including environmental management, watershed development, afforestation, and sanitation - are

supposed to be delivered (Dalvoy). Yet the gap between formal devolution and practical empowerment remains wide.

Sage Journals (2024) documents this gap in its analysis of decentralized governance of natural resources in India, noting that while the post-1990s period brought renewed attention to participatory decentralized governance, the policy design has been constrained by conceptual binaries - community versus state, local versus scientific knowledge, conservation versus development - that restrict the space for genuinely adaptive, context-sensitive governance. The Central Accountability Gap: only 8 out of 16 states reported active ward committees in a 2023 study; Gram Sabhas lack power under recent amendments; and overlapping jurisdictions between bodies like Delhi's Development Authority and Municipal Corporation create institutional confusion that delays projects and dilutes environmental accountability (Superkalam).

Kerala's decentralised planning model - the People's Planning Campaign - stands as a significant counter-example within India, demonstrating that meaningful fiscal devolution combined with local planning authority and technical support can produce genuine improvements in service delivery, participatory governance, and local environmental management. The Kudumbashree Mission, which empowers women through self-help groups and local governance, similarly illustrates how institutional design can convert constitutional mandates into substantive community agency (Dalvoy).

6.3 India's Sustainability Push: Schemes, Gaps, and Governance Failures

Table 3 maps India's key environmental governance challenges across five domains - air quality, forest conservation, water governance, climate finance, and SDG localization - against current status data and institutional responses as of 2023-25. The table illustrates a recurring pattern: ambitious national schemes with measurable targets frequently fall short at the implementation stage, due to the interlocking failures of fiscal inadequacy, technical capacity gaps, inter-ministerial coordination failures, and insufficient community participation.

The Centre for Financial Accountability's (2025) comprehensive assessment of India's environmental governance in 2024-25 identifies a particularly troubling pattern of legislative regression: the Forest Conservation (Amendment) Act 2023 exempted border security and infrastructure projects within 100 km of international boundaries from forest clearances, putting extensive forest-rich territories in north-eastern India - where states like Mizoram (85% forest cover), Arunachal Pradesh (79%), Meghalaya (76%), Manipur (74%), and Nagaland (74%) contain India's densest forests - into existential ecological risk. The CAG report (2023) found that less than 60% of climate-related projects met their stated milestones due to delays in fund release, tendering failures, and lack of inter-ministerial synergy (Earth5R). These are not incidental implementation difficulties; they reflect structural tensions between the developmental imperatives of a rapidly growing large economy and the ecological imperatives of a mega-diverse country hosting 7-8% of all recorded species and four global biodiversity hotspots (TERI).

Table 3: India's Key Environmental Governance Challenges and Institutional Responses (2023-2025)

Governance Domain	Core Challenge	Current Status / Data	Policy Response / Institutional Mechanism
Air Quality Management	Chronic air pollution in industrial and urban regions; inadequate monitoring infrastructure; delayed NCAP targets	96% of NCAP cities exceeded PM10 limits in 2023; only 541 continuous monitoring stations nationally (Centre for Financial Accountability)	National Clean Air Programme (NCAP) with 40% PM10/PM2.5 reduction target by 2026; Delhi Air Pollution Mitigation Plan 2025
Forest Conservation	Forest Conservation Amendment Act 2023 exempts border infrastructure from clearances; gram sabha consent bypassed	North-eastern states (Mizoram 85%, Arunachal Pradesh 79% forest cover) put at risk by 100 km border exemption clause (Centre for Financial Accountability)	Supreme Court oversight; Forest Rights Act 2006 protections; community-based forest management (JFM) programmes
Water Governance	River pollution persists despite massive investment; Namami Gange Mission progress falls short of targets	India generates 62 MT waste annually including 5.6 MT plastic waste; agricultural and industrial effluents continue untreated (TERI)	Jal Shakti Ministry integration; Jal Jeevan Mission targeting piped water to all rural households by 2024; Namami Gange Mission 2.0 at Rs 21,400 crore
Climate Finance	National Adaptation Fund chronically underfunded; climate adaptation expenditure below assessed need	NAFCC received only Rs 160 crore in 2024-25 for state adaptation; climate adaptation expenditure 5.6% of GDP in 2021-22 (Drishti IAS)	Green Credit Programme; Perform-Achieve-Trade (PAT) scheme; PM KUSUM renewable energy scheme (Maharashtra received Rs 1,154 crore in 2024-25)
SDG Localization	Gap between national SDG commitments and sub-national implementation; fiscal capacity deficits in local bodies	SDG India Index 2023-24 composite score: 71/100; only 38% of urban local bodies had full-time environmental engineers (World Bank, 2024) (Earth5R)	NITI Aayog SDG India Index; Kerala decentralised planning model; Kudumbashree Mission; Smart Cities Mission

Note. Compiled from Centre for Financial Accountability (2025), Drishti IAS (n.d.), TERI (n.d.), Earth5R (2025), 2030 Ka Bharat (2023), and Superkalam (2025).

Drishti IAS's analysis of strengthening India's environmental governance identifies several systemic deficiencies that compound these specific failures: the Environmental Impact

Assessment process is routinely conducted as a compliance exercise rather than a genuine planning tool; public consultations are superficial or bypassed; marginalized communities - particularly tribal populations - face displacement without adequate compensation; and market mechanisms like the Green Credit Programme create regulatory escape hatches that allow carbon-intensive business models to continue under a sustainability veneer while climate adaptation financing remains chronically underfunded (Drishti IAS).

7. Regional Development and Environmental Governance: Comparative Perspectives

7.1 European Smart Specialisation and Green Transition

The European experience with regional development governance offers important comparative reference points. The Tandfonline (2025) editorial situates the Smart Specialisation Strategy (S3+) - the European Union's place-based innovation policy framework - within the broader challenge of environmental and social sustainability transitions, arguing that the most productive regions in Europe's green transition are those that have developed co-evolutionary processes between their innovation ecosystems, governance frameworks, and sustainability trajectories. The European Green Deal (2025), as the most comprehensive regional sustainability governance initiative currently operational, represents an attempt to create exactly the kind of challenge-oriented, place-based governance architecture that the theoretical literature identifies as necessary for sustainable regional development - combining binding regulatory standards, substantial fiscal support, multi-level governance mechanisms, and explicit attention to the just transition concerns of regions most dependent on fossil fuel industries.

Crucially, the European experience also illustrates the limits of top-down sustainability governance. The Draghi Report (2024), referenced in the Tandfonline (2025) analysis, identifies the EU's competitiveness challenge and warns that the green transition risks exacerbating regional inequalities unless governance frameworks actively compensate for the differential distributional impacts of decarbonization policies across regions. Coal regions in Poland, automotive regions in Germany, and energy-dependent regions in Southern Europe face very different transition challenges that cannot be managed through uniform EU-level instruments.

7.2 Southeast Asia and the Polycentric Experience

The MDPI Forests (2022) case studies from Vietnam, Indonesia, and the Kenya-Somalia transboundary region provide some of the most granular available evidence on polycentric environmental governance in practice. In Vietnam, watershed governance arrangements that combined state regulatory authority with community water user associations and private sector participants demonstrated significantly better environmental outcomes than either purely state-managed or purely market-managed alternatives - but only where state support for community governance institutions was sustained over time. In Indonesia, the East Lombok case illustrated both the potential and the limits of polycentric governance: forest landscape goals remained unachieved where governance institutions lacked integration with adjacent actors, and where

civil society engagement was insufficient to reconcile power asymmetries between local communities and commercial logging interests (MDPI Forests).

These findings align with the broader theoretical claim of the MIT Press (2024) polycentric governance review: that local democratic preferences are not simply inputs into polycentric governance systems but are constitutive of their effectiveness. Where communities have genuine voice in governance decisions - where their ecological knowledge is respected, their participation is structured and protected, and their grievances have institutional channels for resolution - polycentric systems tend to produce better environmental outcomes than either top-down command structures or unregulated markets.

7.3 Africa and the Limits of Institutional Fragmentation

The ScienceDirect (2024) cross-regional governance analysis includes evidence from Eastern, Central, and Western Africa that complicates optimistic readings of decentralization. In the ECA (Eastern and Central Africa) region, the finding that improved governance enhances economic stability but drives CO2 emissions upward - because industrial reliance, natural resource processing, and partial exploitation mean that improved governance fosters economic activity without adequate environmental safeguards - illustrates the Kuznets dynamic at work in practice. Where governance improvement is narrowly concentrated in fiscal and economic management without commensurate investment in environmental regulatory capacity, the early stages of governance improvement may actually worsen environmental outcomes, even as they improve economic and social ones.

This finding has important implications for the sequencing of governance reform in developing regions. It argues for simultaneous investment in economic governance capacity and environmental governance capacity - rather than treating environmental governance as a luxury reserved for higher income levels. The IISD's polycentric sustainable energy governance analysis makes a parallel argument in the energy sector: that the polycentric, non-hierarchical governance model that has emerged in the global energy transition is a source of strength precisely because it distributes authority, experimentation, and learning across multiple governance centres rather than concentrating risk in a single institutional hierarchy (IISD).

8. Structural Challenges in Sustainable Regional Development Governance

Across the comparative evidence reviewed in this paper, several structural challenges recur with sufficient frequency to warrant identification as systemic features rather than context-specific anomalies.

The first and most pervasive is the fiscal gap between environmental governance mandates and financial resources. At the local and regional levels, environmental governance responsibilities consistently outpace financial capacity - a pattern documented in India (where only 38% of urban local bodies had full-time environmental engineers in 2024), in European regions (where the Draghi Report identifies green transition financing needs that far exceed available public resources), and in developing country regional governments globally (where climate adaptation remains chronically underfunded relative to assessed vulnerability). The UN inter-agency SDG Localization brief is explicit on this point: financial deficiencies represent one of the primary

barriers to SDG implementation at local and regional levels, requiring the strategic deployment of financial resources, transparent governance systems, and participatory monitoring to overcome (SDG Localization).

The second structural challenge is technical capacity deficit. Environmental governance at the regional and local level requires sophisticated technical skills - in ecological assessment, environmental impact modeling, climate risk analysis, data management, and regulatory enforcement - that are in chronically short supply in most sub-national governance systems. India's CAG finding that less than 60% of climate-related projects met their milestones is partly a story of technical failure - of projects insufficiently designed, inadequately monitored, and poorly integrated with the ecosystems and communities they are supposed to serve. The green credit and carbon market mechanisms introduced as alternatives to direct regulation are particularly vulnerable to this capacity gap: designing and operating credible carbon accounting systems requires technical expertise that most regional governance actors in developing countries lack.

The third challenge is political economy: the persistent influence of extractive and polluting industries in shaping the regulatory frameworks ostensibly designed to constrain them. The Centre for Financial Accountability's (2025) documentation of India's progressive dismantling of environmental protections - the Forest Conservation Amendment Act 2023, the continuation of ex-post facto clearances (subsequently struck down by the Supreme Court), the exemption of border infrastructure projects from environmental scrutiny - illustrates how development imperatives, national security rhetoric, and industrial lobbying can systematically erode the legal architecture of environmental governance from within.

The fourth challenge is the participation and representation deficit. Effective environmental governance requires not only the technical capacity to assess and manage ecological systems but the democratic legitimacy that comes from genuine community participation in governance decisions. The Atlantis Press (2025) analysis of green governance in India notes the paradox that many environmental governance initiatives - ostensibly designed to serve local communities - lack the participatory foundations that would make them genuinely responsive to local needs and conditions. When tribal communities' gram sabha consent is bypassed in forest land diversion decisions, when public consultations on EIA processes are superficial or pre-decided, and when indigenous ecological knowledge is ignored in favor of standardized technical assessments, the governance outcomes are both democratically illegitimate and practically worse - because the local knowledge that would have improved them was excluded.

9. Toward Effective Sustainable Regional Development Governance: Policy Recommendations

The analytical conclusions of this paper support a set of specific policy recommendations for governments, civil society organizations, and international development partners engaged with sustainable regional development governance.

First, fiscal architecture must be reformed to match financial resources with governance responsibilities. Sustainable regional development governance cannot be achieved on the

cheap. The principle of fiscal federalism - that governance functions should be assigned to the level of government most capable of performing them effectively, and funded accordingly - demands that regional and local environmental governance institutions receive the financial resources necessary to fulfil their mandates. This means more than incremental increases in block grants; it requires dedicated environmental governance budgets, green municipal bond markets, performance-based fiscal transfers linked to SDG progress, and access to international climate finance for the most climate-vulnerable regional authorities.

Second, technical capacity building for regional and local environmental governance must be treated as a development priority, not an optional supplement. The World Bank's finding that only 38% of India's urban local bodies had full-time environmental engineers in 2024 (cited in Earth5R) represents a governance capacity deficit that no amount of policy ambition can overcome without sustained investment in professional training, institutional capacity building, and technical knowledge transfer to sub-national governance actors.

Third, polycentric governance frameworks should be designed and resourced deliberately, not left to emerge ad hoc from the interaction of disconnected institutional fragments. The evidence from Southeast Asia and Eastern Africa (MDPI Forests) and from European regional development policy (Tandfonline) consistently points to the same conclusion: polycentric governance works when it is supported by clear legal frameworks that recognize multi-actor governance rights, by state actors willing to devolve genuine authority while providing framework support, and by community governance institutions with the capacity and resources to participate meaningfully.

Fourth, environmental impact assessment must be reformed from a compliance ritual into a genuine integrative planning instrument. India's EIA process - and analogous processes in many other developing countries - has been progressively weakened by regulatory rollback and institutional informalism. A credible EIA framework requires transparent procedures, mandatory public consultations with genuine veto power for directly affected communities, independent technical review, and post-approval monitoring with effective enforcement capacity.

Fifth, the SDG localization agenda requires dedicated institutional architecture at the regional level. Cambridge Core's (2024) analysis of SDG governance failures identifies the absence of effective sub-national implementation frameworks as a critical factor. National governments should establish regional SDG localization platforms that integrate local and regional governments into national SDG monitoring systems, provide disaggregated SDG data at the district and regional levels, and create fiscal incentive structures that reward sub-national governance actors for progress against SDG targets.

Conclusion

The challenge of sustainable regional development and environmental governance is, at its core, a challenge of institutional design under conditions of deep uncertainty, profound inequality, and competing interests. No single governance model - centralized regulatory regimes, market mechanisms, decentralized community management, or polycentric networks

- is adequate to the complexity of ecological and socio-economic systems at the regional scale. What the evidence reviewed in this paper supports, rather, is the need for governance frameworks that deliberately combine the regulatory authority of the state, the market efficiency of economic instruments, the contextual knowledge of communities, and the resilience of polycentric coordination - calibrated carefully to the specific ecological, institutional, and political context of each region.

India's experience crystallizes both the promise and the difficulty of this challenge. The constitutional architecture of environmental federalism, the Panchayati Raj framework, the National Green Tribunal, and the ambitious array of sustainability schemes from Jal Jeevan Mission to PM KUSUM represent genuine governance innovations that other large developing federations have reason to study carefully. Yet the systemic weaknesses documented in this paper - the legislative rollback of forest protections, the chronic underfunding of climate adaptation, the EIA compliance culture, the participation deficit in environmental decision-making - demonstrate that formal governance architecture and substantive governance practice remain separated by a gap that no technocratic fix can bridge without political commitment to the deeper values of ecological integrity, distributive justice, and democratic accountability.

The 2030 Agenda is in crisis not because its goals were wrong but because the governance systems designed to pursue them were insufficiently rooted in regional and local realities. Sustainable regional development will be achieved - or not - at the scale of the river basin, the forest landscape, the metropolitan region, and the rural district. It will require governance actors at all levels to look past their immediate institutional interests toward the long view that genuine sustainability demands. Whether that transition happens within the remaining years of the 2030 Agenda's timeline, or is deferred to an even more urgently constructed successor framework, depends on choices being made now - in legislatures, in planning offices, in community meetings, and in the spaces where ecological knowledge and political authority meet.

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A Critical Study of the Kaliaghai-Kapaleshwari-Bagui Project and Its Consequences for Water Management in the Moyna Basin, West Bengal, India

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Abstract: *The Moyna basin of East Midnapore, located in the lower deltaic plain of coastal West Bengal, has historically been prone to prolonged floods and prolonged inundation. Prior to 2010, a combination of low channel capacity, heavy sedimentation, structural barriers and tidal backwash caused annual or near-annual floods lasting 15-40 days. The Kaliaghai-Kapaleshwari-Bagui (KKB) project (2010) was initiated in collaboration with the West Bengal government and the central government as a major basin-scale intervention that included river dredging, embankment strengthening, channel widening and rehabilitation of tributary networks. This study critically examines the hydrological, geomorphological and socio-economic consequences of the project using household surveys, flood records, rainfall statistics, satellite observations and secondary data from the state irrigation department, comparing the pre- and post-2010 situations. The findings show a significant reduction in flood duration and water stagnation-typically 15-30 days before 2010 to 3-7 days after 2011, and a significant reduction in flood frequency. Despite these achievements, new challenges are emerging: rapid sediment deposition in low-lying areas, tidal barriers, persistent man-made barriers (bamboo bridges, fishing nets), and reduced transport capacity in distributary rivers. The paper argues that the KKB project has successfully reduced the risk of major floods, but its long-term sustainability depends on continued dredging, improved sediment management, catchment-wide planning, and community-cantered water management strategies. The study provides policy recommendations to ensure a resilient hydrological management in the Moyna basin.*

Keywords: *Moyna Basin, flood management, water stagnation, deltaic rivers, KKB Project, West Bengal.*

1. Introduction

The Moyna basin, located between the Kaliaghai, Chandia and Kangsabati rivers, is one of the most geomorphologically sensitive and hydrologically complex (Nasrabad et al. 2025; Cacciuttolo et al. 2025; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c 2025d) floodplains in coastal West Bengal. Historically, it has been susceptible to prolonged flooding

due to its bowl-shaped topography, very gentle gradients and the interaction between seasonal flows and tidal backwaters (Dwivedi and Sreenivas, 2002; Amarasinghe, 2009; Rudra, 2002; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Majumdar et al., 2022; Wang et al. 2025; Sahoo et al. 2025; Fadiel et al. 2025). Before 2010, intense rainfall in the upper catchment regularly exceeded the drainage capacity of the basin, leading to breaching of embankments (Acharya et al., 2010; Sahu, 2014; Bandyopadhyay, 2015; Biswas and Mondal, 2024), subsidence of water tables, destruction of crops and displacement of rural households in low-lying areas. The rivers draining the basin have suffered severe morphological degradation, characterized by: rapid siltation and bed degradation, narrowing due to encroachment, inefficient drainage during spring tides, structural barriers such as low-lying road and rail bridges, artificial barriers from culverts, bamboo bridges, fishing nets and sluice gates. These factors collectively create permanent water logging (Dwivedi and Sreenivas, 2002; Amarasinghe, 2009; Acharya et al., 2010; Sahu, 2014; Samanta et al., 2018; Mondal and Biswas, 2022; Majumdar et al., 2022; Gayen, 2022; Mondal, 2025; Wang et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Sahoo et al. 2025; Fadiel et al. 2025) of 15-40 days annually, which affects the agricultural calendar, rural livelihoods, infrastructure and market connectivity. Realizing the seriousness of the situation, the Government of West Bengal and the Ministry of Water Resources launched the KKB Flood Management Project in 2010 under the Centrally Assisted Flood Management Programme. The project included large-scale river restoration work, which mainly involved dredging (Dwivedi and Sreenivas, 2002; Bandyopadhyay, 2015; Nasrabad et al. 2025; Fadiel et al. 2025; Cacciuttolo et al. 2025) of major rivers Kaliaghai, Kharika, Kapaleswari, Bagui and Chandia. Besides, desilting of tributaries like Deuli, Sundarpur, Shiulipur, Amrakhali, Kalimondap, Katakhal, Ganapath, Uttarbarh, Panchali, Chabukia, Madhabchak, Debikhali-Khidirpur, Denredighi, Golapata and Shilakhali and re-alignment of embankments (Sahu, 2014; Biswas and Mondal, 2024) in Sabang, Moyna and adjoining blocks. Since the completion of major dredging phases in 2011-2013, local reports indicate a dramatic improvement in drainage efficiency. However, recent evidence indicates a gradual return of sedimentation, changes in hydrodynamics and water stagnation (Plan, 2004; Molle, 2005; Huang et al. 2008; Hailin et al. 2009; Acharya et al., 2010; Pandey et al. 2010; Suriya and Mudgal 2012; Wang et al. 2011; Kienberger 2012; Roy and Dhar, 2024; Mondal, 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d) in some parts of the basin. Therefore, this study critically assesses the hydrological and management implications of the KKB project to determine its long-term viability, constraints and sustainability.

Flooding in the coastal region of West Bengal has received considerable academic attention due to its association with deltaic geomorphology, high population density and climate variability (Rudra, 2002; Acharya et al., 2010; Mondal and Biswas, 2022; Nasrabad et al. 2025; Cacciuttolo et al. 2025). The Moyna basin has been studied specifically for its chronic flooding and waterlogging challenges (Dwivedi and Sreenivas, 2002). Sahu, (2014) and Gayen, (2022) and Wang et al. (2025) and Sahoo et al. (2025) identified that the basin's low-lying, bowl-shaped morphology and tidal influence create inherent drainage constraints (Mondal and Biswas, 2022; Mondal, 2025). Using GIS-based flood mapping (Plan, 2004; Molle, 2005;

Amarasinghe, 2009; Wang et al. 2011; Acharya et al., 2010; Sahu, 2014; Samanta et al., 2018; Majumdar et al., 2022; Gayen, 2022; Roy and Dhar, 2024; Islam, K., et al., 2024; Mondal et al., 2025a, 2025b, 2025c 2025d; Nasrabad et al. 2025; Cacciuttolo et al. 2025), he showed how rainfall accumulation in concave depressions, independent of external overbank flooding, leads to persistent waterlogging (Dwivedi and Sreenivas, 2002). Samanta et al. (2018) constructed flood susceptibility maps using geospatial frequency ratio models, highlighting how DEM-derived geomorphological indicators indicate flood propagation in a deltaic environment. Such an approach has been applied to the Moyna basin to identify pre- and post-project waterlogging zones (Dwivedi and Sreenivas, 2002). Research by Acharya et al. (2010) and Banerjee, (2015) emphasizes the role of geoinformatics and community preparedness in improving flood management outcomes in rural Bengal. Their work emphasizes the importance of integrating structural and non-structural measures. (Plan, 2004; Molle, 2005; Acharya et al., 2010; Barman, 2021; Majumdar et al., 2022; Mondal and Biswas, 2022; Mondal, 2025; Wang et al. 2025; Sahoo et al. 2025) observed that no major flood events occurred in the Kaliaghai-Kapaleshwari-Bagui basin after 2008, indicating the initial effectiveness of the KKB project. However, (Majumdar et al., 2022; Nasrabad et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Cacciuttolo et al. 2025), studying the adjacent blocks, reported that vulnerabilities remain due to sediment mobility, dam failure, and land use change. Although separate studies discuss waterlogging, disaster management, and basin hydrology, there is no comprehensive assessment explicitly focusing on the long-term hydrological impact of the 2010 KKB project, particularly on comparative pre- and post-project flood regimes (Bandyopadhyay, 2015; Samanta et al., 2018; Biswas and Mondal, 2024; Mondal, 2025; Fadiel et al. 2025), sediment trends, and community-perceived effectiveness. The present study fills this gap by integrating hydrological data, field surveys, rainfall records, and geomorphological analysis to critically assess the consequences of the KKB project on water management in the Moyna Basin.

2. Study Area

The Moyna basin, located in Purba Medinipur district, extends from about 22°40' N to 87°50' E (Figure 1). The basin is mainly drained by the Kaliaghai River in the south, the Chandia River in the north-central and the Kangsabati River in the east. These rivers exhibit a mixed flow-tidal nature, with the upstream monsoon flow interacting with the diurnal tidal oscillations of the Bay of Bengal.

The elevation is 3-10 m above mean sea level, the topography is a saucer-shaped basin with an internal depression, the climate is mainly tropical monsoon, the average annual rainfall is 1,400-1,600 mm, alluvial soil, fine silt soil prone to water stagnation (Plan, 2004; Molle, 2005; Huang et al. 2008; Hailin et al. 2009; Pandey et al. 2010; Suriya and Mudgal 2012; Wang et al. 2011; Kienberger 2012; Bandyopadhyay, 2015; Samanta et al., 2018; Majumdar et al., 2022; Biswas and Mondal, 2024; Roy and Dhar, 2024; Mondal et al., 2025a, 2025b, 2025c 2025d; Mondal, 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025; Wang et al. 2025; Sahoo et al. 2025), land use is mainly agriculture (paddy, betel, vegetables, fisheries), scattered settlements, hydrology is highly sensitive to rainfall variations and tidal backwash. The basin contains 84 villages, which are heavily dependent on agriculture, fishing, and seasonal labour. Historically,

annual floods have caused crop losses, migration, infrastructure disruption, and significant economic hardship. This geographic and socio-economic structure makes this region an ideal example for studying the long-term effects of climate change and flood management interventions.

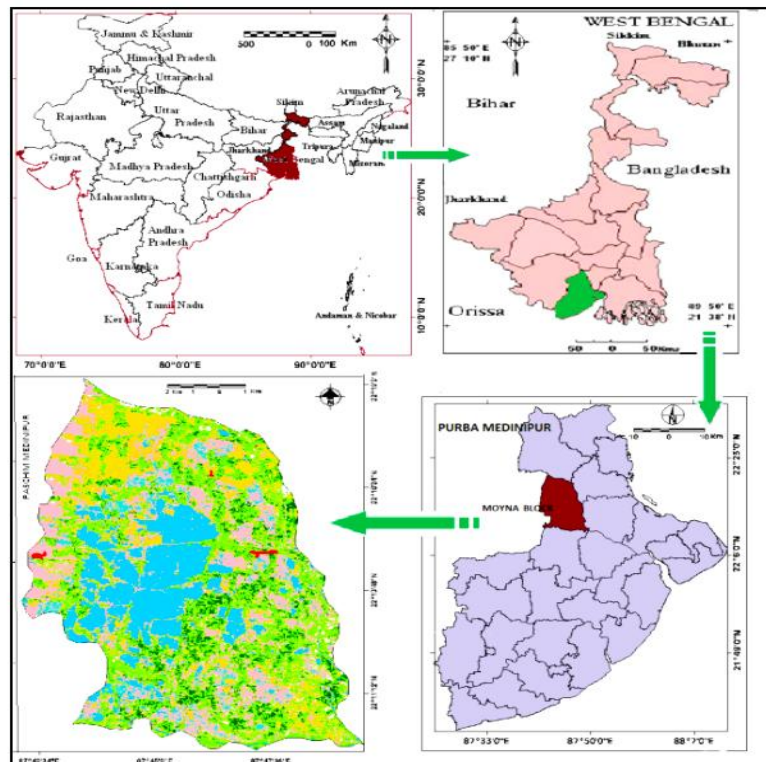


Fig. 2: The Location Map of the Moyna Basin

3. Data Source and Methodology

This study used a mixed methodology to integrate primary and secondary data using both quantitative and qualitative tools.

3.1 Primary Data: A total of 17 representative villages of the Moyna basin were surveyed in a household survey. BDMO (Moyna, Block Disaster Management Officer), Irrigation Officer, Embankment Supervisor, Panchayat member, farmer and jailer were used to interview key informants. Canal depth measurements, sedimentation patterns, condition of embankments (Sahu, 2014) and man-made obstacles were observed.

3.2 Secondary Data: Flood records of Irrigation and Waterways Department of Kaliaghari-Kapaleshwari-Baghai (KKB) Project Division (2000-2020), River level records from Temathani (Table 1) Rainfall data from IMD Observatory, SOI Topographic Sheet (73N/11, 73N/12, 73N/15, and 73N/16 R.F. = 1 : 50,000; year: 1970, 1972, 1973 and 1976) and Cadastral Map, the Comptroller and Auditor General's (CAG, 2020; Nasrabad et al. 2025; Cacciuttolo et al. 2025) performance audit on flood control projects in West Bengal, Satellite Imagery (Landsat, Sentinel-2, Google Earth), Project Report (2010-2018) and Government Annual Report, Academic literature on basin hydrology and flood management. Calculation of flood frequency, duration and magnitude. Regression analysis between rainfall intensity and flood

occurrence. Temporal framework the analysis was divided into the following three phases, namely- (a) pre-project period: 2001-2009, (b) Implementation phase: 2010-2013 and (c) post-project stabilization period: 2014-2020.

Table 1: Secondary Data and their Source

Data collected	Description of the data	Year	Source
Water Velocity Data	Digital Current Meter (Revolutions/40 Sec.)	2022, 2023	Field Survey
Household data	Flood Impact and Flood adaptation	2022, 2023	Field Survey
Topographical Map	73N/11, 73N/12, 73N/15, and 73N/16 R.F. = 1: 50,000	1970, 1972, 1973 and 1976	Survey of India
Flood data	Frequency of flood, Level of flood water, Causes of flood etc	2000 to 2022	Kaliaghai Kapaleswari Baghai Project Division Office (https://wbiwd.gov.in/uploads/tender/ten)
Satellite images	Landsat 7, ASTER GDEM V 3.0 data	2008, 2011 and 2021	United States Geological Survey (USGS) (https://www.usgs.gov)
Satellite images	Remote sensing data, IIRS P6/sensor LISS-III	2008, 2011 and 2021	Bhuvan Indian Geo-platform of ISRO (www.bhuvan.nrsc.gov.in)
Rainfall data	Purba Medinipur District and Paschim Medinipur District	2008-2021	Internet (https://wbiwd.gov.in)
Census report	Purba Medinipur District and Paschim Medinipur District	2011	Census of India (https://censusindia.gov.in)
District Disaster Management Plan	Purba and Paschim Medinipur District, Rainfall, Flood Data	2017 to 2022	Internet (http://wbdmd.gov.in)
Flood Inundation Map	Annual flood layers	2008, 2011 and 2021	Bhuvan Indian Geo-platform of ISRO (www.bhuvan.nrsc.gov.in)

3.3 Methodology: This study uses a mixed methodology based on document review, geospatial analysis, and field-based assessment to assess the hydrological and institutional impacts of the

2010 KKB project in the Moyna basin. Specifically, we first conducted a forensic review of the Detailed Project Report (DPR), construction and payment records, and the Comptroller and Auditor General’s (CAG, 2020) performance audit on flood control projects in West Bengal to reconstruct design objectives, deviations, and maintenance plans. Then, using multi-temporal remote sensing (Landsat/Sentinel) and GIS (Plan, 2004; Molle, 2005; Amarasinghe, 2009; Acharya et al., 2010; Wang et al. 2011; Sahu, 2014; Bandyopadhyay, 2015; Majumdar et al., 2022; Gayen, 2022; Mondal and Biswas, 2022; Roy and Dhar, 2024; Islam, et al., 2024; Biswas and Mondal, 2024; Mondal, 2025; Nasrabad et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Cacciuttolo et al. 2025; Wang et al. 2025; Sahoo et al. 2025), we generated flood-sensitivity and flood-risk maps for the Kaliaghai and Moyna systems, applying bi-geographic statistical models-frequency ratios, Shannon entropy, and information value-according to established methods in the literature. Predictor variables include elevation, slope, geomorphic moisture, drainage density, NDVI, land use, rainfall, and stream power. A flood-point list (from BHUVAN) was used in validation along with ROC curve analysis. We performed analytical-hierarchy-process (AHP) based multi-criteria decision making (using elevation, slope, and use etc.) to identify long-term flood footprints (Dwivedi and Sreenivas, 2002; Plan, 2004; Molle, 2005; Amarasinghe, 2009; Sahu, 2014; Samanta et al., 2018; Roy and Dhar, 2024; Islam, et al., 2024; Mondal, 2025; Wang et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Sahoo et al. 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025). Finally, field-level cross-sections, bathymetry, and hydraulic measurements were combined with the above to explain whether the observed morphological and flood-spread changes were consistent with documented project implementation errors.

4. Results and Discussion

4.1 Duration of Water Stagnation

Table 2: Year wise Water Stagnation Duration in Moyna Basin (2001-2020)

Year	Stagnation Days	Average Days	Year	Stagnation Days	Average Days
2001	25-29	27	2011	10-14	12
2002	28-32	30	2012	5-9	7
2003	15-19	17	2013	11-15	13
2004	40-44	42	2014	2-6	4
2005	27-31	29	2015	1-2	1
2006	35-39	37	2016	0	0
2007	33-37	35	2017	0	0
2008	43-47	45	2018	0	0
2009	19-23	21	2019	7-11	9

2010	18-22	20	2020	0	0
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An assessment of historical flood records shows a clear change in flood patterns in the Moyna basin before and after the implementation of the KKB project in 2010 (Table 2). Prior to this intervention, prolonged flooding was a recurring hazard (Plan, 2004; Molle, 2005; Huang et al. 2008; Hailin et al. 2009; Pandey et al. 2010; Suriya and Mudgal 2012; Wang et al. 2011; Kienberger 2012; Roy and Dhar, 2024; Mondal et al., 2025a, 2025b, 2025c 2025d; Nasrabad et al. 2025; Cacciuttolo et al. 2025; Mondal, 2025). The floods of 2004 and 2008 caused water stagnation for 40 days or more, whereas the severe floods of 2001, 2002, 2005, 2006 and 2007 caused continuous water stagnation for more than 30 days (Figure 2). This long duration reflects the highly silted river system with insufficient river transport capacity and inadequate drainage.

According to government project records, the average flood duration before 2011 was 30 days or more, indicating chronic drainage inefficiency. However, after the large-scale dredging and channel rehabilitation began, there was a sharp decline: after 2011, the average flood duration decreased to about 7 to 8 days. This improvement is further supported by the technical observations of the Executive Engineer of the KKB Project Department (CAG, 2020; Nasrabad et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Cacciuttolo et al. 2025). During the 2013 monsoon, there was 35% more rainfall than normal, which was 46% more than the 2011 rainfall-yet the water level was 1 meter lower than the peak level of the 2011 flood. Most notably, before 2011, the flood water was above the danger level for an average of 261 hours, but after dredging, it exceeded the danger level for only 4 hours in 2013. This trend continued in subsequent years: no water stagnation (Dwivedi and Sreenivas, 2002; Plan, 2004; Molle, 2005; Huang et al. 2008; Amarasinghe, 2009; Hailin et al. 2009; Pandey et al. 2010; Suriya and Mudgal 2012; Wang et al. 2011; Kienberger 2012; Bandyopadhyay, 2015; Majumdar et al., 2022; Biswas and Mondal, 2024; Roy and Dhar, 2024; Nasrabad et al. 2025; Cacciuttolo et al. 2025) events were observed in 2015, 2016, 2017, 2018 or 2020. However, minor water logging was observed in 2011, 2013 and 2019. These results collectively indicate a significant improvement in the drainage efficiency and hydrological responsiveness of the basin after the project (KKB, 2010). A complete analysis and chart of waterlogging (2001-2020) in the Moyna basin is presented. The graph clearly shows a strong decreasing trend after the KKB project of 2010, which is consistent with the research argument as a right step towards improved drainage and flood management (Abulgaziev et al. 2024; Biswas and Mondal, 2024). Thus, the project reduced the water stagnation (Plan, 2004; Molle, 2005; Huang et al. 2008; Hailin et al. 2009; Suriya and Mudgal 2012; Kienberger 2012; Wang et al. 2011; Pandey et al. 2010; Samanta et al., 2018; Majumdar et al., 2022; Mondal, 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025) duration by 60-80%, indicating major improvement in channel conveyance capacity.

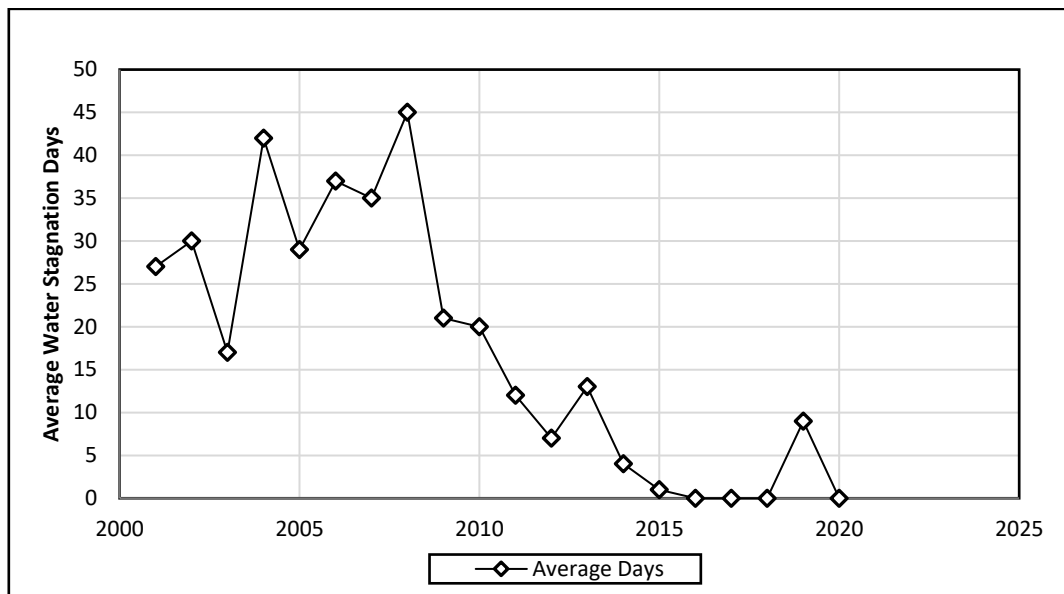


Fig. 2: Water Stagnation Duration in Moyna Basin (2001-2020)

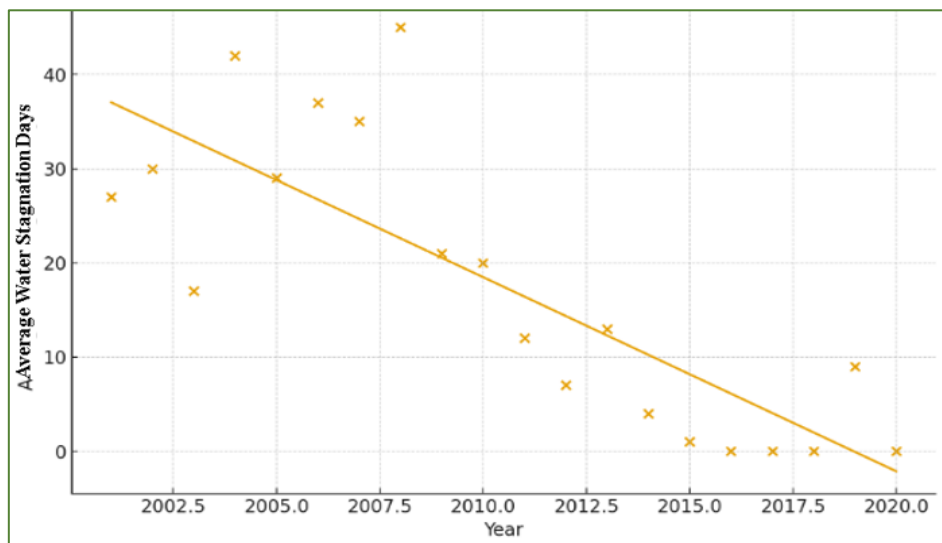


Fig. 3: Trend Line for Water Stagnation in Moyna Basin (2001-2020)

4.2 Flood frequency in the study area

A long-term review of flood events since 2001 further reinforces the significant changes in the flood regime (Sahu, 2014; Fadiel et al. 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025) of the basin. Before 2010, the Moyna basin experienced almost annual floods or prolonged inundation lasting more than 30 days on average. Recorded floods occurred in 2001, 2002, 2004, 2005, 2006, 2007 and 2008, with particularly severe floods in 2004 and 2008. Floods were also recorded in 2009 and 2010, affecting the Kaliaghai and Chandia rivers adjacent to the basin. In 2008, a dam breach on the right bank of the Kaliaghai river caused severe flooding in a large part of the districts of Patashpur-1, Patashpur-2, Bhagwanpur-1, Bhagwanpur-2,

Deshpraan, Chandipur, Egra-1. Floods also occurred in the entire Sabang block and the Moyna basin on the left bank of the Kaliaghai river. This incident highlights the urgent need for structural mitigation measures (Amarasinghe, 2009; Sahu, 2014; Mondal and Biswas, 2022; Gayen, 2022; Abulgaziev et al. 2024; Mondal et al., 2025a, 2025b, 2025c 2025d; Fadiel et al. 2025). As a result, in 2010, the central and state governments jointly undertook a comprehensive flood management initiative at a cost of Rs 633 crore, which included the re-drainage of the Kaliaghai, Kapaleshwari, Bagui and Chandia rivers and several tributaries including Deuli, Sundarpur, Shiulipur, Amrakhali, Kalimondap, Katakali, Ganapath, Uttarbarh, Panchali, Chabukia, Madhabchak, Debikhali-Khidirpur, Denredighi, Golapata and Shilakhali. Significant improvements have been seen since the intervention. After the 2008 disaster, the basin has not seen any major floods. Although some local, short-term floods still occur, they do not escalate into large-scale floods. The comprehensive rehabilitation programme carried out between 2010 and 2020 under the government's flood management programme has significantly increased the channel capacity and reduced the intensity of floods (Dwivedi and Sreenivas, 2002; Biswas and Mondal, 2024; Abulgaziev et al. 2024). As observed by Acharya et al. (2010) and Barman (2021), the restored Kaliaghai river now plays a central role in regional flood control. The basin has shifted from a high-frequency flood regime (Mondal, 2025; Fadiel et al. 2025) to a low-frequency, low-intensity regime (Acharya et al., 2010; Samanta et al., 2018; Majumdar et al., 2022; Mondal et al., 2025a, 2025b, 2025c 2025d; Nasrabad et al. 2025; Cacciuttolo et al. 2025).

Table 3: Year wise Flood Frequency in Moyna Basin

Year	Flood	Frequency/year	Year	Flood	Frequency/year
2001	Flood	1	2011	No flood	0
2002	Flood	1	2012	No flood	0
2003	No flood	0	2013	Flood	1
2004	Devastating flood	2	2014	No flood	0
2005	Flood	1	2015	No flood	0
2006	Flood	2	2016	No flood	0
2007	Flood	1	2017	No flood	0
2008	Devastating flood	1	2018	No flood	0
2009	Flood	1	2019	Flood	1
2010	Flood	1	2020	No flood	0

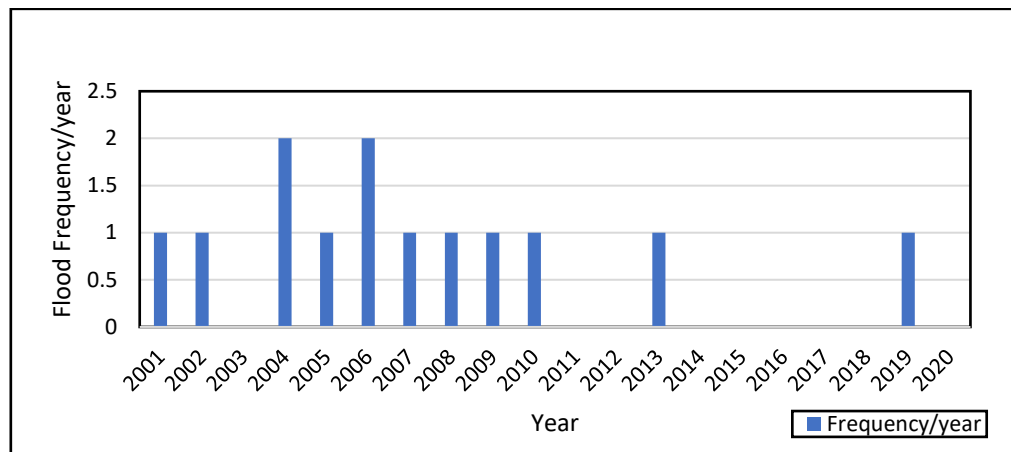


Fig. 4: Flood Frequency/year in Moyna Basin (2001-2020)

4.3 Hydrological Improvements After Dredging:

Dredging of Kaliaghai and Kapaleshwari-Bagui rivers under KKB project- increased canal depth by 2-4 meters at many places, widening of canals in the blocked areas, improved drainage in Chandia and lower floodplains (Abulgaziev et al. 2024), reduced upstream flow during peak discharge, increased efficiency of tidal water drainage (Rudra, 2002; Plan, 2004; Molle, 2005; Amarasinghe, 2009; Acharya et al., 2010; Majumdar et al., 2022; Mondal, 2025; Wang et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Sahoo et al. 2025; Nasrabad et al. 2025; Cacciuttolo et al. 2025). These changes significantly reduced (Bandyopadhyay, 2015; Abulgaziev et al. 2024; Mondal, 2025) the accumulation of stormwater during monsoons.

4.4 Sedimentation-the New Emerging Problem:

Despite initial success, sedimentation has started to accumulate again, low banks are located near the intersection of the tides, rapid sedimentation is occurring in areas blocked by bamboo bridges and nets, the distributary channel has started to narrow (Acharya et al., 2010; Sahu, 2014), upstream banks are affected due to uncontrolled land use practices. Field observations have shown that the level has risen by 0.25-0.80 meters in some parts between 2016 and 2020. This poses a threat to the long-term sustainability of the project.

4.5 Role of Anthropogenic Obstructions

More than 23 bamboo culverts, fishing nets, temporary check dams and informal river crossings by boats obstruct sediment movement and reduce flow velocity (Abulgaziev et al. 2024; Mondal, 2025). These structures encourage local sediment deposition, create artificial backwater effects, obstruct debris movement (Acharya et al., 2010; Barman, 2021; Mondal, 2025), and impede navigation and water transport. Without community awareness and enforcement, these obstructions will compromise the benefits of the KKB project.

4.6 Interaction with Tidal Dynamics

The lower Moyna basin interacts with the Kaliaghai-Haldi-Bay of Bengal tidal system. During spring tides, water cannot effectively exit the basin, the tidal backwash slows the river's drainage, and the silt carried from upstream deposits in the lower reaches is a major hydrogeological challenge (Sahu, 2014; Samanta et al., 2018; Majumdar et al., 2022; Biswas

and Mondal, 2024; Abulgaziev et al. 2024; Mondal, 2025; Mondal et al., 2025a, 2025b, 2025c 2025d) that simple dredging cannot fully address.

4.7 Socio-Economic Effects of the Project

(a) Positive Outcomes:

- Restoration of timely agricultural cycles.
- Reduced risk of crop damage.
- Improved access to markets and services.
- Increased household resilience.
- Reduced need for temporary migration.
- Higher agricultural productivity due to reduced waterlogging.

(b) Remaining Concerns:

- Localized waterlogging of low-lying rice fields continues.
- Sedimentation poses a threat to long-term flood protection.
- Embankment encroachment continues.
- Fisheries-related disruptions remain widespread.

5. Findings

- Flood duration has decreased from an average of 30-35 days (before 2010) to an average of
- 7-8 days (after 2011).
- Flood frequency has decreased dramatically, with no major floods occurring between 2010 and 2020.
- Dredging has significantly increased water carrying capacity, but without maintenance this benefit may decline.
- Sedimentation is rapidly accumulating, especially in the riverbed.
- Human encroachment remains a serious problem.
- The project, while successful, is not structurally self-sustaining; it requires institutional and community oversight.

6. Policy Recommendations

- Regular dredging cycle: A 5-year rolling dredging policy should be introduced.
- Sediment governance framework: Soil conservation upstream should be implemented.
- Barrier removal: The number of bamboo bridges should be reduced; fishing nets and illegal encroachment should be controlled.
- Improved embankment management: Strong monitoring and maintenance of embankment lines is required.
- Water-monitoring stations: Real-time water-level sensors and rainfall-flow monitoring systems should be installed.
- Community-based flood management: Village committees should monitor minor channels and barriers.
- Integration with tidal river management (TRM): To address tidal backflow-induced siltation.

- Flood-resilient agriculture: Short-duration rice varieties and integrated farming systems should be introduced.

7. Limitations

7.1 Limited Availability and Reliability of Hydrological Data

A major limitation of the study is the inadequate availability of long-term, high-resolution hydrological and geomorphological data for the Moyna Basin. Many government records are either fragmented, outdated, or not publicly accessible, which constrains precise assessment of pre- and post-project changes in river discharge, sediment load, and drainage efficiency. This data gap may lead to partial interpretation of the actual impacts of the Kaliaghai-Kapaleshwari-Bagui Project on flood dynamics and water management.

7.2 Insufficient Consideration of Local Socio-Environmental Variability

The study area exhibits significant spatial heterogeneity in terms of land use, elevation, drainage congestion, and community adaptation practices. However, capturing this micro-level variability across the entire Moyna Basin is challenging within a limited research framework. As a result, the findings may not fully represent localized experiences of waterlogging, flood vulnerability, and livelihood impacts, thereby affecting the generalization of conclusions regarding the project's effectiveness.

8. Conclusion

The Kaliaghai-Kapaleshwari-Bagui project (2010) is one of the most effective flood mitigation measures (Sahu, 2014; Samanta et al., 2018; Mondal and Biswas, 2022; Majumdar et al., 2022; Gayen, 2022; Mondal et al., 2025a, 2025b, 2025c 2025d; Mondal, 2025; Fadiel et al. 2025) undertaken in coastal West Bengal. Its immediate results were transformative: the frequency and duration of floods have been dramatically reduced (Dwivedi and Sreenivas, 2002; Biswas and Mondal, 2024; Abulgaziev et al., 2024), agricultural stability has improved, and community resilience has increased. However, the long-term hydrological behaviour of the delta system suggests that the project's benefits may create adverse effects if not continuously maintained. Sedimentation, tidal barriers, and human-induced disturbances are re-emerging threats that, if neglected, could restore the pre-2010 flood regime (Dwivedi and Sreenivas, 2002; Bandyopadhyay, 2015; Samanta et al., 2018; Majumdar et al., 2022; Biswas and Mondal, 2024; Abulgaziev et al. 2024; Mondal, 2025; Fadiel et al. 2025; Mondal et al., 2025a, 2025b, 2025c 2025d; Nasrabad et al. 2025; Cacciuttolo et al. 2025). Therefore, the future of water security in the Moyna basin depends on sustainable investment, integrated reservoir management, modern monitoring systems, and active community participation. One-time interventions cannot guarantee permanent flood control in a dynamic deltaic environment; only continuous scientific management can do so.

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Regional Pattern of Gender Inequality in Jharkhand: A District Level Analysis

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***Abstract:** This study examines the regional pattern of gender inequality in Jharkhand using district-level data from Census 2011, NFHS-5, and other secondary sources. The analysis focuses on key indicators such as sex ratio, female literacy, health conditions, and economic participation of women. The findings reveal significant variations across districts, with tribal-dominated areas generally showing better sex ratios compared to more industrialized districts. Despite some improvement in the overall sex ratio after the formation of the state, gender inequality remains a major concern due to factors like low female literacy, poverty, patriarchal social norms, and limited access to healthcare and education. The study highlights that gender inequality in Jharkhand is multidimensional in nature and varies spatially across districts. It concludes that targeted district-level policies, improvement in education and healthcare, and stronger awareness programs are essential to promote gender equality and balanced regional development.*

***Keywords:** Gender Inequality, Sex Ratio, Jharkhand, District-Level Analysis, Female Literacy, Health Indicators, Regional Disparities, Socio-economic Factors, Women Empowerment, Spatial Pattern*

Introduction

Population composition denotes population structure. The composition of the population includes various types of elements of the population which systematically describe the structure of the population. That includes age structure, sex composition, Literacy level, occupational structure, and rural-urban composition and many more. According to Franklin (1956, P. 168) rightly observes: Among all components of population composition, the study of sex composition (age or gender composition) becomes extremely important because it directly influences the social, economic and demographic structure of a society. Franklin (1956, P. 168) rightly observes that sex ratio was an index of economy prevailing in an area and was a useful tool for regional analysis. The profound effect of the proportion of the two sexes upon the other

demographic elements like population growth, marriage rates, occupational structure, has also been well recognized. (Shryock, 1976, P. 105). Thus, the knowledge of sex ratio is essential for understanding the employment and consumption patterns, social need etc. of a community. (Trewartha (1953) According to Trewartha - the proportion of two sexes is fundamental to the geographic analysis of an area because it is not only an important feature of the landscape but it also influences the other demographic elements significantly and as such provides an additional means for analysing the regional landscape. (Trewartha). Thus we can understand that the sex ratio refers to the proportion of females and males in a population. Now, we can understand that the sex Ratio is the most important indicator for showing gender inequality in any region. As per 2011 census, the overall sex ratio of India was (940) females per 1000 males, whereas in Jharkhand, the sex ratio was (943) females per 1000 males.

If we look at different states of India, there are significant variations in the sex ratio found. As per 2011 census, the highest sex ratio was found in Kerala (1084) whereas the lowest sex ratio was observed in Haryana (879).

Demographic profile of Jharkhand

Jharkhand is a tribal dominated State of India, which was established on 15 November 2000 after being separated from Bihar. At the time of its formation, there were a total eighteen districts here, but later the number of districts increased to 24 at present. The total geographical area of Jharkhand is about 79,714 square kilometres, which is approximately 2.4% of the total geographical area of India. According to the census of India 2011, the total population of the state is 3.29 Crore (32988134) which constitutes 2.72% of the country's population where ratio of male and female population are 1.69 crore and 1.60 crore as well. Jharkhand is predominantly a rural area where 76% of population are living in rural areas.

The overall sex ratio of Jharkhand is 948 which means that there are only 948 females in per 1000 male population. If we talk about educational level, the overall literacy rate of Jharkhand is 66.41%, while the female literacy rate is about 56.21%. Women in Jharkhand face multiple challenges such as low literacy, poor health services, early problems of early marriage and economic vulnerability but at the same time, different government schemes and rising awareness towards women empowerment are contributing towards women empowerment in the state.

Objectives of the study

- I. To examine the key indicators of gender inequality at the district level.
- II. To examine the spatial distribution of sex ratio across districts of Jharkhand.
- III. To study socio-economic determinants influencing gender inequality.

Data sources and Methodology

For the analysis of the present study, the data used has primarily been derived from secondary sources such as Census of Jharkhand 2011, Statistical handbook of Jharkhand, National family health survey data-15 (2019-21), District census handbook of all 24 districts and various other references have been utilized. For this study data and information has been collected with the

help of books, research articles and many government reports. The numerical measurement of sex composition in a population is usually expressed in terms of sex ratio. In various countries, sex ratio is calculated in different norms (Maurya, 2015 Pg - 155). But in India it is calculated as under:-

$$\text{Sex Ratio} = (\text{Total females} / \text{Total Males}) \times 1000$$

$$\text{or } (P_f / P_m) \times 1000$$

It means the number of females in per 1000 males population. where P_f = number of female, P_m = number of male (Chandana, 1986 Pg-132)

Key indicators of gender inequality at the district level

Gender inequality in Jharkhand can be assessed through various indicators, which reflect the prevailing gender inequality in society. This inequality can be seen in Jharkhand in the form of social, economic, demographic, educational levels, Health services and women's participation in decision making. The pattern of gender inequality in various districts of Jharkhand can be understood through the following given chart:

Table: 1 Indicators of gender inequality in Jharkhand.

SN	Main Indicator	Sub-indicators
1	Demographic	1. Sex Ratio
		2. Child Sex Ratio
2	Educational Status	1. Female Literacy Rate
		2. Gender Gap in Literacy Rate
		3. Dropout Rate of Girls
		4. School Admission of Girls
3	Economic Status	1. Female Work Participation Rate
		2. Wage and Employment Gap
		3. Monthly Income of Women
4	Health Status	1. Maternal Mortality Rate
		2. Nutritional Value
		3. Anaemia among Women
		4. Infant Mortality Rate
5	Social Indicators	1. Domestic Violence
		2. Women Participation in Decision Making
		3. Early Marriage

Source: Compiled by the author with the help of NFHS-5 (2019–21) data.

Table 2: Some prevalent main indicator of gender inequality in Jharkhand

SN	Districts	Female Population ¹	Sex Ratio ²	Anaemia among Women (%) ⁵	Female Literacy Rate (%) ³	Female Work Participation Rate (%) ⁴
1	Sahibganj	561176	952	71.8	43.31	34.6
2	Godda	608000	938	68.5	46.25	34.7
3	Pakur	451000	989	69.9	40.52	37.9
4	Deoghar	702000	925	66.4	51.80	26.5
5	Dumka	647000	971	67.2	48.82	37.8
6	Jamtara	395000	954	65.7	52.15	33.7
7	Giridih	1218000	944	64.8	48.82	31.0
8	Koderma	366000	950	63.9	53.23	28.1
9	Hazaribagh	832000	947	62.5	58.95	28.4
10	Chatra	549000	953	64.1	49.92	32.1
11	Bokaro	1022000	922	60.8	60.63	23.7
12	Dhanbad	1208000	909	59.7	64.29	22.5
13	Ramgarh	463000	921	60.5	63.09	22.7
14	Khunti	270000	997	61.9	53.69	41.5
15	Gumla	514000	993	57.3	55.90	42.6
16	Simdega	300000	997	55.9	59.92	44.3
17	Lohardaga	225000	985	59.8	57.69	41.8
18	Latehar	373000	967	63.4	48.68	38.3
19	Palamau	969000	928	64.7	52.09	31.5
20	Ranchi	1419316	949	58.2	67.44	28.11
21	Garhwa	648000	935	65.2	47.58	31.6
22	West Singhbhum	747000	1005	61.5	46.25	41.2
23	East Singhbhum	1110000	949	58.6	66.81	25.0
24	Seraikela-Kharsawan	530000	956	60.2	55.88	33.8

Source: Data of superscripted parameters (1,2,3 &4) of above table is taken from census of Jharkhand 2011(Primary Census Abstract). Data of superscripted parameters 5 of above table is taken from National Family Health survey-5,District fact-sheet 2019-21.

Table No. 2 represents the statistical data of selected indicators of gender inequality in Jharkhand, there are several major indicators and sub-indicators used to understand gender inequality, however due to unavailability of comprehensive and reliable data for all indicators for all 24 districts of Jharkhand, only a limited but significant set of indicators has been selected for this study. Accordingly, Table No. 2 includes key indicators such as the total female population, sex ratio data, female literacy rate (%), percentage of women anaemia among women and the female work participation rate (%), which together help in understand the situation of gender inequality in the state. If we consider the total female population in

Jharkhand, it constitutes approximately [blank] % of the state's population. However, this proportion alone does not fully explain the nature of gender imbalance.

In comparative terms, several districts of Jharkhand show a relatively higher proportion of female population such as Ranchi, Giridih, Dhanbad, Bokaro, and East Singhbhum. Jharkhand currently has a total of twenty-four districts, among which some of the most developed districts include Ranchi, Hazaribagh, Giridih, Bokaro, and Palamu. Ranchi, being the capital and a relatively developed urban center, has better economic conditions, educational facilities, healthcare services, and overall standard of living. Despite this, the sex ratio in Ranchi is only 949 females per 1000 males, which is just slightly above the state average. Although it records the highest female literacy rate in the state (around 67.44 percent), the prevalence of anaemia among women remains high at 58.2 percent, indicating gaps in healthcare delivery. Additionally, female work participation in this district is relatively low. In other developed districts such as Giridih, Bokaro, Dhanbad, and East Singhbhum, where the female population exceeds one million, female literacy levels range between 48 to 65 percent. The sex ratio in these districts is comparatively lower than in tribal-dominated regions, reflecting persistent gender inequality in more industrialized areas. The burden of anaemia among women is particularly severe in districts like Sahibganj (71.8 percent), Deoghar (66.4 percent), Dumka (67.2 percent), and Palamu (64.7 percent), where a large proportion of women suffer from anaemia and the sex ratio remains below the state average. In contrast, West Singhbhum records the highest sex ratio in the state (1005 females per 1000 males), suggesting relatively better gender balance. Similarly, tribal-dominated districts such as Lohardaga, Gumla, Simdega, Latehar, Khunti, Koderma, and Pakur show sex ratios higher than the state average. This reflects relatively better status and empowerment of women in rural and tribal societies. Furthermore, districts such as Simdega, Lohardaga, Gumla, and Khunti exhibit the highest female work participation rates in the state. However, despite higher participation in economic activities, the level of female literacy in these districts remains moderate, generally ranging between 45 to 60 percent.

Spatial distribution of sex ratio across all districts, 2011

An analysis of the sex ratio across all districts of Jharkhand reveals that the highest sex ratio is recorded in West Singhbhum (1005), whereas the lowest sex ratio is found in Ramgarh (921). Furthermore, it is observed that out of the total 24 districts in the state, nearly 50% of the districts have a sex ratio higher than the overall state average that was 948 in 2011 census. This wide gap highlights the uneven demographic pattern within the state. Districts with higher sex ratios are predominantly Tribal dominated areas such as West Singhbhum (1005), Dumka (977), Gumla (993), Pakur (989), Khunti (997), Simdega (997) and Lohardaga (985), where traditional social structures tend to offer relatively better status to women. On the other side, all such districts have higher industrial and economic development, a relatively low sex ratio is observed. such as Dhanbad (909), Bokaro (922), Palamau (928), West Deoghar Singhbhum (925) and Ramgarh (921).

In the table given below, Jharkhand has been classified into five major categories on the basis of sex ratio (Jhariya & Jain 2016) which are as follows:

Table 3: Variations of sex ratio in Jharkhand 2011

Groups of Sex Ratio	Range	No. of Districts	Name of Districts
Very High	> 1000	1	West Singhbhum
High	971–1000	6	Dumka, Gumla, Pakur, Khunti, Simdega, Lohardaga
Moderate	951–970	5	Sahibganj, Chatra, Saraikela, Jamtara, Latehar
Low	930–950	7	Ranchi, Giridih, East Singhbhum, Hazaribagh, Garhwa, Godda, Koderma
Very Low	< 930	5	Dhanbad, Bokaro, Palamau, Ramgarh, Deoghar

Source: Compiled by author with the help of sex ratio data.

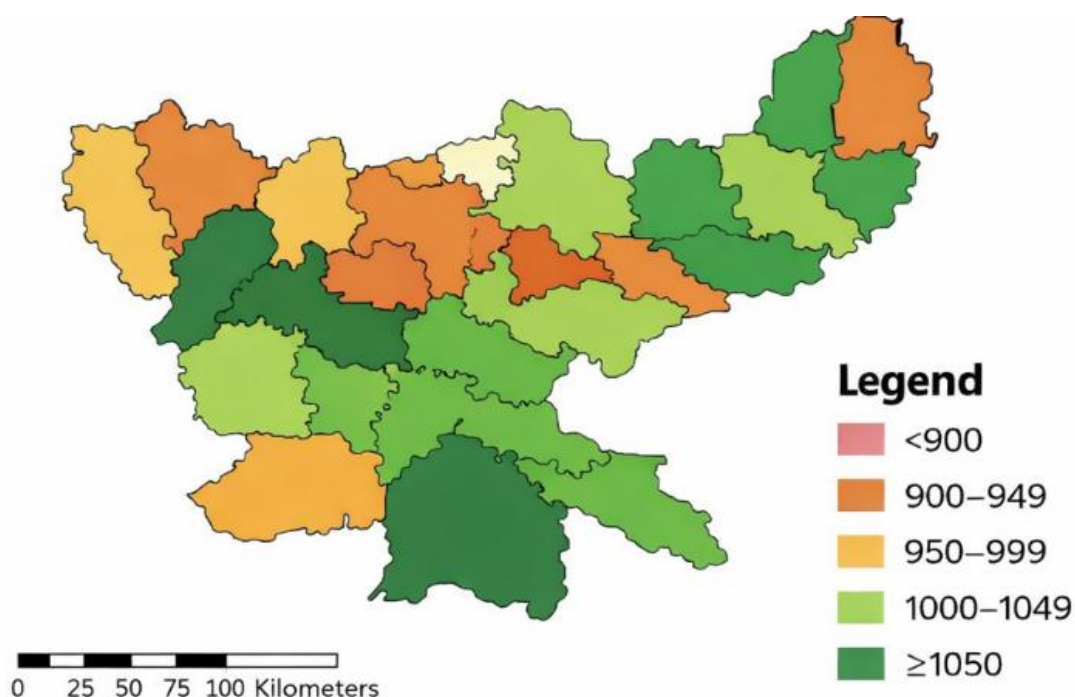


Fig. 1: Regional Pattern of Sex Ratio in Jharkhand (2011)

Table 4: Comparison of sex ratio between India and Jharkhand

Year	India ¹	Jharkhand ²
1951	946	961
1961	941	960
1971	930	945
1981	934	940
1991	927	924
2001	933	941
2011	943	948

Source: 1: Census of India (1951-2011) (Primary Census Abstract), 2: A. Prakash (2001) and Census Publication (1991-2001)

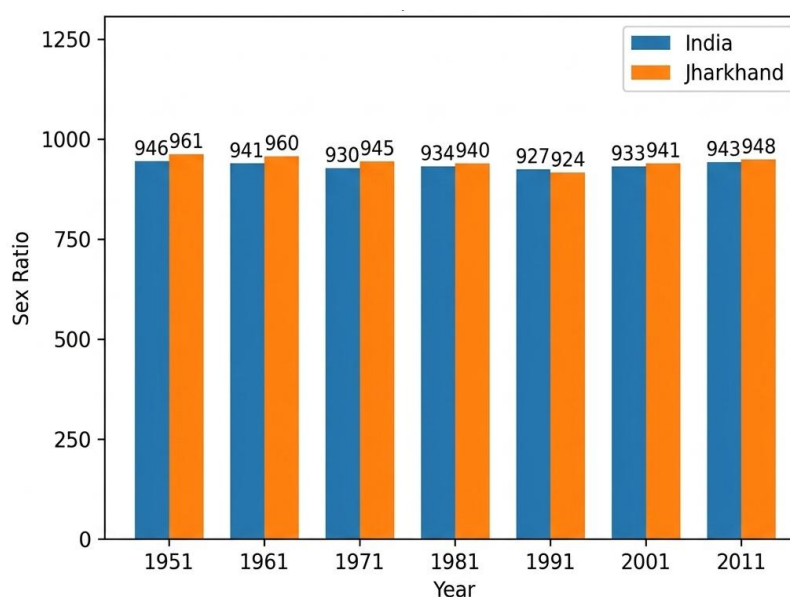


Fig. 2: Comparison of Sex Ratio between India and Jharkhand

Source: 1: Census of India (1951-2011) (Primary Census Abstract) ,2: A. Prakash (2001) and Census Publication (1991-2001)

The data reveals important trends in the sex ratio of India and Jharkhand over last six decades from (1951 to 2011). Since 2000 Jharkhand was a part of Bihar before the year 2000, that is why separate and independent data on sex ratio were not distinctly available in official census report. Therefore, the data of sex ratio have been collected through secondary sources such as A. Prakash (2001), Census Publication (1991–2001). This source indicates that the sex ratio in the Jharkhand regions showed declining trend from 1951 to 2001, which occurred as a result

of widespread socio-economic factors, a male dominated society and regional disparities in Jharkhand. But after the formation of Jharkhand in 2000, an improvement in the sex ratio was observed, which increased to 948 in 2011. On the other side India's sex ratio also fell from 946 to 927 during 1951 to 1991. After 1991 India's sex ratio improved from 927 (1991) to 933 (2001) and further to 943 (2011). This improvement in both regions may be attributed to government initiatives, rising awareness, better female literacy and health services.

Key determinants and causes of the declining sex ratio in Jharkhand

- Female Foeticide
- Deep rooted son preference in family
- Poverty and different economic factors
- Low female literacy and Education
- Patriarchal Social Norms
- Weak implementation of PCPNDT Act
- Male selective migration
- Girls trafficking
- Increased Violence
- Dowry System
- Declining child sex ratio (0-6 Age group)
- Gender discrimination in feeding system
- Lack of women empowerment

Conclusion

The study clearly shows that gender inequality in Jharkhand is still a serious issue, though some improvements have been seen over time. The sex ratio, literacy rate, health conditions, and economic participation of women vary widely across different districts, showing an uneven pattern of development. Tribal-dominated districts generally have better gender balance, while industrial and economically developed areas show lower sex ratios. Major causes of inequality include low female literacy, poverty, social norms, and lack of awareness. However, government efforts and increasing awareness are slowly improving the situation. Therefore, more focused policies, better education, healthcare facilities, and strong social awareness are needed to reduce gender inequality and ensure equal opportunities for women in all districts of Jharkhand.

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The Commodification of Life: An Ecocritical Approach to *Oryx and Crake*

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Abstract: *In the present times, the so-called human development and progress have become inversely proportional to the degradation of nature. Where humans have mindlessly exploited nature that has resulted ecological imbalance. An urgent call to awaken the masses toward their responsibility and ethical duty to preserve and protect nature is vital. Ecocriticism looks at the relationship between man and nature as presented in literature. This paper attempts to apply an ecocritical lens to Margaret Atwood's *Oryx and Crake* (2003). In her work she illustrates the repercussions of selfish human behaviour and insatiable greed, which have led to a chain of environmental disaster. Through her work she makes an endeavour to present how humans' mindless exploitation has spoilt the natural balance. She presents how the anthropocentric attitude has encouraged abuse of technology and scientific developments to improve the human lifestyle without taking into consideration the aftermath of these selfish decisions. Her work *Oryx and Crake* can be seen as a warning to the humans of an impending disaster and an urging to retrace their steps back and have an ecocentric approach. She advocates respect toward all beings of the earth, as well as the understanding of the fact that between nature and human beings there is no superiority.*

Keywords: *Ecocriticism, Climate Change, Genetic engineering, Dystopian fiction*

Introduction

With the dawn of Industrialisation, began a race of scientific advancement, where the humans negated themselves from taking any responsibility towards the exploitation of nature that they have caused and continue to do the same as long as it could fill their coffers. The twentieth century has witnessed how the so-called human development and progress have become inversely proportional to the degradation of nature. Where the mindless exploitation of natural resources by humans and their innate nature to dominate nature have led to ecological crises and rendered our ecosystem into a proverbial wasteland. A call to awaken the masses toward their responsibility and ethical duty to protect and preserve our home brooks no delay. With this sense of collective responsibility the writer and critics in their work present real or imagined scenarios with the aim of urging people to take concrete steps to save and protect the

environment and to combat the ecological crisis and also to make them aware of how an anthropocentric attitude has rendered the earth into a wasteland that is at the mercy of humans. Ecocriticism looks at the relationship between man and nature as presented in literature. In her work *Oryx and Crake* (2003) she presents how the mindless exploitation of earth's natural resources has severely damaged the ecological balance and how human insatiable greed and selfish behaviour have led to a chain of ecological disaster. She presents how, in order to better human life we humans have indiscriminately encouraged abuse of technology and unregulated scientific developments without taking into consideration their aftermath. In this paper an attempt has been made to study Margaret Atwood's *Oryx and Crake* (2003) from an ecocritical perspective and try to see how the present deteriorating ecological balance serves as a warning to humans of an impending disaster and urges the masses to mend their ways and have an ecocentric approach towards nature.

Ecocriticism is a recent addition in the field of critical studies, which urges the readers to look at the interconnections between physical nature and man as presented in literature. It urges the masses to think from an ecocentric approach, which places nature at the centre of things. It essentially condemns any form of exploitation of nature by man. Willam Ruckert was first to coin the term "ecocriticism," which was a way "to find the grounds upon which the two communities-the humans, the natural can co-exist, cooperate and flourish in biosphere" (The Ecocriticism Reader, 107). Nature and literature have always been closely associated, as we find in the literary works of different poets and authors throughout history. However, the recent anthropogenic activities, which have invariably resulted in ecological imbalance, have raised concern for its protection and preservation, and its reflection in literature has given birth to the concept of "Ecocriticism". It was through the efforts of Cheryll Glotfelty that ecocriticism expanded and became widely discussed as a literary and cultural theory by the early 1990s which led to the formation of the Association for the Study of Literature and Environment (ASLE) followed by the publication of its journal, *Interdisciplinary Studies in Literature and Environment*.

Purpose

The objective of this research paper is to analyse ecocritically Margaret Atwood's *Oryx and Crake* where she imagines a dystopian world which could be a reality if human beings do not mend their ways. It can be seen as a warning of an impending apocalypse if man fails to realize its wrong doing and retrace its step back and have an ecocentric approach. The lesson derived from the study will help addressing the ecological crisis qualitatively.

Methodology

The paper is research based and qualitative in methodology, sourcing the materials from reference books and the internet. The cited materials have been examined in terms of their relevance and usefulness to the issue in question and have formed part of the findings.

Discussions and Findings

Margaret Atwood is Canada's most eminent novelist and poet; she also writes short stories, critical studies, screenplays, and books for children. She has been renowned for her assessment

pertaining to ecological issues and wilderness. The essence of her fictional works essentially concerns woman's existence, nationalised individuality of Canada, and ecological catastrophe owing to the unsupervised expansion of science and technology by ethics and morals. In her *Oryx and Crake* (2003) she portrays a dystopian world as an aftermath of misuse of technology of genetic engineering.

The backdrop novel *Oryx and Crake* is a futuristic dystopia that has emerged after the collapse of the global ecosystem. It mainly voices the ecological issues such as global warming, climate change overpopulation.

...as time went on and the coastal aquifers turned salty and the northern permafrost melted and the vast tundra bubbled with methane, and the drought in the midcontinent plains region went on and on, and the Asian steppes turned to sand dunes, and meat became harder to come by, some people had their doubts. (p.31)

We find a lone survivor of the manmade global catastrophe in the futuristic wasteland, Snowman who is the protagonist and narrator, must reside all alone in the world's ruin.

He is probably mankind's only survivor in the post-pandemic world, and he is portrayed as the representative of humanity. He thinks

Maybe that's the real him, the last Homo sapiens- a white illusion of a man, here today, gone tomorrow, so easily shoved over, left to melt in the sun, getting thinner and thinner until he liquefies and tickles away altogether. As Snowman is doing now. (p,224)

Whatever living beings he meets are the products, as Jay Sanders put it, of "genetically engineered animals" and "hybrid creatures" (2013, p, 219). These are especially designed to serve humans; pigoons for instance, were created and raised for organ plantation; the Crakers, who are immune to diseases, tame, innocent, humanlike, and beautiful. The novel critiques Crake's Paradise Model; a bioengineering project that aims to create a superior race that would supposedly replace humans. Crake is in charge of this top-secret project, where we find him blinded by his optimism in science and technology as he downplays the natural Darwinian conception of evolution. Through this project he expects to realize the human's dream of permanent youth and beauty. Atwood voices her concern as to how humans see themselves as creators and justify their acts of interference in the natural order of things. We find that genetic engineering has opened Pandora's Box in Atwood's commercialized environment, where human beings have overstepped the boundary and something impermissible has taken place. We also find that unsupervised technological advances fuelled by human lust to interfere in the natural processes have created a man-made nature, which will ultimately be metamorphosed into a proverbial wasteland. Atwood has a deep understanding of human behaviours as she perceives the potential of unethical human use of technology and portrays the hazardous consequences of bioengineering. Through her work *Oryx and Crake*, Atwood imagines a futuristic wasteland that is not in a distant future but rather much nearer future reality, according to the existing phenomena in today's society. Crake has the capability to change the world, though aware of the negative effects of "BlyssPluss", he seeks to save the planet from humans' destructive and environmentally hostile traits. But we find that his environmentalism relies on

the principle of human exception for solving environmental problems. He consciously contributes to the apocalypse. Atwood, thus, invokes a sense of ethical responsibility in the scientists who are engaged in the development and advancement of science and technology. Science when bereft of serious regulation and guided by the insatiable greed of the people will wreak havoc, which could lead to irreversible damage to our environment. Jimmy's mother reveals the consumerist ideology of the society in an argument with Jimmy's father where she exposes the dark side of the corporate institutions with the sole objective to exploit people and natural resources for profit-making:

...You and your smart partners. Your Colleagues. It's wrong, the whole organization is wrong, it's moral cesspool and you know it."

At NooSkins' prices it is. You hype your wares and take all their money and then they run out of cash, and it's no more treatments for them. They can rot as far as you and your pals are concerned. Don't you remember the way we used to talk, everything we wanted to do? Making life better for people- not just people with money You used to be so... you had ideals, then." (OC 64)

Atwood presents a horrifying yet real picture of the disastrous consequence of overpopulation. She directs our attention and compels us to rethink our social policy, which, if solely guided by humans' unrestricted materialism, would inevitably lead to a dystopian world. As Greg Garrad states, "population will always increase to the point where 'misery and vice' halt it, Malthus claimed" (2004, p. 94). Here "misery and vice" are manifested as famine, plague and war from overpopulation. In *Oryx* and *Crake* the environment is facing deterioration due to overpopulation. As population puts a strain on the limited resources, the ecosystem invariably collapses, leading to famine and plague. Population has become a malignant tumour, and the only real cure is radical surgery. Since humans were neither willing to curb their population nor restrict their insatiable materialistic demand, Crake for the environment and for humankind performs a radical surgery with the view of slashing the population by spreading a fatal pestilence. Crake comprehends humans as

You can't couple a minimum access to food with an expanding population indefinitely. Homo sapiens doesn't seem able to cut himself off at the supply end. He's one of the few species that doesn't limit reproduction in the face of dwindling resources" (OC,2003,p-119)

Humanity has reached to a place of no return and has always failed to mend their ways, making "the same cretinous mistakes over and over, trading short-term gain for long-term pain" (p. 243).

Crake's grand plan of bioterrorism and the genetic experimentation to replace the flawed humanity with genetically engineered humanoids called as Crakers, implies the lack of human values and ethics. The contemporary bioengineered test-tube babies, is perhaps the perfect example that humans have already started to walk towards the dystopian world that Atwood has imagined. Atwood underscores the folly in the social order of things, which needs to be addressed without any detail. She further expresses her conviction that "everything is

connected to everything else and that literature does not float above the material world in some aesthetic ether but rather, plays a part in an immensely complex global system in which energy, matter and ideas interact” (Heise, par.7-9)

The modern world has given prominence to science and its advancement, where human emotions have taken a backseat. People are guided by materialistic aspirations which have robbed them of moral and human values.

The dystopian world in *Oryx and Crake*, Atwood warns, is potential disastrous end of human race in the near future if humans are not ready to retrace their steps and have ecocentric approach towards the environment. One also finds in her narrative a ray of hope that appeals to the masses; that all is not lost. She gives a picture of the possible future, which can only change with a combined effort of all humanity and ecocentric approach towards the environment.

Conclusion

This paper analyses through an ecocritical approach the anthropocentric attitudes of the people that have led to the collapse of the ecosystem. It also illustrates how humans’ mindless exploitation of natural resources has ruined the natural balance. It also depicts how the anthropocentric activities have encouraged abuse of science and technology. She cautions the humans of an impending disaster, which is not too far if humans fail to mend their ways. She advocates respect toward all beings of the earth, as well as the understanding of the fact that between nature and human beings there is no superiority.

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Assessment of Women Empowerment in the Rural Areas of East Singhbhum, Jharkhand

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***Abstract:** Women empowerment is an important aspect of rural development, especially in states like Jharkhand where social and economic conditions continue to influence gender roles. The present study assesses the level of women empowerment in the rural areas of East Singhbhum district based on primary data collected during January and February 2026. A total of 140 women respondents were surveyed using a structured questionnaire covering different dimensions such as livelihood, decision-making, mobility and awareness. A composite Women Empowerment Index (WEI) was used to measure the overall level of empowerment. The findings show that a large proportion of women fall under the medium level of empowerment, while a significant section still remains in the low category. Economic participation is limited, with many women engaged in low-paid or irregular work. Although participation in Self-Help Groups has improved financial awareness and confidence, income levels remain low. Decision-making power is still largely shared or influenced by male members and independent decision-making is limited. Mobility restrictions and low participation in social activities also affect empowerment levels. The study further highlights that women engaged in income-generating activities exhibit higher levels of confidence, awareness and participation in household decision-making. This indicates a strong link between livelihood and empowerment. However, factors such as education, social norms and access to information continue to shape the extent of empowerment. The study suggests that improving livelihood opportunities, strengthening Self-Help Groups and increasing awareness can play a key role in enhancing women empowerment in rural areas.*

***Keywords:** Women Empowerment; Rural Development; East Singhbhum; Livelihood; Decision-Making; Self-Help Groups; Women Empowerment Index; Jharkhand*

1. Introduction

Women empowerment has become an important focus in development studies, especially in a country like India, where gender inequality still shapes everyday life. Empowerment is not limited to earning income. It includes education, the ability to make decisions, freedom to move

outside the home and awareness about rights and opportunities. In rural areas, these aspects are closely connected with social norms, economic condition and access to basic services.

In India, different programmes have been introduced to improve the status of women. Self-Help Groups (SHGs), microfinance initiatives and rural employment schemes have helped many women to participate in income-generating activities. Studies have shown that SHGs not only improve income but also increase confidence and participation in household decisions (NABARD, 2019; Deininger & Liu, 2013). Evidence from the National Family Health Survey also suggests that there has been some improvement in women's education and health, but gaps remain in terms of autonomy and control over resources (International Institute for Population Sciences [IIPS], 2021).

Jharkhand presents a unique situation in this context. The state has a large tribal population and a strong dependence on agriculture and forest-based livelihoods. In districts like East Singhbhum, rural women are often involved in household work, agriculture and informal activities. However, their role in decision-making and access to resources is still limited. Social customs, low levels of education and poverty continue to restrict their participation in economic and social life. Studies in Jharkhand have pointed out that women, particularly in tribal areas, face multiple disadvantages related to livelihood, education and institutional access (Sharma, 2015; Singh & Kiran, 2018).

At the same time, gradual changes are visible. The spread of SHGs, government welfare schemes and local development programmes has started to influence women's lives. Many women are now involved in savings groups, small businesses and community activities. This has improved their confidence and social position to some extent. However, this progress is uneven. Some women are able to take advantage of these opportunities, while others remain excluded due to a lack of awareness, resources, or social support.

Several studies have examined women empowerment in rural India, focusing on aspects such as income, education and health. For example, Panda and Agarwal (2005) highlighted the importance of economic independence in improving women's status, while Kabeer (1999) emphasised the role of resources, agency and achievements in understanding empowerment. However, many of these studies are either broad in scale or limited to specific indicators. There is still a lack of micro-level studies that examine multiple dimensions of empowerment together in rural settings, particularly in Jharkhand.

This creates a gap in understanding how different factors, such as livelihood, mobility, decision-making and awareness, interact at the local level. In the case of East Singhbhum, very few field-based studies have explored women empowerment in a comprehensive manner. Without such a detailed understanding, policy interventions may fail to address the real issues faced by rural women.

Therefore, the present study aims to assess the level of women empowerment in the rural areas of East Singhbhum district, Jharkhand. It focuses on key dimensions such as economic participation, decision-making power, mobility and access to services. The study also seeks to understand how livelihood activities influence women's empowerment in the rural context.

2. Study Area

East Singhbhum is one of the important districts of Jharkhand, located in the state's south-eastern part. It shares its boundaries with West Singhbhum in the west, Saraikela-Kharsawan in the north and West Bengal in the east. Geographically, the district lies within the Chotanagpur Plateau region and is characterised by undulating terrain, forested uplands and river valleys. The Subarnarekha and Kharkai rivers are the major river systems that support agriculture and local livelihoods in the region (Government of Jharkhand, 2020).

According to the Census of India (2011), East Singhbhum has a diverse population with a significant proportion of Scheduled Tribes and Scheduled Castes. A large part of the population lives in rural areas and depends on agriculture, forest resources and informal work for livelihood. The literacy rate in the district is relatively higher compared to some other districts of Jharkhand, yet a gender gap persists, with female literacy lower than male literacy (Census of India, 2011).

The rural economy of East Singhbhum is largely agrarian, supported by seasonal cultivation, small-scale farming and forest-based activities. In many villages, women actively participate in agricultural work, the collection of minor forest produce and household-based economic activities. However, their contribution often remains unrecognised and control over income and resources is limited. Studies have shown that in tribal-dominated regions, women play a significant role in livelihood activities but have limited access to formal employment and decision-making structures (Sharma, 2015; Singh & Kiran, 2018).

Despite the presence of industrial centres like Jamshedpur in the district, the benefits of industrial development are not evenly distributed across rural areas. Many villages continue to face challenges, including limited access to healthcare, education and financial services. Infrastructure gaps and low levels of awareness further limit women's participation in development processes.

In recent years, government initiatives such as Self-Help Groups (SHGs), rural employment schemes and livelihood programmes have started influencing rural households. These initiatives have created opportunities for women to engage in income-generating activities and improve their socio-economic status. However, the level of participation and benefits varies across villages depending on factors such as education, social background and access to resources (NABARD, 2019).

Thus, East Singhbhum represents a typical rural setting where traditional livelihood practices coexist with emerging development opportunities. The district provides a suitable context for examining the level of women empowerment and its linkage with livelihood and socio-economic conditions at the grassroots level.

3. Data and Methodology

The present study is based on primary data collected from rural areas of East Singhbhum district, Jharkhand. A field survey was conducted during January and February 2026 to

understand different dimensions of women empowerment at the village level. The study follows a micro-level approach, focusing on the lived experiences of women in rural settings.

3.1 Data Sources and Sampling

The study mainly relies on primary data, collected through a structured questionnaire and personal interviews. The questionnaire was designed to capture information related to socio-economic conditions, livelihood activities, decision-making roles, mobility and awareness levels. In addition, field observations and informal discussions were used to better understand local conditions.

Secondary data have been used to support the analysis of the study area and to provide background information. These were collected from sources such as the *Census of India (2011)*, district statistical reports and relevant academic studies.

A multi-stage sampling method was adopted for the study. At first, a few villages were selected from different parts of the district to capture variation in socio-economic conditions. From each selected village, households were chosen randomly.

A total of 140 women respondents were surveyed. All respondents were aged 18 or older. Care was taken to include women from different age groups, educational backgrounds and occupational categories. This helped to ensure that the sample reflects the diversity of rural society in the district.

3.2 Data Collection Technique

Data were collected through face-to-face interviews, which helped obtain reliable, detailed responses. Since many respondents were not comfortable with formal survey methods, the questions were asked in a simple, conversational manner. Local language was used wherever required to make respondents feel comfortable.

The questionnaire included both closed-ended and open-ended questions. In some cases, follow-up questions were asked to clarify responses. This approach helped to capture both quantitative and qualitative aspects of women empowerment.

3.3 Construction of Women Empowerment Index (WEI)

A composite Women Empowerment Index (WEI) was developed to measure the overall level of empowerment. Each response was assigned a score based on its level of empowerment. For example, higher scores were given to responses indicating independence or active participation, while lower scores were assigned to limited or no participation.

The total score for each respondent was calculated by adding all indicator scores and then converting it into a standardised value. This helped compare the levels of empowerment across respondents.

Based on the WEI values, respondents were grouped into three categories: low, medium and high empowerment. This classification provided a clear understanding of the distribution of empowerment levels among rural women in the study area.

3.4 Methods of Analysis

The collected data were analysed using simple statistical methods such as percentage, average and index calculation. Cross-analysis was also carried out to examine the relationship between livelihood and empowerment.

This methodological approach helps to present a clear and realistic picture of women empowerment in the rural areas of East Singhbhum district.

4. Results and Discussion

4.1 Background Characteristics of the Respondents

The basic profile of the respondents shows that a large share of women belongs to the economically active age group. Around 52 percent of the respondents fall within the age group of 21–40 years, followed by 30 percent in the 41–60 age group. Only a small proportion is below 20 or above 60. This indicates that most respondents are actively involved in household and livelihood activities.

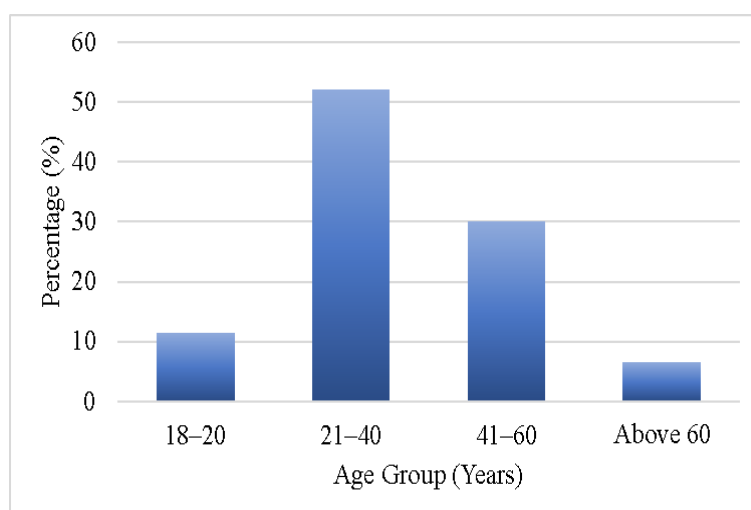


Fig. 1: Age-wise Distribution of Respondents (N = 140)

In terms of education, about 22 percent of the women are illiterate, while 28 percent have primary education. Around 30 percent have completed secondary level and only 20 percent have education beyond that. This shows that although literacy has improved, higher education among rural women is still limited. Similar trends have been observed in rural Jharkhand where gender gaps in education continue to exist (IIPS, 2021).

Table 1. Educational Status of Respondents

Education Level	Number of Respondents	Percentage (%)
Illiterate	31	22.1
Primary	39	27.9
Secondary	42	30.0
Higher Secondary & Above	28	20.0
Total	140	100.0

Most of the respondents belong to nuclear families and household size varies between 4 and 6 members. The occupational pattern shows that about 40 percent of women are engaged mainly in household work, while others are involved in agriculture, daily labour, or small-scale activities.

4.2 Livelihood Status and Economic Participation

Livelihood analysis shows that around 46 percent of women are involved in some form of income-generating activity. These include agricultural work, wage labour, small businesses and SHG-based activities. The remaining women depend mainly on household income.

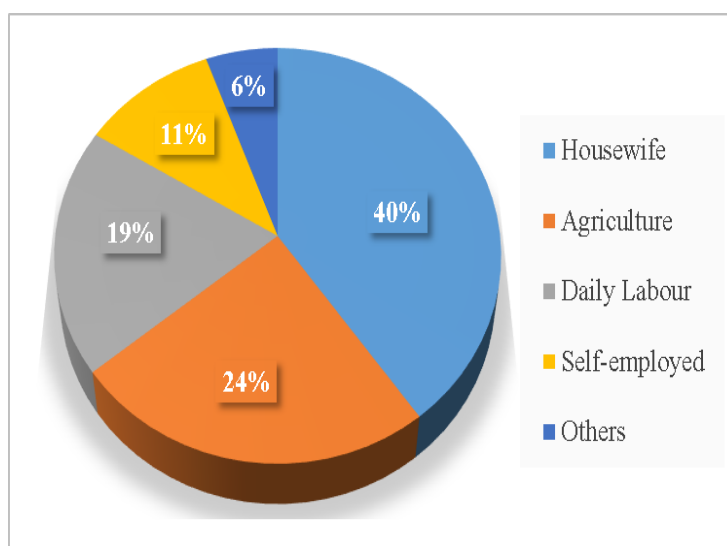


Fig. 2: Occupational Pattern of Respondents

About 62 percent of respondents have access to a bank account, but regular use is limited. Participation in Self-Help Groups is reported by 38 percent of women. Those involved in SHGs show better savings habits and financial awareness. Studies have also highlighted the positive role of SHGs in improving women’s economic condition and confidence (NABARD, 2019).

Table 2. Participation in Income-Generating Activities

Participation Status	Number of Respondents	Percentage (%)
Yes	64	45.7
No	76	54.3
Total	140	100.0

However, income levels remain low and many women earn irregular wages. This limits their financial independence and ability to contribute significantly to household expenses.

4.3 Role in Household and Financial Decisions

Decision-making power among women shows a mixed pattern. About 20 percent of respondents reported making decisions independently in household matters. A larger share, around 48 percent, reported joint decision-making with family members, while 32 percent indicated that decisions are mainly taken by male members.

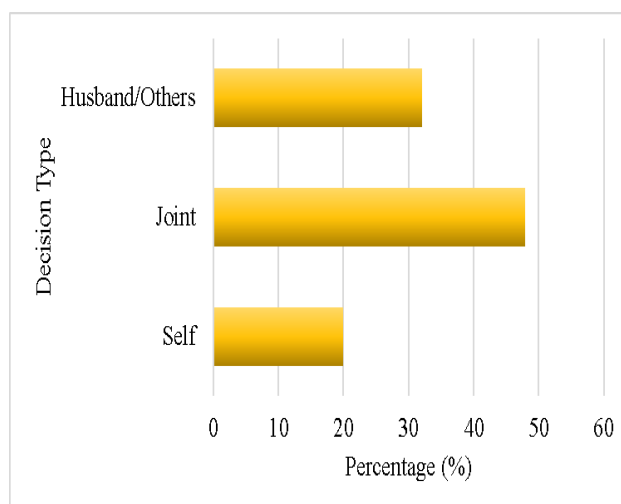


Fig. 3: Decision-Making Pattern in the Household

In financial matters, only 24 percent of women have independent control over income, while others either share control or have limited involvement. This indicates that although women are gradually participating in decision-making, full autonomy remains limited. This finding supports earlier studies that highlight the continued dominance of patriarchal norms in rural India (Panda & Agarwal, 2005).

4.4 Freedom of Movement and Social Engagement

Mobility is an important indicator of empowerment. The study shows that about 44 percent of women can move independently to nearby places such as markets or health centres. Around 36 percent require permission, while 20 percent face restrictions on movement.

Table 3. Mobility Status of Respondents

Mobility Level	Number of Respondents	Percentage (%)
Independent	62	44.3
With Permission	50	35.7
Restricted	28	20.0
Total	140	100.0

Participation in social activities is also limited. Only 25 percent of respondents reported regular participation in community meetings or group activities, while others participate occasionally or not at all. Limited mobility and social exposure reduce opportunities for awareness and empowerment.

4.5 Access to Health Services and Awareness Level

Access to healthcare is relatively better, with around 70 percent of respondents reporting that they can access nearby health facilities when needed. However, awareness of government schemes is relatively low. Only 42 percent of women are aware of schemes related to health, livelihood, or welfare.

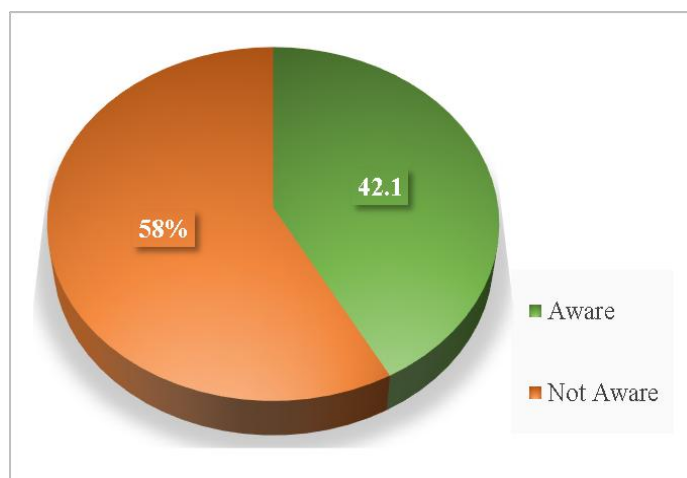


Fig. 4: Awareness of Government Schemes among the respondents (In Percent)

Sanitation practices have improved, with most households using basic sanitation facilities. However, awareness about nutrition, reproductive health and welfare programmes still needs improvement. Findings from NFHS reports also show similar gaps in awareness among rural women (IIPS, 2021).

4.6 Composite Level of Empowerment (WEI Analysis)

The Women Empowerment Index shows that 31 percent of respondents fall under the low empowerment category. Around 47 percent are in the medium category, while only 22 percent are highly empowered.

Table 4. Women Empowerment Index (WEI) Classification

WEI Category	Number of Respondents	Percentage (%)
Low	43	30.7
Medium	66	47.1
High	31	22.1
Total	140	100.0

This distribution indicates that although some progress has been made, a large proportion of women are still moderately empowered. Full empowerment is limited to a smaller group of women with greater access to education, income and social participation.

4.7 Link between Livelihood and Empowerment

A clear relationship is observed between livelihood participation and empowerment. Women engaged in income-generating activities show higher levels of confidence, better decision-making and greater mobility than those who are not working.

Participation in SHGs and small-scale economic activities positively impacts empowerment. Women involved in such activities are more aware of schemes, more active in social groups and more involved in household decisions.

Overall, the results suggest that livelihood opportunities play a key role in improving women empowerment in rural areas. However, factors such as education, social norms and access to resources continue to influence the extent of empowerment.

5. Challenges

5.1 Limited Economic Opportunities

One of the major problems observed in the study area is the lack of stable income opportunities for women. Although some women are involved in agricultural work, daily labor, or small activities, these sources are often irregular and low-paying. A large number of women remain dependent on family income, which limits their financial independence and overall empowerment.

5.2 Low Level of Education and Awareness

Education plays an important role in empowerment, but a significant proportion of women in the study area have only primary or secondary education. Higher education is still limited. Along with this, awareness about government schemes, rights and opportunities remains low. This reduces their ability to take advantage of available programmes. Similar patterns have been reported in rural India, where lack of awareness continues to be a major barrier (IIPS, 2021).

5.3 Restricted Decision-Making Power

The study shows that many women still have limited control over household and financial decisions. In most cases, decisions are taken jointly or dominated by male members.

Independent decision-making is relatively low, which reflects the continued influence of traditional and patriarchal social structures (Panda & Agarwal, 2005).

5.4 Mobility Constraints

Mobility is another important issue. A significant number of women require permission to move outside the home and some face restrictions altogether. This limits their access to markets, healthcare and social participation. Reduced mobility also affects their chances of engaging in economic activities and gaining exposure to new opportunities.

5.5 Weak Participation in Social and Institutional Activities

Participation in community groups and local institutions is relatively low among women. Although Self-Help Groups are available, not all women participate in them. Limited participation reduces their exposure to information, training and collective support systems, which are important for empowerment.

5.6 Inadequate Access to Information and Services

Even where services such as healthcare and welfare schemes are available, many women are not fully aware of them. This gap between availability and utilisation affects their overall well-being. Lack of proper communication and outreach at the village level is one of the key reasons behind this issue.

5.7 Social and Cultural Barriers

Traditional norms and social practices continue to influence women's roles in rural areas. Expectations related to household responsibilities and gender roles often limit their participation in economic and social activities. These cultural factors act as a barrier to achieving full empowerment.

Overall, these problems show that women empowerment in rural East Singhbhum is influenced by multiple factors. Addressing these challenges requires combined efforts focusing on economic, social and institutional improvements.

6. Recommendations

6.1 Strengthening Livelihood Opportunities

There is a clear need to improve income-generating opportunities for women in rural areas. Training programmes related to agriculture, livestock, handicrafts and small businesses can help women earn a stable income. Local markets and support for small enterprises should also be developed to enable women to sell their products more easily. When women have regular income, their role in the household and society improves.

6.2 Promotion of Self-Help Groups (SHGs)

Self-Help Groups should be strengthened and expanded to include more women. These groups provide financial support, savings opportunities and a platform for sharing ideas. Training in financial management and linking SHGs with banks and markets can further improve their

effectiveness. Studies in India have shown that SHGs play a strong role in improving women's confidence and decision-making ability (NABARD, 2019).

6.3 Improving Education and Awareness

Efforts should be made to improve both formal and informal education among women. Adult education programmes and awareness campaigns can help women understand their rights and available government schemes. Information should be provided in simple language and through local platforms such as village meetings and community workers.

6.4 Enhancing Decision-Making Capacity

Women should be encouraged to participate in household and community decision-making. Awareness programmes and group activities can help build confidence and leadership skills. Support from family members and local institutions is also important in improving women's role in decision-making processes.

6.5 Improving Mobility and Access

Improving infrastructure, such as roads, transport and safety measures, can help increase women's mobility. When women can move freely, they can access markets, health services and social networks more easily. This also increases their chances of participating in economic activities.

6.6 Strengthening Health and Welfare Services

Healthcare services should be made more accessible and information about them should be widely shared. Awareness about nutrition, maternal health and sanitation needs to be improved. Local health workers can play an important role in spreading information and supporting women at the village level.

6.7 Encouraging Participation in Community Activities

Women's participation in local groups, village meetings and development programmes should be encouraged. This will help them gain confidence, share experiences and become more aware of social and economic opportunities. Active participation also helps in building collective strength among women.

Overall, these recommendations highlight that women empowerment requires a combined effort. Economic support, education, awareness and social change must work together to improve the condition of women in rural East Singhbhum.

7. Conclusion

The study highlights that women empowerment in the rural areas of East Singhbhum is gradually improving, but the progress remains uneven. A large number of women are still dependent on family income and have limited control over resources. Participation in decision-making is increasing, but full independence is yet to be achieved. Mobility and social participation are also restricted for many women, which affects their access to opportunities and services.

The findings clearly show that livelihood plays an important role in empowerment. Women engaged in income-generating activities, especially through Self-Help Groups and small-scale work, show greater confidence, awareness and participation in household decision-making. At the same time, factors such as education, social norms and access to information continue to influence the level of empowerment.

Overall, the study suggests that women empowerment in rural areas is a gradual process influenced by both economic and social conditions. Improving livelihood opportunities, strengthening local institutions and increasing awareness can help enhance the status of women. A balanced approach that addresses both economic and social aspects is necessary for achieving sustainable development in the region.

However, the study has certain limitations. The analysis is based on data collected from a limited number of villages and respondents, which may not fully represent the district as a whole. The study focuses mainly on selected indicators of empowerment and other aspects, such as psychological or political empowerment, could not be examined in detail. In addition, the data were collected over a short period, which may not reflect seasonal or long-term changes in livelihood and social conditions. Future studies can expand the sample size, include more detailed indicators and adopt a longer time frame to provide a deeper understanding of women empowerment in rural Jharkhand.

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Traditional Water Conservation Techniques of the Munda Tribe

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Abstract: *The Munda Tribe is a major tribe primarily residing in Jharkhand. They share a deep and traditional relationship with the environment. They live in harmony with nature and play an important role in environmental conversation. For example, they conserve forests, water and soil and also use these resources for their livelihood. The Munda community has rich environmental knowledge and they have always preserved this knowledge. They learn from their experiences with nature and pass this knowledge forward. They play an important role in water conservation. They strengthen their socio-economic condition through water conservation. They conserve water sources like rivers, ponds, and wells, and use them carefully. The most important technique in their water conservation methods is building 'dobha'. It is a simple and effective means of storing rainwater. They also use the 'ahar-pyne' and 'medh bandi' techniques. Today, when the entire world is struggling with a water crisis, not only the traditional water conservation techniques of the Munda tribe are relevant but also provide guidance for modern water management. This research paper highlights the water conservation system of the Mundas, its social-cultural significance, and its utility in the present context from the perspectives of both the Indian Knowledge System and formal knowledge systems. Its objective is to underline the importance of indigenous knowledge in promoting effective and sustainable water conservation strategies.*

Keywords *Conservation, Technique, Dobha, Ahar-Pyne, Medh Bandi, Water crisis, Mentor, Sustainable development, Natural resources, Indigenous practices.*

Introduction

Tribes of the world are known for their deep connection with nature. Among them, the Munda tribe of India, which mainly resides in the regions of Jharkhand, Odisha, Bihar, and Chhattisgarh, is especially renowned for its traditional water conservation techniques. They have been living in balance with nature for centuries. Their life is based on water, forest, and land. They use these resources in an extremely balanced and sustainable manner. In their water conservation techniques, a remarkable connection of local knowledge, community participation, and environmental sensitivity can be seen. The economic condition of the Mundas mainly depends on agriculture. Like other tribes, the Mundas also have 'don' and 'tanr' land. "They remain engaged in farming activities for 7 to 8 months of the year"¹, which is

why water conservation becomes essential. The techniques of the Mundas for water conservation can be examined under the following headings.

Findings and Discussion

1. Dobha: - The most important technique of the Mundas for water conservation is building 'dobha'. We also know dobha as small ponds. It exists in both natural and man-made forms. It is built near fields or in low-lying areas so that rainwater collects in it. Dobha is a simple and effective means of storing rainwater. The water from dobha is used for irrigation and for livestock. Sometimes people also bathe in it. Since it is also man-made, its depth is greater. During the rainy season it remains filled with water, and in summer it may dry up. Dobha is constructed through collective voluntary labor. It is built on one person's field, but its use is communal. Fish farming is also done in it. Natural dobha is also used collectively. The edges of a natural dobha have trees, plants, and large stones or rocks. These rocks are used for sitting and for drying clothes. Dobha is a traditional water source of the Mundas and holds great importance. The importance of dobha is not only as a water source, but it is also a community center for the people of the Munda tribe. Dobha is an important part of their life. The number of dobhas in a village is not fixed. It depends on the size and geographical location of the village. Generally, a village may have dozens of dobhas. Among the Mundas, there are also many proverbs and riddles about dobha. One riddle is - 'Moyod dubare jid hai kadakom ko - Dobha.' It means, 'What is it that has live fish and crab in a single bowl?' The answer is Dobha. The Munda people consider water sources to be sacred. Dobha is also a water source, and they have made special rules for its conservation — such as you cannot catch fish in it alone. You cannot spit in the water. After defecation, you cannot wash directly in it. The bathing times for women and men are separate. Menstrual cloths cannot be washed directly in it. If you are using the dobha for the first time, you should first clap or drop a small pebble into the dobha and only then use it, so that if there are any venomous snakes, they move away and you remain safe. Through this collective effort, the water source can be kept safe for a long time. This perspective makes them naturally sensitive toward water conservation.

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2. Ahar-Pyne - The Munda tribe also uses the Ahar-Pyne technique, which is a traditional method of water management. In this technique, 'Ahar' (water collection area) and 'Pyne' (small canals) are included, which collect rainwater and carry it to the fields. This reduces water wastage and ensures that crops receive sufficient water even during drought conditions. Ahar is a ditch dug three to four feet wide along the edges of the field, lengthwise, in which rainwater is stored. Each person may have this ahar in their own field, and from there they can draw water as needed by making a pyne. This technique is individual. The owner can use the water as they wish. Taking water is prohibited for others. The owner may choose to share the water or not.

3. Daari - The residential areas of the Munda tribe generally depend on rain-fed agriculture. There is instability in these areas. "This tribe has always been of an extremely self-respecting and resilient nature"². To deal with this challenge, the Munda community developed many effective water

conservation techniques over time. The main objective of these techniques is to ensure maximum harvesting of rainwater, recharge, and balanced use of water. Their special feature is that they are completely based on local resources, low-cost, and environmentally friendly.

Daari is the most prominent traditional drinking water system of the Munda tribe. It is a natural water source. To maintain the purity of the water, they surround the daari on all sides with large pieces of jamun tree bark. Jamun bark contains tannins. Tannins disrupt the oxidative phosphorylation of parasites in the water, preventing them from producing energy. They absorb organic pollutants, dyes, heavy metals, and toxins. "Research in Bihar found that soaking jamun, mango, and neem leaves in water for a few hours absorbs arsenic, fluoride, and iron"³.

Daari is cleaned from time to time. It is also cleaned collectively by the public. "If any particular individual dirties it, then as a punishment that person alone has to clean the daari"⁴. It provides a source of water throughout the year and keeps water available even during drought. Just like dobha, prohibitions and rules also apply to it.

4. Banda (Pond) - Each village of the Munda tribes has four to five ponds. These ponds are built through public voluntary labour. Therefore, their use is also public. Ponds are a good source for collecting rainwater. Some ponds are built adjacent to the village, while some are built a little farther from the village. Pond water is multipurpose. It is used by people and animals for bathing. Animals quench their thirst from these ponds. Women rely on ponds and rivers for washing clothes. Pond water is used for irrigation. The bathing times for women and men in the pond are fixed separately. In Munda villages, ponds are traditionally the main source for bathing, washing clothes, and irrigation. Even if there are hand pumps or taps in the village, the use of ponds does not stop. Ponds also have fish and snails which are used as food. You can use the fish and snails from the pond for personal use as well. Ponds also hold religious and cultural significance. During the **Roghar** festival, women break a pot at the village boundary and, on their way back, bathe in the pond along the way so that diseases and evil spirits stay away. Pond water is also used in worship and purification. That is, for the Munda community, a pond is not just a source of water, but is also connected to cleanliness, food, culture, and daily discipline. When a newly married couple comes home after marriage, on the second day they have to complete the "**banasna**" ritual in the pond itself. In this way, we see that the pond plays an important role in the life of the Mundas.

5. Medbandi Technique (Contour Bunding) - The Munda tribe living in hilly areas uses the medbandi technique. In this, bunds are made according to the slope of the land, which slows down the flow of rainwater. Due to the medbandi technique, soil erosion is prevented. Water percolates into the ground and the fertility of the land is maintained. This technique is helpful not only in water conservation but also in increasing agricultural production. That is why the Munda tribe practices terraced farming in the mountains. The Munda community makes small pits and channels to allow rainwater to seep into the ground. These pits hold the water and let it gradually seep into the ground, which increases the groundwater level. This technique is especially useful in areas where water flows rapidly.

6. Forest Conservation Technique - The Munda tribe does not limit water conservation to only structural measures, rather they consider forest conservation an important part of water management. They impose a ban on cutting trees around water sources and plant new trees. Trees attract rainfall and help water to percolate into the ground. The life of the Munda community is deeply connected to the forest. For them, the forest is not just wood or a resource, but a deity, ancestors, and life-giver. That is why their forest conservation techniques are based on tradition, religion, and collective discipline.

1. **Sarna** – The Concept of Sacred Grove. Every Munda village has a Sarna site – a part of the forest that is considered the most sacred. **Rules:** Using an axe, cutting trees, plucking leaves, and hunting are completely prohibited in the Sarna forest. Only the village Pahan can take a few flowers or leaves for worship during Sarhul, karma and other festivals. It is believed that the village deities and the spirits of ancestors reside here. Harming it brings calamity upon the entire village. This technique preserves biodiversity hotspots without any formal law.

2. Community Rules and Punishment System - Selective harvesting: Only dry twigs and fallen trees are taken for firewood. Cutting green trees is forbidden. Limited to personal need: Wood/leaves from the forest can be taken only for household use, not for selling. Collective monitoring: The entire village together guards the forest. If anyone breaks a rule, the Panchayat/Hatu Sabha punishes them – with a fine or social boycott. Control on grazing: Animals are prevented from grazing in areas with new saplings so the forest can regenerate.

3. Buru Bonga and Hill Conservation- The Munda people consider hills to be Buru Bonga, i.e., the Mountain Deity. Once a year, Buru bonga is performed, during which a vow is taken to plant trees on the hill and not to set fires. Instead of shifting cultivation, permanent terraced farming is promoted on hills so that the forest does not have to be burned every year.

4. Reforestation through Traditional Knowledge:- Scattering seeds: While walking in the forest, seeds of mahua, karanj, sal, and mango are deliberately dropped. Promoting sacred trees: Trees like sal, karam, and jamun are never cut because they are religiously associated. This naturally maintains a mixed forest. Fire protection: In summer, village youth together create fire-lines – they clear a 10–15 feet wide strip in the forest to prevent fire from spreading.

5. Understanding the Water-Forest Connection-Mundas believe "if the forest remains, water will remain". Therefore, cutting trees in the catchment area of daari, dobha and dams is strictly prohibited. Bamboo and jamun are planted along rivers and streams – jamun roots bind the soil and its leaves help clean the water. The foundation of the Munda's forest conservation technique is the "give before you take" rule. If you take 1 tree from the forest, plant 2. Their technique does not require the forest department or law – community faith and fear itself is the biggest guard. This is why dense sal forests still survive in Munda-dominated areas of Jharkhand.

Suggestion - In today's time, there is a need to integrate these traditional techniques of the Munda tribe with modern science, such as developing the dobha with a scientific design. Using modern water management techniques in the ahar-pyne system can make water conservation even more effective. In the present time, due to climate change and a growing population, the water crisis is increasing day by day. In such a situation, the techniques of the Munda tribe can prove to be extremely useful. Water can be conserved at low cost in a way that is environmentally friendly. This will promote community participation. Due to the impact of modernity and urbanization, the use of these traditional techniques is declining. The younger generation is moving away from them, so it is necessary to document these techniques. The government and institutions should promote them and they should be included in education. The traditional water conservation techniques of the Munda tribe are an excellent example of balance with nature and community cooperation. These techniques not only present a solution to the water crisis but also teach us that the path of development is possible only in harmony with nature.

Conclusion - The biggest feature of the Munda tribe's water conservation technique is community participation. They establish collective ownership of water sources. They have rules for water use, and violation of these rules results in social punishment. Because of these rules, water is not misused and everyone gets water equally.

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Photo plates: Traditional Water Conservation Techniques of the Munda Tribe



Community Resilience and Disaster Management: A Study of the Cyclone-Prone Indian Sundarban

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Abstract: *The Indian Sundarban is one of the most environmentally vulnerable coastal regions of India, frequently affected by cyclones, flooding, embankment breaches and salinity intrusion. The present study examines disaster management and community resilience in the cyclone-prone Sundarban region based on household-level analysis. The study is based on both primary and secondary data. Primary data were collected through a field survey conducted during January and February 2026 from 150 households in selected villages of the Indian Sundarban. The findings reveal that recurrent cyclones such as Aila, Amphan and Yaas have significantly affected local livelihoods, housing, agriculture and infrastructure. Agriculture and fishing were found to be the most vulnerable livelihood sectors due to repeated flooding and salinity intrusion. The study further shows that although local communities face severe environmental and economic stress, they have developed several coping and adaptation strategies, including livelihood diversification, community cooperation, use of cyclone shelters and participation in Self-Help Groups. The Community Resilience Index indicates that most households belong to the medium resilience category, while economically weaker households remain highly vulnerable due to limited resources and inadequate recovery capacity. The study also identifies several challenges, including weak embankments, infrastructure limitations, inadequate preparedness and institutional gaps in disaster management. The paper suggests that strengthening local infrastructure, improving disaster preparedness, promoting sustainable livelihoods and encouraging community participation are essential for enhancing resilience in the Sundarban region.*

Keywords: *Community Resilience; Disaster Management; Indian Sundarban; Cyclones; Climate Vulnerability; Coastal Hazards; Livelihood Insecurity; Adaptation Strategies*

1. Introduction

Disasters have become a major challenge to sustainable development, particularly in coastal regions where environmental vulnerability and population pressure are high. In recent decades, the frequency and intensity of hydro-meteorological disasters such as cyclones, storm surges, floods and coastal erosion have increased significantly due to climate change and environmental degradation. These disasters not only damage infrastructure and livelihoods but also affect the social and economic stability of vulnerable communities. As a result, disaster management and community resilience have gained increasing importance in academic and policy discussions.

Community resilience refers to the ability of individuals and communities to prepare for, respond to and recover from disasters while maintaining their basic functions and livelihoods. In disaster-prone regions, resilience depends on factors such as livelihood security, social networks, awareness, institutional support and access to resources (Adger, 2000). In the Indian context, coastal populations are particularly vulnerable because of poverty, dependence on natural resources and weak infrastructure.

The Indian Sundarban represents one of the most climate-sensitive and hazard-prone regions of the country. Located in the lower Gangetic delta, the region is characterised by low-lying islands, tidal rivers, mud embankments and fragile ecological conditions. The area experiences recurrent cyclones, flooding, embankment breaches, salinity intrusion and riverbank erosion. Major cyclones such as Aila (2009), Amphan (2020) and Yaas (2021) caused severe damage to lives, livelihoods, agriculture and infrastructure across the Sundarban region (Hazra et al., 2020).

The livelihood structure of the Sundarban is highly dependent on climate-sensitive sectors, including agriculture, fishing, forest resource collection and daily wage labour. Frequent disasters disrupt these activities and increase livelihood insecurity. In many cases, repeated disaster impacts force households to adopt coping mechanisms such as migration, borrowing, or occupational change. Women, children and economically weaker groups often face greater vulnerability during and after disasters (Banerjee, 2015).

Several studies have examined environmental vulnerability, climate change impacts and livelihood stress in the Sundarban region. Hazra et al. (2020) highlighted the increasing frequency of extreme climatic events and their ecological consequences. Ghosh and Boykoff (2018) discussed climate adaptation challenges in the deltaic environment, while Das (2019) examined the socio-economic vulnerability of coastal communities. These studies provide valuable insights into environmental and livelihood issues in the Sundarban. However, many existing works focus mainly on physical vulnerability or climate impacts, while fewer studies examine the role of local communities in disaster preparedness and grassroots resilience building.

This creates an important research gap. There is limited micro-level understanding of how local households cope with repeated disasters, what factors shape resilience and how institutional support influences recovery processes in the cyclone-prone Sundarban region. Understanding

these aspects is essential for developing effective disaster management strategies and climate-resilient planning.

Against this background, the present study aims to examine disaster management and community resilience in the Indian Sundarban. The study focuses on the nature of disaster vulnerability, household-level preparedness, adaptation practices and the role of institutions in enhancing resilience among local communities.

2. Study Area

The Indian Sundarbans are located in the southern part of West Bengal, within the lower Ganges delta region. It forms a part of the world's largest mangrove ecosystem and mainly covers areas of the North 24 Parganas and South 24 Parganas districts. The region consists of numerous low-lying islands, tidal rivers, creeks and mud embankments, making it environmentally fragile and highly disaster-prone.

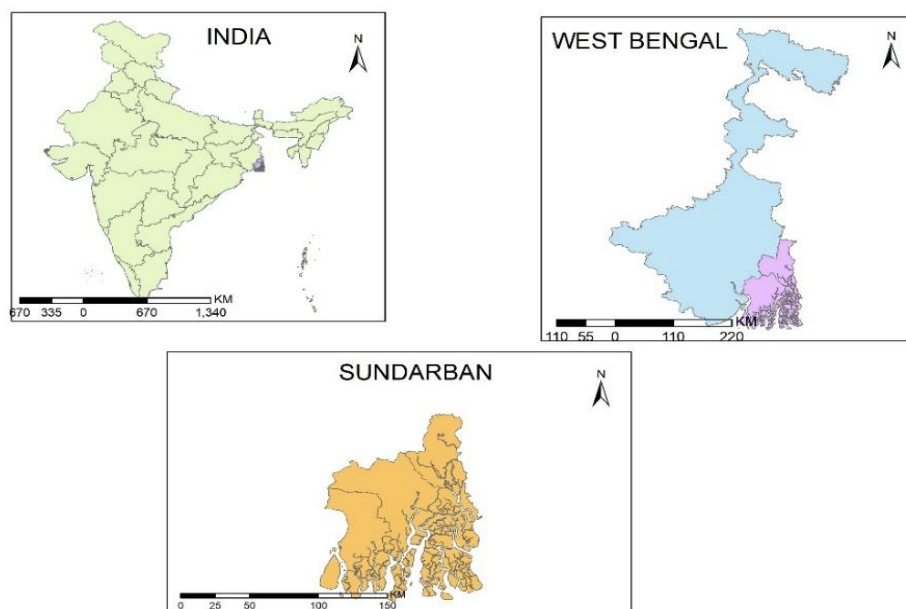


Fig. 1: Location Map of the Study Area

The climate is tropical and humid with heavy monsoonal rainfall and frequent cyclones originating from the Bay of Bengal. Major cyclones such as Aila (2009), Amphan (2020) and Yaas (2021) caused severe damage to houses, embankments, agriculture and livelihoods across the region (Hazra et al., 2020). Riverbank erosion, tidal flooding and salinity intrusion are also common environmental problems.

The economy of the Sundarban is mainly based on agriculture, fishing, forest resource collection and daily wage labour. Since these activities are highly dependent on climate conditions, local communities remain vulnerable to repeated disasters. Poor infrastructure, weak embankments, limited healthcare and inadequate transport facilities further increase disaster risk and livelihood insecurity (Banerjee, 2015).

The Sundarban also has high ecological importance due to its mangrove forests and biodiversity. However, increasing environmental pressure and climate-related hazards have

intensified the vulnerability of both ecosystems and local communities. Therefore, the region provides an important setting for studying disaster management and community resilience in a cyclone-prone coastal environment.

3. Data and Methodology

The present study is based on both primary and secondary data to examine disaster management and community resilience in the cyclone-prone Indian Sundarban. Primary data were collected through a household survey conducted during January and February 2026 in selected villages of the Sundarban region. The survey focused on disaster experience, livelihood loss, preparedness measures, adaptation practices and recovery strategies adopted by local households.

A multi-stage sampling method was used for selecting the respondents. At first, a few cyclone-affected villages were selected from the Indian Sundarban region. From these villages, households were chosen randomly for the survey. A total of 150 households were surveyed to understand community-level patterns of vulnerability and resilience.

Data were collected through structured questionnaires, personal interviews and field observations. Questions were asked regarding cyclone impacts, damage to livelihood and property, access to relief measures, preparedness practices and community support systems. Informal discussions with local residents were also conducted to understand local coping mechanisms and disaster experiences.

Secondary data were collected from government reports, Census publications, disaster management documents and published research articles related to climate change, cyclones and the Sundarban region.

For the analysis, different indicators related to disaster resilience were considered. These included housing condition, livelihood security, awareness level, access to cyclone shelters, early warning response, social participation and recovery capacity. Simple statistical methods such as percentage analysis and comparative interpretation were used to examine the data.

A Community Resilience Index (CRI) was also prepared by combining selected socio-economic and preparedness indicators. Based on the calculated values, households were grouped into low, medium and high resilience categories. This helped to assess the variation in resilience levels among surveyed households.

4. Results and Discussion

4.1 Major Disasters and Environmental Vulnerability

The Indian Sundarban is highly vulnerable to different environmental hazards, particularly cyclones and tidal flooding. The field survey clearly indicates that cyclones pose the most serious environmental threat to local households. Recurrent cyclones such as Aila, Amphan and Yaas caused extensive damage to agriculture, housing, embankments and local infrastructure. In addition, riverbank erosion and salinity intrusion have increased environmental stress in several villages.

The table below shows that 88 per cent of the surveyed households identified cyclones and storm surges as the region's major environmental problems. Around 69.3 per cent reported salinity intrusion, while 64 per cent experienced riverbank erosion. Tidal flooding and waterlogging were also significant environmental issues affecting daily life and livelihood activities.

Table 1. Major Environmental Problems Faced by Households

Environmental Problem	Number of Households	Percentage (%)
Cyclone and Storm Surge	132	88.0
Riverbank Erosion	96	64.0
Salinity Intrusion	104	69.3
Tidal Flooding	89	59.3
Waterlogging	71	47.3

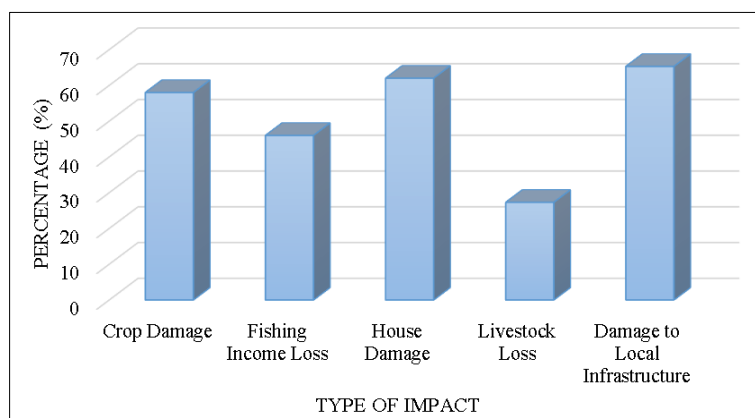
Source: Primary data

These environmental problems have increased livelihood insecurity and reduced local communities' adaptive capacity. Similar findings were also reported in earlier studies on climate vulnerability in the Sundarban region (Hazra et al., 2020).

4.2 Impact on Livelihood and Infrastructure

Disasters have significantly affected livelihood systems in the Sundarban region. Agriculture and fishing, the region's primary sources of livelihood, are highly sensitive to cyclones and salinity intrusion. Repeated disasters reduce crop productivity, damage fishing equipment and create long-term economic stress for rural households.

The figure below shows that 58 per cent of households experienced severe crop damage due to flooding and saline water intrusion. Around 46 per cent reported a decline in fishing-related income after recent cyclones. House damage was reported by 62 per cent of households, while 65.3 per cent mentioned damage to local infrastructure such as roads, embankments and transport facilities.



Source: Primary data

Fig. 2: Impact of Recent Cyclones on Livelihood and Property

The findings indicate that environmental disasters affect both household economy and community infrastructure, making recovery difficult for economically weaker households.

4.3 Household-Level Disaster Preparedness

Preparedness plays an important role in reducing disaster risk. The survey shows that awareness regarding cyclones and evacuation has improved in recent years, mainly due to government initiatives and increased exposure to repeated disasters. However, preparedness levels still vary among households.

The table below shows that 55.3 per cent of households receive early warning information via mobile phones, local announcements, or television. Around 49.3 per cent use cyclone shelters during severe weather events. However, only 38 per cent of households store emergency food and drinking water before disasters, indicating limited preparedness capacity in many villages.

Table 2: Household-Level Disaster Preparedness Measures

Preparedness Measure	Number of Households	Percentage (%)
Receive Early Warning Information	83	55.3
Store Emergency Food and Water	57	38.0
Use Cyclone Shelters	74	49.3
Keep Emergency Medicine	49	32.7
Participate in Preparedness Activities	44	29.3

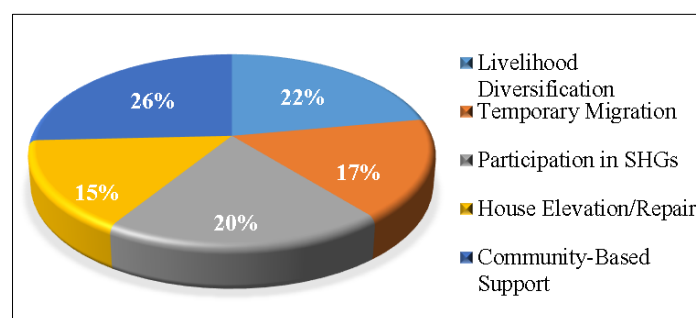
Source: Primary data

The findings suggest that although awareness has increased, resource constraints and infrastructural limitations continue to affect preparedness at the household level.

4.4 Community Resilience and Adaptation Practices

Communities in the Sundarban have developed various coping and adaptation strategies to address recurring environmental disasters. Livelihood diversification, temporary migration and community cooperation are some of the major strategies adopted by local households.

The figure below shows that 45.3 per cent of households adopted alternative livelihood activities to reduce dependence on climate-sensitive occupations. Around 40.7 per cent participated in Self-Help Groups, while 52.7 per cent relied on community-based support during and after disasters. Temporary migration was also reported by several households as a coping strategy during periods of economic crisis.



Source: Primary data

Fig. 3: Adaptation and Coping Strategies Adopted by Households

These adaptation practices reflect the growing importance of local resilience and collective support systems in disaster-prone regions.

4.5 Role of Government and Institutions

Government agencies and local institutions play a crucial role in disaster management and post-disaster recovery in the Sundarban. Cyclone shelters, relief distribution and warning systems have improved community response during recent disasters. However, institutional gaps still remain in several areas.

The table below indicates that 61.3 per cent of households received relief materials after major cyclones, while 48.7 per cent received shelter support. Financial assistance and healthcare support were comparatively lower. Around 18.7 per cent of respondents stated that they did not receive any significant institutional support after disasters.

Table 3: Institutional Support Received after Major Cyclones

Type of Support	Number of Households	Percentage (%)
Relief Materials	92	61.3
Financial Assistance	54	36.0
Shelter Support	73	48.7
Healthcare Assistance	39	26.0
No Significant Support	28	18.7

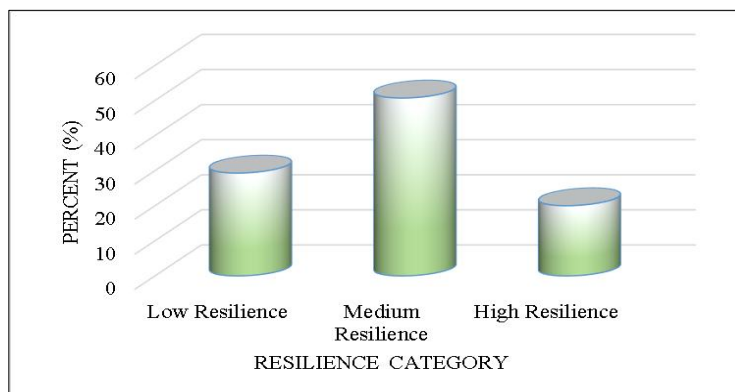
Source: Primary data

The findings highlight that although government interventions have increased, better coordination and faster rehabilitation measures are still needed.

4.6 Community Resilience Assessment

The Community Resilience Index (CRI) was used to assess the resilience level of surveyed households based on livelihood security, preparedness, housing condition, awareness and social participation.

The figure below shows that 50.7 per cent of households belong to the medium resilience category, while 29.3 per cent fall under low resilience. Only 20 per cent of households were found to have high resilience.



Source: Primary data

Fig. 4: Community Resilience Index (CRI) Classification

Households with diversified income sources, greater social participation and better housing conditions showed greater resilience. On the other hand, economically weaker households, mainly dependent on agriculture and fishing, remained highly vulnerable to repeated disasters.

Overall, the findings suggest that community resilience in the Sundarban is gradually improving through adaptation practices and institutional support. However, increasing environmental vulnerability and economic insecurity continue to pose major challenges to long-term resilience in the region.

5. Problems and Challenges

5.1 Weak Embankment and Infrastructure System

One of the major challenges in the Sundarban region is the fragile condition of embankments and rural infrastructure. During cyclones and high tides, embankments are frequently damaged, leading to flooding and salinity intrusion. Poor road connectivity and inadequate transport facilities further create difficulties during evacuation and relief operations. In many villages, healthcare and communication facilities remain insufficient during emergencies.

5.2 Livelihood Insecurity and Poverty

The economy of the Sundarban is highly dependent on agriculture, fishing and forest-based activities, all of which are sensitive to climatic hazards. Repeated cyclones, flooding and soil salinity reduce agricultural productivity and income opportunities. As a result, many households experience economic insecurity and seasonal unemployment. Poor households often lack the financial capacity to recover quickly after disasters.

5.3 Increasing Climate Vulnerability

Climate change has intensified environmental risks in the Sundarban region. Rising sea level, changing rainfall patterns, salinity intrusion and increasing cyclone intensity have increased the vulnerability of local communities. Frequent disasters reduce the ability of households to rebuild and adapt, particularly in economically weaker areas.

5.4 Limited Preparedness and Awareness

Although awareness regarding cyclones has improved in recent years, many households still lack adequate preparedness measures. Some families do not have access to emergency resources, secure housing, or nearby cyclone shelters. In remote villages, access to timely warning information also remains a challenge.

5.5 Institutional and Governance Issues

Government agencies and local institutions play an important role in disaster management, but several problems remain. Respondents reported delays in relief distribution, inadequate compensation and poor maintenance of embankments. Coordination among different institutions is sometimes weak, affecting the effectiveness of disaster response and recovery programmes.

5.6 Social Vulnerability

Women, children, elderly people and economically weaker households face greater difficulties during disasters. In many cases, women have limited access to financial resources and decision-making processes, which affects their coping capacity. Repeated disasters also disrupt education, healthcare and social stability at the community level.

Overall, these challenges show that disaster vulnerability in the Sundarban is not only environmental but also socio-economic and institutional. Strengthening resilience, therefore, requires integrated planning and long-term support at both community and policy levels.

6. Recommendations

6.1 Strengthening Embankments and Rural Infrastructure

There is an urgent need to strengthen embankments across the Sundarban region to reduce flooding and salinity intrusion during cyclones. Durable, climate-resilient embankment systems should be developed through scientific planning and regular maintenance. Improvements to roads, transport facilities, communication networks and healthcare infrastructure are also necessary to support effective disaster response and recovery.

6.2 Improving Early Warning and Preparedness Systems

Early warning systems should be made more accessible at the village level. Warning messages need to reach remote households quickly through mobile communication, local volunteers and public announcement systems. Awareness programmes and mock drills should be organised regularly to better prepare local communities for disasters. Increasing the number and accessibility of cyclone shelters can also reduce disaster risk.

6.3 Promoting Sustainable Livelihood Opportunities

Livelihood diversification is important for reducing economic vulnerability. Dependence on agriculture and fishing alone increases the risk during environmental disasters. Therefore, alternative income opportunities such as poultry farming, handicrafts, eco-tourism, small businesses and skill-based employment should be promoted. Financial assistance and training programmes can help households build more stable livelihoods.

6.4 Encouraging Community-Based Disaster Management

Local communities should be actively involved in disaster management planning and implementation. Community participation improves awareness, preparedness and collective response during emergencies. Self-Help Groups, youth groups and village committees can play an important role in relief distribution, evacuation and awareness activities. Traditional knowledge and local experiences should also be integrated into disaster management strategies.

6.5 Strengthening Institutional Coordination

Better coordination between government agencies, local administration, NGOs and community organisations is essential for effective disaster management. Relief and rehabilitation processes should become faster and more transparent. Regular monitoring of vulnerable areas and proper implementation of disaster management policies can improve long-term resilience in the region.

6.6 Climate-Resilient Development Planning

Development planning in the Sundarban should focus on long-term climate resilience. Policies related to housing, agriculture, water management and infrastructure need to consider increasing climate risks. Mangrove conservation and ecosystem restoration should also be prioritised because mangroves act as natural protective barriers against cyclones and tidal surges (Hazra et al., 2020).

Overall, these recommendations highlight that disaster resilience in the Sundarban requires a combined approach involving infrastructure development, livelihood support, community participation and climate-sensitive planning. Strengthening these aspects can reduce vulnerability and enhance local communities' adaptive capacity.

7. Conclusion

The study highlights that the Indian Sundarban is one of the most disaster-prone coastal regions of India, where environmental vulnerability and livelihood insecurity are closely interconnected. Frequent cyclones, flooding, embankment breaches, riverbank erosion and salinity intrusion have significantly affected the lives and livelihoods of local communities. The findings show that agriculture, fishing and other climate-sensitive occupations remain highly vulnerable to repeated disasters, increasing economic insecurity among rural households.

The study also reveals that local communities have developed diverse coping and adaptation strategies to address environmental stress. Community cooperation, alternative livelihood activities, the use of cyclone shelters and participation in local groups have contributed to improved household resilience. However, resilience levels vary across households depending on income, infrastructure, awareness and institutional support. Economically weaker households remain more vulnerable due to limited resources and inadequate recovery capacity.

Government agencies and local institutions play an important role in disaster management through relief distribution, early warning systems and shelter facilities. Despite these efforts, several challenges, such as weak embankments, infrastructural gaps and delays in rehabilitation, continue to affect the effectiveness of disaster management in the region.

Overall, the study suggests that strengthening community resilience in the Sundarban requires an integrated approach that combines disaster preparedness, sustainable livelihood development, infrastructure improvement and climate-resilient planning. Greater participation by local communities and stronger institutional coordination are necessary to reduce long-term disaster vulnerability in the region.

However, the study has certain limitations. The analysis is based on a limited number of surveyed households and selected villages, which may not fully represent the entire Sundarban region. The study mainly focuses on socio-economic and disaster-related aspects and does not include detailed environmental or geospatial analysis. In addition, the data were collected over a short period and may therefore not capture seasonal variations or long-term changes in resilience patterns. Future research can include larger sample sizes, advanced spatial techniques

and comparative analysis across different islands of the Sundarban to provide a more comprehensive understanding of disaster resilience and climate vulnerability.

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The Life - Changing Impact of Women's Literacy on Poverty Reduction in Paschim Bardhaman: A Study Towards Sustainable Future

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Abstract: *Women's literacy is an important factor influencing poverty reduction and sustainable socio-economic development in India. The present study examines the relationship between women's literacy and poverty reduction in selected areas of Paschim Bardhaman district, namely Barabani, Pandabeswar, Raniganj and Durgapur MC. The study is based on both primary and secondary data. Primary data were collected through a field survey conducted from October to December 2025 covering 220 women respondents from different socio-economic backgrounds. The findings reveal that literacy significantly improves women's participation in economic activities, household decision-making, health awareness and children's education. Educated women were found to have better employment opportunities, higher household income and greater financial participation compared to illiterate respondents. The study also indicates that women from urban-industrial areas such as Durgapur MC showed comparatively higher literacy and socio-economic well-being than women from mining and semi-rural regions. The analysis further highlights that poverty, financial constraints, gender bias and early marriage continue to affect educational attainment among women in several study areas. Despite these challenges, literacy has positively influenced living standards, social confidence and awareness regarding healthcare and sanitation. The study concludes that women's literacy plays a transformative role in poverty reduction and sustainable development. Strengthening female education, skill development and employment opportunities can significantly improve the socio-economic condition of women and contribute to long-term community development in Paschim Bardhaman district.*

Keywords: *Women's Literacy; Poverty Reduction; Women Empowerment; Sustainable Development; Paschim Bardhaman; Socio-Economic Development; Gender Equality; Educational Empowerment*

1. Introduction

Women's literacy is widely recognised as one of the most important indicators of social and economic development. Education not only improves the knowledge and skills of women but also enhances their ability to participate in household decision-making, economic activities and community development. In developing countries like India, where poverty and gender inequality still remain major challenges, women's literacy plays a transformative role in improving the overall quality of life. Literate women are generally more aware of health, sanitation, nutrition and educational opportunities, which ultimately contributes to poverty reduction and sustainable development.

Poverty is not only related to low income but also to limited access to education, healthcare, employment and social opportunities. In many rural and economically backward regions, women often face multiple disadvantages because of gender discrimination, financial constraints and social barriers. Education helps women overcome these limitations by increasing awareness, improving employability and strengthening their social position. Studies conducted in India have shown that women's education significantly influences household income, child education, fertility behaviour and health outcomes (Dreze & Sen, 2013).

In recent decades, the Government of India and different state governments have introduced several schemes to improve female literacy and educational participation. Programmes such as Sarva Shiksha Abhiyan, Beti Bachao Beti Padhao, Kanyashree and adult literacy initiatives have contributed to increasing female enrolment and reducing gender disparity in education. West Bengal, in particular, has made noticeable progress in female education through various scholarship and awareness programmes. However, disparities still exist across regions and social groups, especially in economically vulnerable and industrial-mining areas.

Paschim Bardhaman district presents an interesting context for examining the relationship between women's literacy and poverty reduction. The district is characterised by a mixed socio-economic structure consisting of mining areas, industrial towns and semi-rural settlements. Despite industrial development in areas like Durgapur and Raniganj, many households still experience poverty, unemployment and educational inequality. Women from economically weaker families often face difficulties in accessing higher education and stable employment opportunities.

Several studies have examined the relationship between education and socio-economic development in India. Tilak (2002) highlighted that literacy contributes directly to poverty alleviation by increasing productivity and employment opportunities. Kingdon (2007) observed that female education improves labour force participation and enhances family welfare. Research in West Bengal has also pointed out that women's literacy positively affects health awareness, child education and social empowerment (Chattopadhyay, 2016). However, many earlier studies mainly focused on state-level or national-level analysis, while fewer studies have explored the issue at the district or local level, particularly in the mining-industrial belt of Paschim Bardhaman.

This creates an important research gap. There is limited micro-level understanding of how women's literacy influences poverty reduction, household welfare and sustainable development in different socio-economic settings within the district. The selected study areas, including Barabani, Pandabeswar, Raniganj and Durgapur MC, represent varied economic and educational conditions, making them suitable for examining the role of literacy in social transformation.

Against this background, the present study aims to analyse the impact of women's literacy on poverty reduction in Paschim Bardhaman district. The study focuses on literacy status, economic participation, household decision-making, health awareness and quality of life to understand how education contributes to sustainable socio-economic development among women.

2. Study Area

Paschim Bardhaman district is located in the western part of West Bengal and was formed in 2017 after the division of the former Bardhaman district. The district is one of the major industrial and mining regions of eastern India and is widely known for coal mining, thermal power generation and industrial activities. The Damodar River flows through the district and has played an important role in its industrial growth and settlement development.

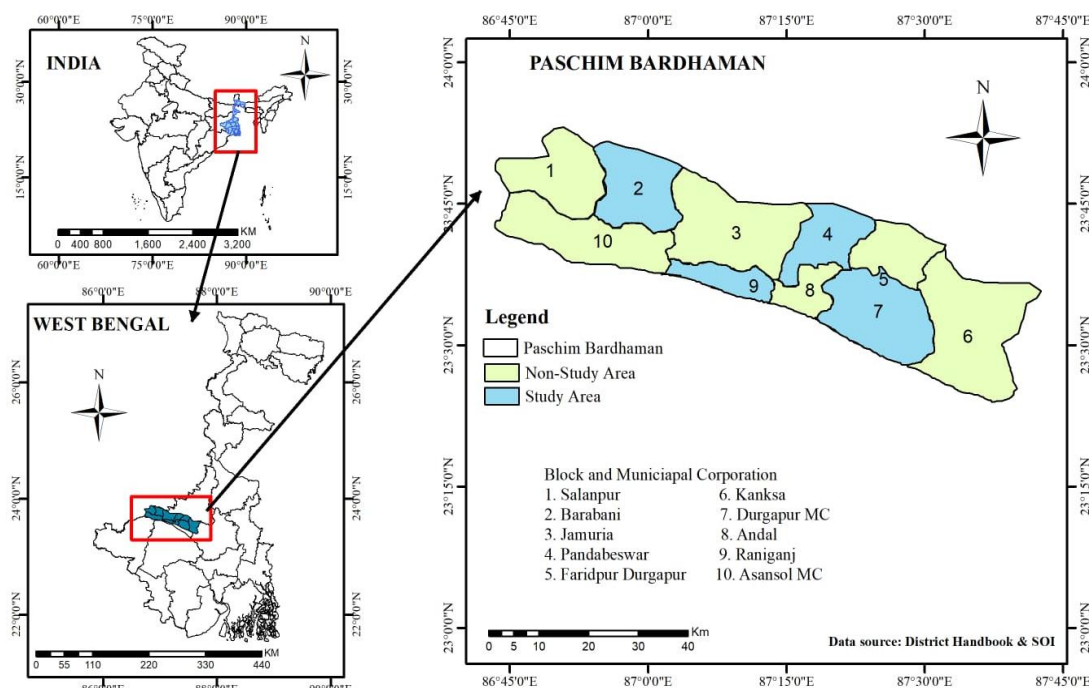


Fig. 1: Location Map of the Study Area

The present study focuses on four selected areas of the district, namely Barabani, Pandabeswar, Raniganj and Durgapur Municipal Corporation (MC). These areas represent different socio-economic settings ranging from mining-dominated semi-rural regions to urban-industrial centres. Barabani and Pandabeswar are mainly associated with coal mining and informal labour

activities, while Raniganj has a mixed mining-urban character. Durgapur MC is comparatively more urbanised with better educational and infrastructural facilities.

According to the Census of India (2011), the district has a relatively high literacy rate, but gender disparity in education and employment still exists. Women in mining and economically weaker areas often face limited educational and employment opportunities. Previous studies have also highlighted that socio-economic inequality and uneven development continue to influence educational attainment in industrial regions of West Bengal (Chattopadhyay, 2016).

The selected study areas, therefore, provide a suitable setting to examine the relationship between women's literacy and poverty reduction under different social and economic conditions.

3. Data Sources and Methodology

The present study is based on both primary and secondary data to examine the relationship between women's literacy and poverty reduction in Paschim Bardhaman district. Primary data were collected through a field survey conducted during October to December 2025 in the selected study areas of Barabani, Pandabeswar, Raniganj and Durgapur MC.

A total of 220 women respondents were surveyed using a structured questionnaire and personal interviews. The respondents were selected through a multi-stage sampling method to ensure representation from different socio-economic backgrounds. The sample distribution included 60 respondents from Barabani, 55 from Pandabeswar, 50 from Raniganj and 55 from Durgapur MC.

The survey collected information related to educational status, occupation, income level, household condition, health awareness, participation in decision-making and children's education. Informal discussions and field observations were also conducted to understand the socio-economic condition of women in the study areas. Secondary data were collected from sources such as the Census of India, District Statistical Handbook, government reports and published research articles related to literacy, poverty and women empowerment.

For analysis, different socio-economic indicators were considered to understand the impact of literacy on poverty reduction. Simple statistical methods such as percentage analysis and comparative interpretation were used for examining the collected data. The study also compares literacy-related socio-economic conditions across the selected study areas to identify variations in women's empowerment and household well-being.

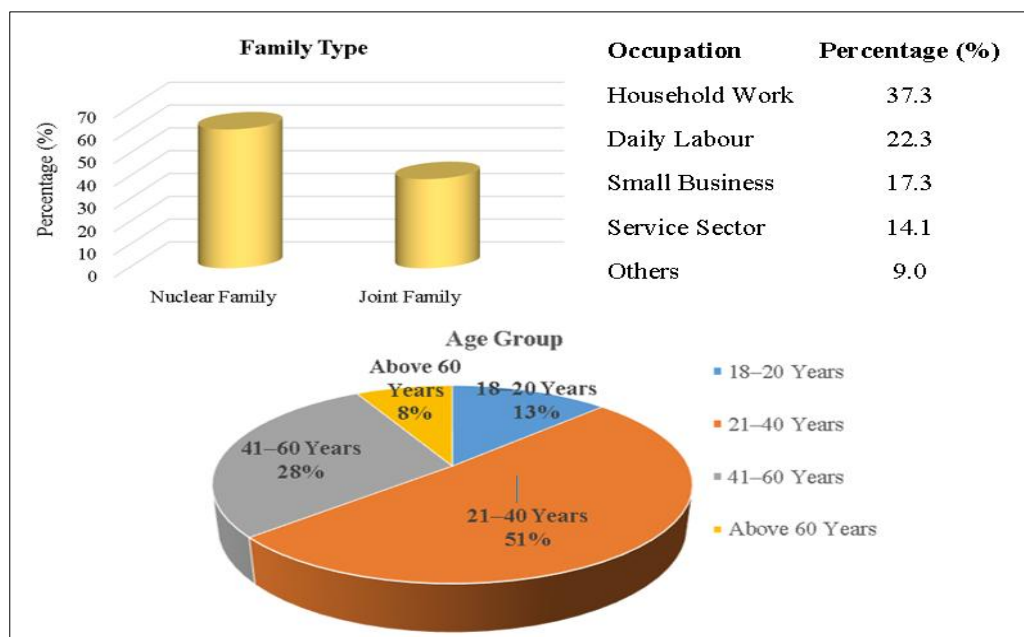
4. Results and Discussion

4.1 Socio-Economic Background of Respondents

The socio-economic profile of the respondents reflects the mixed urban-industrial and mining-based character of the selected study areas. Most of the surveyed women belonged to lower-middle and economically weaker households. Considerable variation was observed in

occupation, family structure and income level across the four study areas. Respondents from Durgapur MC showed relatively better educational and occupational conditions, whereas women from Barabani and Pandabeswar were more dependent on informal labour and household-based activities.

The field survey indicates that a large proportion of respondents belonged to the economically active age group. Women in the age group of 21–40 years formed the largest share of respondents. This age group was found to be more involved in household management, child education and economic participation. Nuclear families were more common in urban areas such as Durgapur MC and Raniganj, while joint family structures were comparatively more visible in mining and semi-rural regions.



Source Primary Data

Fig. 2: Socio-Economic Profile of the Respondents

The above figure clearly shows that household work remains the dominant occupation among women respondents. However, participation in small business and service activities was relatively higher in Durgapur MC and Raniganj due to better educational and economic opportunities. In contrast, women from mining areas were more dependent on irregular wage labour and informal occupations.

Monthly household income also showed considerable variation. Families associated with service and organised sectors generally reported better economic conditions compared to households dependent on mining-related labour activities. The findings suggest that socio-economic inequality still exists within the district despite industrial growth and urbanisation. Similar observations were noted by Chattopadhyay (2016), who highlighted the uneven pattern of educational and social development in industrial regions of West Bengal.

4.2 Literacy Status of Women

Women's literacy is one of the most important indicators of social development and empowerment. The study reveals noticeable variation in literacy levels among the selected study areas. Urban influence, better educational infrastructure and economic opportunities contributed to higher literacy levels in Durgapur MC, whereas comparatively lower educational attainment was observed in Barabani and Pandabeswar.

The field survey indicates that younger women had comparatively better educational attainment than older respondents. This reflects the gradual improvement of female education in recent decades due to government initiatives and increased social awareness. However, educational discontinuation after secondary level remains a major concern among economically weaker households.

Table 1: Educational Status of Respondents

Educational Level	Number of Respondents	Percentage (%)
Illiterate	46	20.9
Primary Education	58	26.4
Secondary Education	59	26.8
Higher Secondary	35	15.9
Graduate & above	22	10.0
Total	220	100.0

Source Primary Data

The above table shows that secondary education forms the largest educational category among respondents. Around 20.9 per cent of women were found to be illiterate, while only a small proportion had graduate-level education. Educational inequality was more visible among women from poor and mining-dependent households. Financial difficulties, early marriage, household responsibilities and lack of educational support were identified as some of the major reasons behind low educational attainment.

The findings also suggest that women's literacy is closely connected with occupational opportunities and social awareness. Educated respondents showed greater participation in employment, decision-making and healthcare-related activities. Similar findings were reported by Kingdon (2007), who observed that female education significantly improves social participation and economic mobility in India.

4.3 Literacy and Economic Participation

The relationship between literacy and economic participation was clearly visible in the study areas. Women with higher educational attainment were found to be more actively engaged in income-generating activities compared to illiterate respondents. Education helped women access better employment opportunities, financial independence and improved household living conditions.

In mining and semi-rural regions, illiterate and less educated women mainly depended on daily wage labour, household work and informal economic activities. In contrast, women with secondary and higher education were more involved in private service, teaching, small businesses and office-related work.

Table 2: Literacy and Income Level of Respondents

Educational Level	Average Monthly Household Income (In Rs.)	Main Occupational Pattern
Illiterate	6,500	Household Work/Daily Labour
Primary Education	8,200	Informal Labour/Small Business
Secondary Education	11,400	Small Business/Service
Higher Secondary	14,300	Service/Private Employment
Graduate & above	18,600	Organised Service Sector

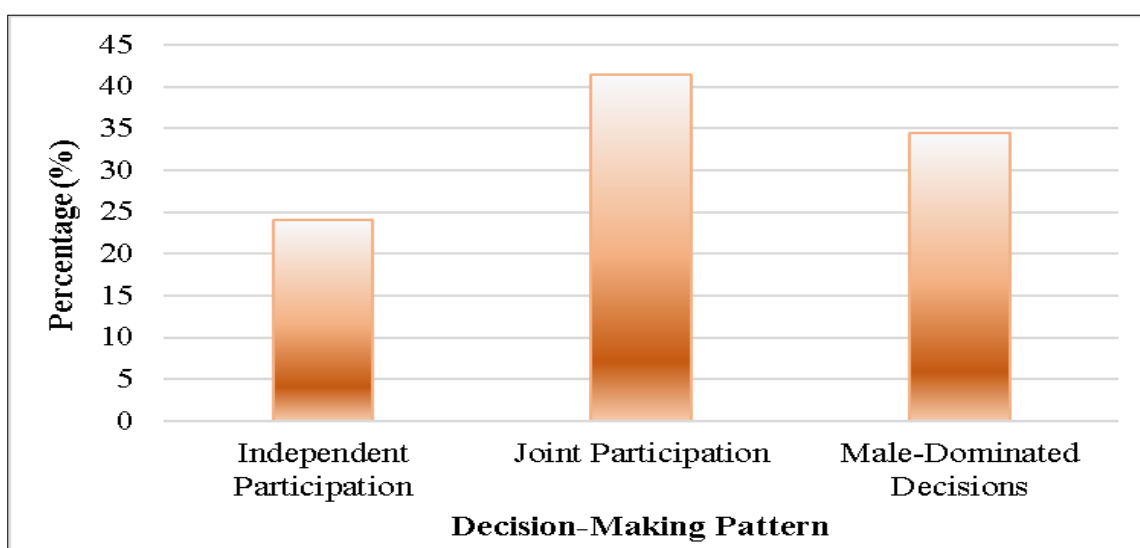
Source Primary Data

The above table clearly indicates that household income increases with higher educational attainment. Respondents with graduate-level education reported nearly three times higher average household income compared to illiterate women. Better education improved employability and economic participation, which ultimately contributed to poverty reduction.

The field survey further revealed that literate women were more confident in handling banking activities, savings and financial planning. Some respondents from Durgapur MC and Raniganj also reported participation in Self-Help Groups and small entrepreneurship activities. These findings support the argument that education acts as a catalyst for economic empowerment and social mobility. Tilak (2002) also emphasised that education contributes significantly to poverty alleviation through increased productivity and employment opportunities.

4.4 Literacy and Household Decision-Making

Women’s literacy has a strong influence on household decision-making and social participation. Educated women were found to have greater involvement in decisions related to children’s education, healthcare, expenditure and social matters. Literacy improves confidence, awareness and communication ability, which strengthens women’s role within the family.



Source Primary Data

Fig. 3: Participation in Household Decision-Making

The above figure shows that 41.4 percent of respondents participated jointly in household decision-making. Independent participation was reported by 24.1 per cent of women, while male-dominated decisions were still common in economically weaker households.

Women with higher education levels showed comparatively greater independence and social participation. They were more likely to discuss financial matters, educational decisions and healthcare needs within the family. On the other hand, illiterate women often remained dependent on male family members for important decisions. The findings indicate that literacy gradually changes traditional gender relations and improves women's social position within households.

4.5 Literacy, Health Awareness and Child Education

The study reveals that women's literacy has a strong influence on health awareness, sanitation practices and children's education. Educated women were generally more aware of hygiene, nutrition, immunisation and healthcare facilities compared to illiterate respondents. They also showed greater interest in ensuring regular schooling and educational support for their children.

During the field survey, it was observed that women with secondary and higher education were more likely to visit healthcare centres, maintain sanitation practices and seek medical treatment during illness. In contrast, respondents with low educational attainment often depended on traditional practices and lacked proper awareness regarding health and nutrition.

Table 3: Literacy and Health Awareness Indicators

Indicators	Number of Respondents	Percentage (%)
Awareness of Child Immunisation	164	74.5
Use of Sanitary Toilets	152	69.1
Awareness of Government Health Schemes	118	53.6
Regular School Attendance of Children	173	78.6

Source Primary Data

The above table indicates that awareness regarding child immunisation was relatively high among respondents. Around 78.6 per cent of women reported regular school attendance of their children, while 69.1 per cent used sanitary toilets. However, awareness regarding government health schemes remained comparatively lower, especially among women from economically weaker households.

The survey also revealed that literate mothers were more concerned about children's education and future employment opportunities. In many households, educated women actively participated in helping children with school activities and maintaining regular communication with teachers. These findings suggest that women's literacy not only improves individual awareness but also contributes to long-term human resource development within families.

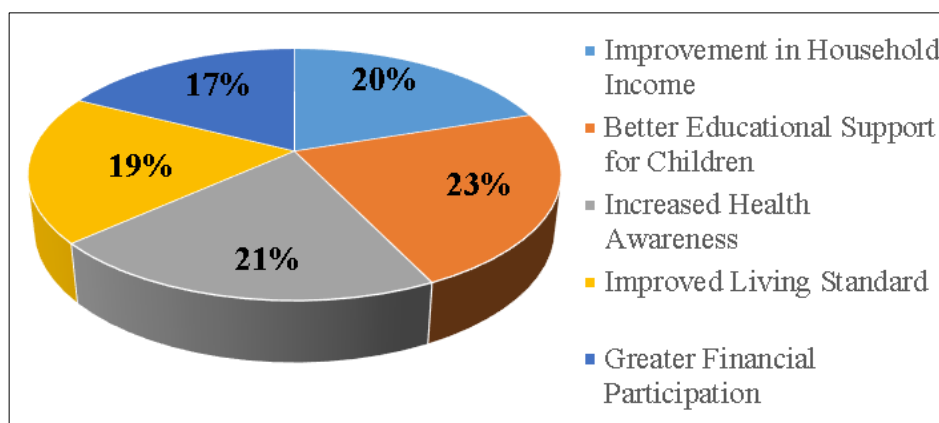
Health and educational awareness were found to be comparatively better in Durgapur MC and Raniganj due to better access to schools, healthcare facilities and communication networks. In Barabani and Pandabeswar, however, poverty and low educational attainment continued to affect healthcare utilisation and educational continuity among children.

Previous studies in India have also shown that female literacy plays a crucial role in improving child welfare and family health conditions (Dreze & Sen, 2013). Thus, women’s education contributes significantly to social development and intergenerational improvement in living conditions.

4.6 Women’s Literacy and Poverty Reduction

The findings of the study clearly indicate that women’s literacy has a significant impact on poverty reduction and improvement in household well-being. Educated women were more capable of participating in income-generating activities, managing household expenditure and supporting children’s education. Literacy also increased awareness regarding savings, healthcare and government welfare programmes.

Households with educated women generally reported better housing conditions, more stable income sources and improved living standards. In contrast, illiterate households were more dependent on irregular labour activities and faced greater economic insecurity. Women with secondary and higher education were also more likely to contribute financially to household expenses, which reduced economic dependency on male family members.



Source Primary Data

Fig. 4: Perceived Impact of Literacy on Household Well-Being

The above figure shows that a large proportion of respondents believed literacy had positively improved household income, health awareness and educational support for children. Around 82.3 per cent reported that literacy helped them provide better educational opportunities for their children, while 68.6 per cent experienced improvement in overall living standards.

The field survey further indicates that educated women were more likely to participate in savings groups, banking activities and small entrepreneurship initiatives. In Durgapur MC and

Raniganj, several respondents reported involvement in private service, tailoring, tuition and small businesses, which helped strengthen household income.

The findings suggest that literacy acts as an important tool for socio-economic mobility and poverty alleviation. Similar observations were made by Tilak (2002), who argued that education directly contributes to poverty reduction by increasing employment opportunities and productivity.

Overall, the study demonstrates that women's literacy has both direct and indirect effects on poverty reduction. It not only improves economic participation but also strengthens social awareness, health practices and long-term family welfare.

4.7 Sustainable Development Perspective

Women's literacy is closely connected with sustainable development because it influences economic growth, social equality, health awareness and community participation. The study findings indicate that educated women are more aware of social responsibilities, environmental cleanliness, healthcare practices and educational opportunities for children. Such awareness contributes to long-term social and economic development within communities.

The survey also revealed that literate women were more interested in stable employment, savings and skill development activities. Many respondents expressed that education increased their confidence and social recognition within society. Women with higher literacy levels were more likely to encourage girls' education and oppose early marriage practices. This reflects the broader social impact of literacy on gender equality and social transformation.

In urban-industrial areas such as Durgapur MC, women showed comparatively better participation in organised employment and social activities. On the other hand, women from mining and semi-rural regions faced greater socio-economic challenges despite gradual improvement in literacy levels. These regional variations highlight the need for balanced and inclusive development planning.

The findings therefore suggest that women's literacy should not be viewed only as an educational issue but also as a major component of sustainable development and poverty reduction. Improving female literacy can strengthen human capital, reduce social inequality and improve the overall resilience of households and communities.

5. Problems and Challenges

5.1 Educational Inequality

Although female literacy has improved in Paschim Bardhaman district, educational inequality still remains a major challenge. Considerable variation exists between urban-industrial and mining-semi-rural areas. Women from Durgapur MC showed comparatively better educational attainment, whereas lower literacy levels were more common in Barabani and Pandabeswar. Financial hardship, lack of educational support and poor awareness continue to affect women's education in economically weaker households.

In several cases, girls discontinue education after the secondary level due to family responsibilities and economic pressure. Access to higher education is also limited for women belonging to low-income families. These inequalities create long-term barriers to socio-economic development and poverty reduction.

5.2 Poverty and Financial Constraints

Poverty remains one of the major obstacles to women's literacy and empowerment. Many families in mining and labour-dependent areas struggle to meet daily household expenses, making education a secondary priority. Women from economically weaker households are often engaged in household work or informal labour activities from an early age.

The field survey revealed that several respondents could not continue higher education because of financial difficulties. In some households, educational expenditure for male children received greater importance compared to girls. Such economic constraints directly affect literacy levels and employment opportunities among women.

5.3 Gender Bias and Social Barriers

Traditional social attitudes and gender bias continue to influence women's educational participation in some study areas. In conservative households, women's role is still largely confined to domestic responsibilities. Limited decision-making power and dependency on male family members reduce educational and economic opportunities for women.

The survey also indicated that women from less educated households often faced restrictions regarding employment, mobility and participation in social activities. Although social attitudes are gradually changing, gender discrimination still affects women's empowerment in several communities.

5.4 School Dropout and Early Marriage

School dropout among girls remains another important challenge, particularly in economically weaker and semi-rural regions. Financial difficulties, household responsibilities and lack of educational motivation contribute to discontinuation of studies. Early marriage was also identified as an important factor affecting female education.

Many respondents stated that girls are often expected to support household work after adolescence, which affects educational continuity. Early marriage further limits opportunities for higher education, employment and financial independence. This creates a cycle where low literacy and poverty continue across generations.

5.5 Limited Employment Opportunities

Although literacy improves employability, suitable employment opportunities for women are still limited in several parts of the district. Women with lower educational attainment mainly depend on informal labour, household work, or low-paid economic activities. Even educated women often face difficulty in obtaining stable and secure employment.

In mining and industrial regions, employment opportunities are largely male-dominated and women's participation in organised sectors remains comparatively low. Lack of skill development and vocational training also limits economic advancement among women.

Overall, these challenges indicate that improving women's literacy alone is not sufficient for sustainable poverty reduction. Educational development must be supported by economic opportunities, social awareness, gender equality and inclusive policy measures to ensure long-term socio-economic transformation.

6. Recommendations

6.1 Strengthening Female Education

Improving women's literacy requires greater attention towards female education at both school and community levels. Educational facilities should be strengthened in mining and economically weaker areas where female literacy remains comparatively low. Financial assistance, free educational materials and scholarship programmes can help reduce school dropout among girls. Awareness campaigns should also be organised to encourage families to support higher education for women.

6.2 Expansion of Adult Literacy Programmes

A significant number of women in the study area still remain illiterate or have only primary-level education. Therefore, adult literacy programmes should be expanded, particularly in semi-rural and labour-dominated regions. Evening learning centres and community-based literacy initiatives can help women continue education even after marriage or household responsibilities.

Special attention should be given to functional literacy, including financial awareness, digital literacy and health education, so that literacy directly contributes to socio-economic improvement.

6.3 Skill Development and Employment Support

Education should be linked with livelihood opportunities to ensure sustainable poverty reduction. Skill development programmes related to tailoring, handicrafts, computer training, entrepreneurship and small business management can improve women's economic participation.

Government agencies and local institutions should create more employment opportunities for educated women, especially in mining and industrial regions where female participation in organised sectors remains limited. Support for Self-Help Groups and small entrepreneurship activities can also strengthen financial independence among women.

6.4 Improvement of Health and Social Awareness

Awareness programmes related to health, sanitation, nutrition and child welfare should be strengthened at the community level. Educated women can play an important role in spreading awareness regarding healthcare practices and educational participation within families.

Community meetings, school campaigns and local women's groups can help increase social awareness and encourage positive social change. Such initiatives are particularly important in economically weaker and socially conservative areas.

6.5 Reducing Gender Bias and Social Barriers

Social attitudes towards women's education and employment need further improvement. Families and communities should be encouraged to provide equal educational opportunities for girls. Awareness programmes against early marriage and gender discrimination can help improve educational continuity among women.

Local administration, schools and community organisations should work together to promote gender equality and women's participation in social and economic activities.

6.6 Inclusive and Sustainable Development Planning

Development planning in Paschim Bardhaman should focus on reducing regional and social inequality in education and employment. Special attention is required in mining and economically backward areas where women continue to face educational and financial disadvantages.

Policies related to literacy, employment, healthcare and women empowerment should be integrated to ensure long-term socio-economic development. Improving women's literacy will not only reduce poverty but also contribute to sustainable community development and social resilience.

Overall, the study suggests that women's literacy should be treated as a major development priority. Combined efforts in education, skill development, employment generation and social awareness can significantly improve the socio-economic condition of women and help build a more sustainable future in Paschim Bardhaman district.

7. Conclusion

The study highlights that women's literacy plays an important role in poverty reduction and socio-economic development in Paschim Bardhaman district. Educated women were found to have better participation in economic activities, greater awareness regarding health and education and stronger involvement in household decision-making. Literacy also contributed to improved living standards, financial participation and child welfare.

The findings show clear variation among the selected study areas. Women from Durgapur MC had comparatively better educational and employment opportunities, while respondents from mining and semi-rural regions continued to face challenges related to poverty, low educational attainment and limited employment opportunities. Gender bias, financial constraints and early marriage were identified as important barriers affecting women's educational progress.

Overall, the study suggests that women's literacy is closely linked with sustainable development and long-term social transformation. Improving female education can strengthen household well-being, reduce poverty and improve community development in the district. However, educational progress must be supported by employment generation, social awareness and inclusive policy measures to ensure sustainable socio-economic improvement.

However, the study has certain limitations. The analysis is based on selected study areas and a limited number of respondents, which may not fully represent the entire district. The study also focuses mainly on socio-economic aspects and does not include detailed statistical or spatial analysis. Future research can include larger sample sizes and more advanced analytical methods for deeper understanding of the relationship between women's literacy and poverty reduction.

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**Environmental Conservation and Sustainable Development in India: A
Multidisciplinary Perspective**

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Abstract: *Environmental conservation and sustainable development have become major global concerns due to increasing environmental degradation, climate change, biodiversity loss and resource depletion. In India, rapid industrialisation, urbanisation, population growth and excessive exploitation of natural resources have intensified environmental challenges in recent decades. The present study examines environmental conservation and sustainable development in India from a multidisciplinary perspective. The paper highlights the importance of integrating Geography, Ecology, Sociology, Economics, Environmental Science, Technology and Public Policy for effective environmental management and long-term sustainability. The study is mainly based on secondary sources including books, government reports, journal articles and policy documents related to environmental conservation and sustainable development. The analysis identifies major environmental challenges in India such as deforestation, biodiversity loss, pollution, climate change, land degradation and unplanned urbanisation. The study further discusses the role of GIS, remote sensing, environmental governance, community participation, renewable energy and environmental education in promoting sustainable environmental management. The findings suggest that environmental problems in India are closely linked with socio-economic development and therefore require integrated and multidisciplinary solutions. Conservation strategies based only on technological or policy approaches are often insufficient without community participation and environmental awareness. The study concludes that sustainable development in India depends on balanced resource utilisation, effective governance, scientific planning and coordinated environmental management practices. Strengthening multidisciplinary research, climate-resilient planning and sustainable resource management will be essential for ensuring ecological sustainability and environmental security in the future.*

Keywords: *Environmental Conservation; Sustainable Development; Multidisciplinary Approach; Environmental Management; Climate Change; Biodiversity Conservation*

1. Introduction

Environmental conservation has become one of the most important global concerns in the twenty-first century. Rapid industrialisation, urbanisation, population growth, deforestation, biodiversity loss and climate change have created serious environmental challenges across the world. In developing countries like India, environmental degradation directly affects natural resources, public health, livelihood systems and sustainable development. As environmental problems have become more complex and interconnected, a multidisciplinary approach is increasingly necessary for understanding and managing these issues effectively.

Environmental conservation refers to the protection, preservation and sustainable management of natural resources and ecosystems for present and future generations. It includes the conservation of forests, wildlife, water resources, biodiversity and ecological balance. Sustainable development, as defined by the World Commission on Environment and Development (1987), focuses on meeting present needs without compromising the ability of future generations to meet their own needs. Therefore, environmental conservation and sustainable development are closely interrelated concepts.

India is one of the most environmentally diverse countries in the world, possessing rich biodiversity, varied climatic conditions, forests, rivers, mountains and coastal ecosystems. At the same time, the country faces severe environmental problems such as air and water pollution, land degradation, climate change, deforestation and loss of biodiversity. Rapid economic growth and increasing resource consumption have intensified environmental stress in many regions of the country. According to Gadgil and Guha (1995), environmental problems in India are deeply connected with social inequality, economic development and resource utilisation patterns.

The complexity of environmental issues cannot be understood through a single discipline alone. Environmental conservation requires the combined contribution of Geography, Ecology, Sociology, Economics, Environmental Science, Public Policy and Technology. For example, climate change involves scientific understanding of atmospheric processes, economic analysis of resource use, geographical assessment of spatial impacts and policy interventions for mitigation and adaptation. Similarly, biodiversity conservation requires ecological knowledge, community participation, legal protection and sustainable resource management.

Several scholars have highlighted the importance of integrated and multidisciplinary approaches in environmental management. Sachs (2015) emphasised that sustainable development can only be achieved through cooperation among environmental, social, economic and institutional sectors. Lele and Menon (2014) observed that environmental governance in India requires both scientific knowledge and community-based participation for long-term sustainability. Similarly, Shiva (2005) argued that ecological conservation and social justice are interconnected in developing countries like India.

Although many studies have discussed environmental conservation and sustainable development, a large number of them focus mainly on individual environmental problems such as pollution, deforestation, or climate change separately. Limited attention has been given to

understanding how different disciplines collectively contribute to environmental management and sustainability in the Indian context. This creates an important research gap in multidisciplinary environmental studies.

Against this background, the present study aims to examine environmental conservation and sustainable development in India from a multidisciplinary perspective. The study focuses on major environmental challenges, the role of different disciplines in conservation and the importance of integrated approaches for sustainable environmental management.

2. Conceptual Framework

2.1 Multidisciplinary Perspective in Environmental Studies

Environmental issues are multidimensional in nature and therefore cannot be understood through a single discipline alone. A multidisciplinary perspective combines knowledge, methods and approaches from different subjects to address complex environmental problems in a comprehensive manner. Environmental studies integrate concepts from Geography, Ecology, Sociology, Economics, Political Science, Environmental Science and Technology to analyse the relationship between human society and the natural environment.

For example, climate change is not only an environmental problem but also an economic, social and political issue. Similarly, biodiversity conservation requires ecological understanding, policy intervention, technological support and community participation. Thus, environmental conservation demands coordinated efforts among various disciplines for effective planning and sustainable management.

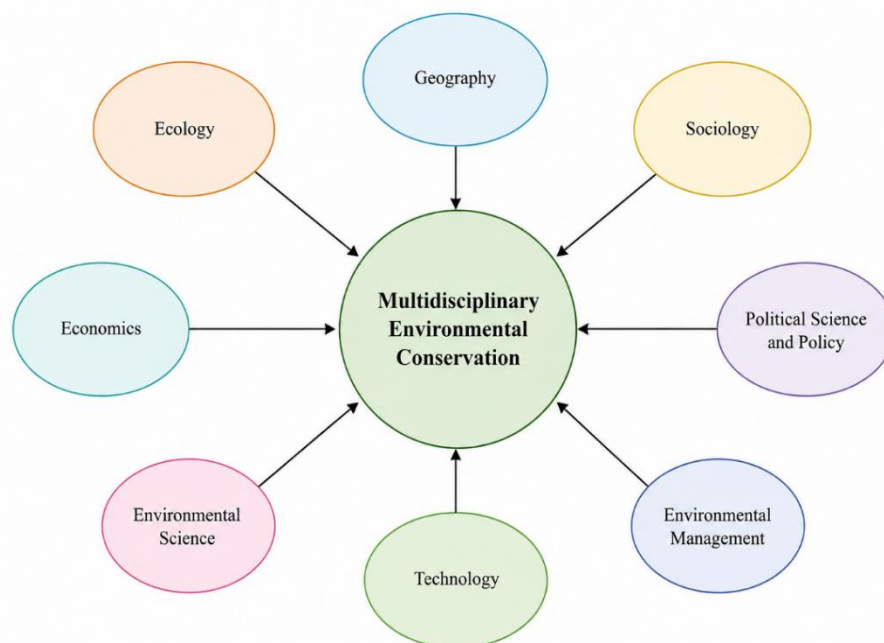


Fig. 1: Conceptual Diagram showing the Multidisciplinary Nature of Environmental Studies

2.2 Environment and Sustainable Development

The concept of sustainable development emphasises the balanced relationship between economic growth, social well-being and environmental protection. Sustainable development aims to ensure resource utilisation without degrading ecological systems or reducing the opportunities of future generations. Environmental conservation therefore forms an essential component of sustainable development planning.

In India, increasing industrialisation, urban growth and resource exploitation have intensified pressure on forests, rivers, biodiversity and land resources. Sustainable management of these resources has become necessary for maintaining ecological balance and improving human well-being. According to Sachs (2015), sustainable development requires integration between environmental sustainability, economic development and social equity.

2.3 Interrelationship between Nature, Society and Economy

Nature, society and economy are closely interconnected systems. Human societies depend on natural resources such as water, forests, minerals and biodiversity for economic activities and livelihood support. At the same time, unsustainable economic practices often lead to environmental degradation and ecological imbalance.

In developing countries like India, environmental degradation directly affects vulnerable communities that depend heavily on natural resources for survival. Deforestation, pollution and climate change reduce agricultural productivity, water availability and livelihood opportunities. Therefore, environmental conservation is not only an ecological necessity but also a social and economic requirement.

The multidisciplinary perspective helps to understand how environmental problems influence social inequality, health conditions, migration and economic development simultaneously. Gadgil and Guha (1995) argued that environmental conflicts in India are strongly linked with resource distribution and socio-economic disparities.

2.4 Importance of Integrated Environmental Management

Integrated environmental management refers to the coordinated use of scientific knowledge, technology, policy measures and community participation for environmental conservation and sustainable development. It promotes cooperation among different sectors and disciplines for effective resource management.

Modern environmental management increasingly depends on tools such as Geographic Information Systems (GIS), remote sensing, environmental impact assessment, climate modelling and biodiversity monitoring. Community participation and local knowledge also play important roles in conservation planning, particularly in forest and rural regions.

Table 1: Role of Different Disciplines in Environmental Management

Discipline	Major Contribution to Environmental Management
Geography	Spatial analysis and resource planning
Ecology	Ecosystem and biodiversity conservation
Sociology	Community participation and social awareness
Economics	Sustainable resource utilisation
Technology	GIS, remote sensing, environmental monitoring
Political Science	Environmental governance and policy formulation
Environmental Science	Pollution control and environmental assessment

The above table shows that environmental management depends on the combined contribution of multiple disciplines. This integrated approach improves understanding of environmental problems and supports more sustainable and effective conservation strategies.

3. Major Environmental Challenges in India

3.1 Biodiversity Loss and Deforestation

India is one of the world’s megadiverse countries, possessing rich biodiversity and varied ecosystems such as forests, wetlands, mountains, deserts, grasslands and coastal regions. However, rapid deforestation, urban expansion, industrial growth, mining and infrastructure development have significantly affected biodiversity in recent decades. Habitat destruction has emerged as one of the major causes of species decline and ecological imbalance.

Large-scale deforestation for agriculture, road construction and industrial activities has reduced forest cover in many regions. Biodiversity hotspots such as the Western Ghats, Eastern Himalayas and Sundarban are increasingly facing environmental pressure due to human activities. According to Shiva (2005), uncontrolled exploitation of natural resources threatens ecological sustainability and weakens the relationship between communities and nature.

Table 2: Major Causes of Biodiversity Loss in India

Causes	Major Impacts
Deforestation	Habitat destruction and species decline
Urbanisation	Land-use change and ecological stress
Industrialisation	Pollution and environmental degradation
Mining Activities	Forest loss and soil degradation
Climate Change	Ecosystem imbalance and biodiversity loss
Overexploitation of Resources	Reduction of natural resource availability

The above table shows that biodiversity loss in India is influenced by both natural and human-induced factors. Sustainable conservation strategies are therefore necessary for protecting ecological balance and natural heritage.

3.2 Climate Change and Global Warming

Climate change has become one of the most serious environmental challenges in India. Rising temperature, irregular rainfall, glacier melting, sea-level rise and extreme weather events have increased environmental vulnerability across different regions of the country. Coastal areas, mountainous regions and drought-prone zones are particularly sensitive to climate-related hazards.

India has experienced increasing frequency of floods, cyclones, heatwaves and droughts in recent decades. Cyclones such as Amphan and frequent flooding events in Assam, Bihar and Kerala highlight the growing impact of climate variability. Climate change also affects agriculture, water resources, biodiversity and public health.

The multidisciplinary nature of climate change requires scientific research, policy planning, technological innovation and community participation for mitigation and adaptation. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), integrated climate-resilient planning is essential for reducing long-term environmental and socio-economic risks.

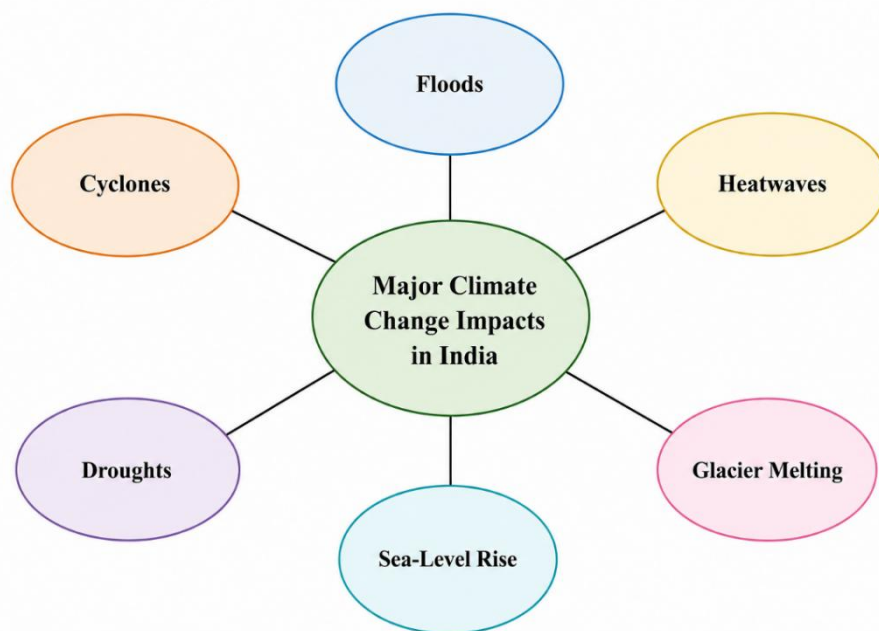


Fig. 2: Major Climate Change Impacts in India

3.3 Water Pollution and Water Scarcity

Water pollution and water scarcity are major environmental concerns in India. Rapid urbanisation, industrial discharge, agricultural chemicals and domestic waste have severely polluted rivers, lakes and groundwater resources. Rivers such as the Ganga, Yamuna, Damodar and Godavari face serious pollution problems due to untreated sewage and industrial effluents.

In addition to pollution, increasing population pressure and excessive groundwater extraction have intensified water scarcity in several parts of the country. Many urban and rural areas face

difficulties in accessing clean drinking water, especially during dry seasons. Water-related environmental problems also affect agriculture, public health and livelihood systems.

Table 3: Major Sources of Water Pollution in India

Sources of Pollution	Environmental Impact
Industrial Effluents	River and groundwater contamination
Domestic Sewage	Waterborne diseases and poor sanitation
Agricultural Chemicals	Soil and water toxicity
Plastic Waste	Aquatic ecosystem degradation
Mining Activities	Heavy metal contamination

The above table indicates that both urban and rural activities contribute significantly to water pollution in India. Effective water management therefore requires scientific planning, pollution control and public awareness.

3.4 Land Degradation and Soil Erosion

Land degradation is another serious environmental issue affecting agricultural productivity and ecological sustainability in India. Soil erosion, desertification, mining activities, deforestation and unscientific agricultural practices have degraded large areas of land across the country.

In regions such as Rajasthan, Jharkhand, Chhattisgarh and parts of the Deccan Plateau, land degradation has affected agricultural activities and rural livelihoods. Excessive use of chemical fertilisers and overgrazing also contribute to declining soil quality.

Environmental conservation strategies such as afforestation, watershed management and sustainable agricultural practices are necessary for reducing land degradation and maintaining soil fertility.

3.5 Urbanisation and Industrial Pollution

Rapid urbanisation and industrialisation have significantly transformed the environmental condition of Indian cities. Increasing population density, vehicular emissions, industrial waste and unplanned urban growth have intensified air, water and noise pollution in metropolitan and industrial regions.

Industrial belts such as Delhi NCR, Mumbai, Kolkata, Durgapur-Asansol and Ahmedabad experience serious environmental stress due to industrial emissions and urban congestion. Air pollution has become a major public health concern in many Indian cities. According to the World Health Organization (WHO, 2018), several Indian cities rank among the most polluted urban centres in the world.

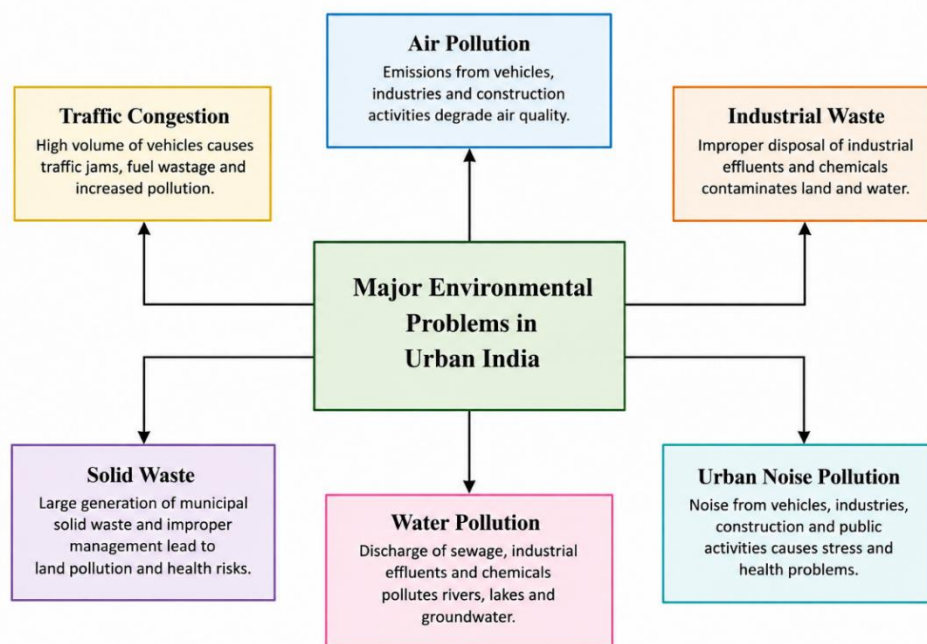


Fig. 3: Major Environmental Problems in Urban India

The increasing environmental challenges associated with urbanisation highlight the need for sustainable urban planning, pollution control measures and integrated environmental management approaches.

4. Role of Different Disciplines in Environmental Conservation

4.1 Geography and Environmental Planning

Geography plays a significant role in environmental conservation through spatial analysis, resource assessment and regional planning. Geographical studies help in understanding the relationship between human activities and the natural environment. Tools such as Geographic Information System (GIS), remote sensing and spatial mapping are widely used for monitoring deforestation, land-use change, urban expansion and environmental degradation.

Geography also contributes to disaster management, climate vulnerability assessment, watershed management and sustainable regional planning. In India, geographical techniques are increasingly used in forest monitoring, flood hazard mapping and environmental impact assessment.

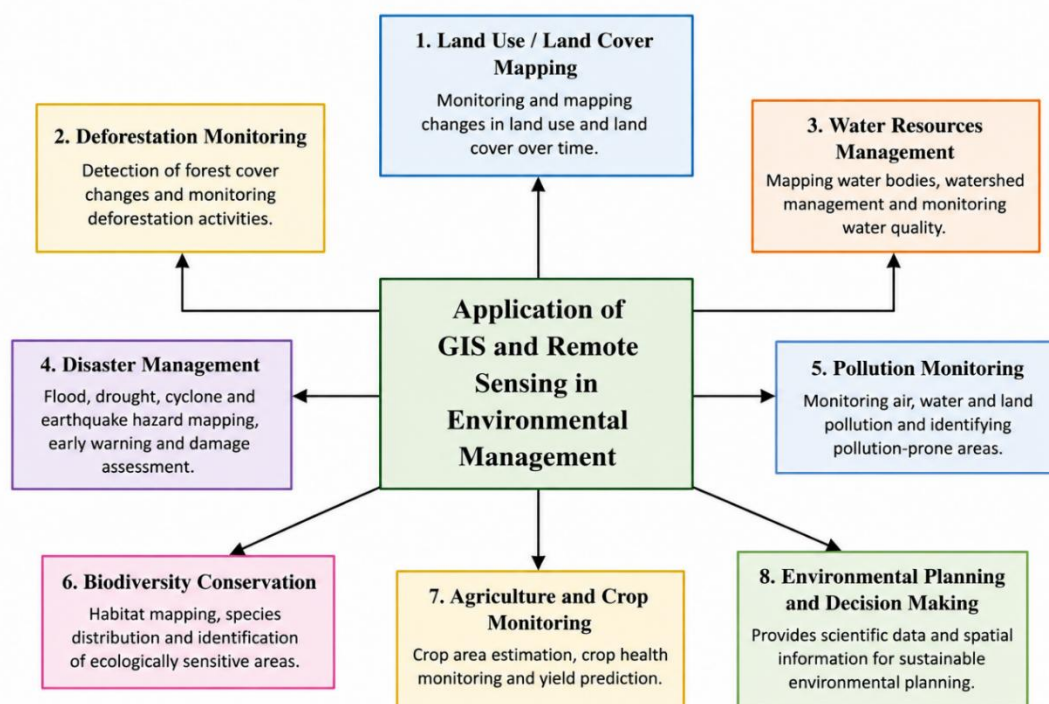


Fig. 4: Application of GIS and Remote Sensing in Environmental Management

4.2 Ecology and Biodiversity Conservation

Ecology is essential for understanding ecosystems, biodiversity, food chains and ecological balance. Ecological studies help identify threatened species, habitat degradation and ecosystem changes caused by human activities. Conservation of forests, wetlands, mangroves and wildlife habitats largely depends on ecological knowledge and scientific monitoring.

India has established several national parks, wildlife sanctuaries and biosphere reserves to protect biodiversity and ecological stability. Ecological research also supports climate adaptation and restoration of degraded ecosystems. According to Gadgil and Guha (1995), ecological conservation in India requires balancing environmental protection with livelihood needs of local communities.

Table 4: Major Ecological Conservation Initiatives in India

Conservation Initiative	Major Objective
Project Tiger	Protection of tiger population
Project Elephant	Conservation of elephants and habitats
Biosphere Reserves	Protection of biodiversity and ecosystems
National Afforestation Programme	Forest restoration
Wetland Conservation Programme	Protection of aquatic ecosystems

The above table highlights some major ecological conservation initiatives undertaken in India for biodiversity protection and sustainable ecosystem management.

4.3 Sociology and Community Participation

Environmental conservation is closely connected with society and community behaviour. Sociology helps in understanding environmental awareness, social attitudes, traditional knowledge and community participation in conservation activities. Local communities play an important role in protecting forests, water resources and biodiversity, especially in rural and tribal regions.

Community-based conservation programmes have shown positive results in many parts of India. Joint Forest Management (JFM) programmes encourage local participation in forest conservation and sustainable resource use. Social awareness campaigns and environmental education also help strengthen public participation in environmental protection.

Traditional ecological knowledge possessed by indigenous communities often contributes significantly to sustainable resource management. Therefore, environmental conservation requires not only scientific approaches but also social cooperation and local involvement.

4.4 Economics and Sustainable Resource Management

Economics contributes to environmental conservation by promoting sustainable use of natural resources and reducing environmental degradation. Environmental economics focuses on resource management, pollution control, ecological valuation and sustainable development planning.

Rapid industrialisation and economic growth often increase pressure on forests, water resources, minerals and biodiversity. Sustainable resource management therefore becomes essential for balancing economic development and environmental protection. Economic tools such as green taxation, pollution control policies, carbon management and renewable energy investment are increasingly used for environmental sustainability.

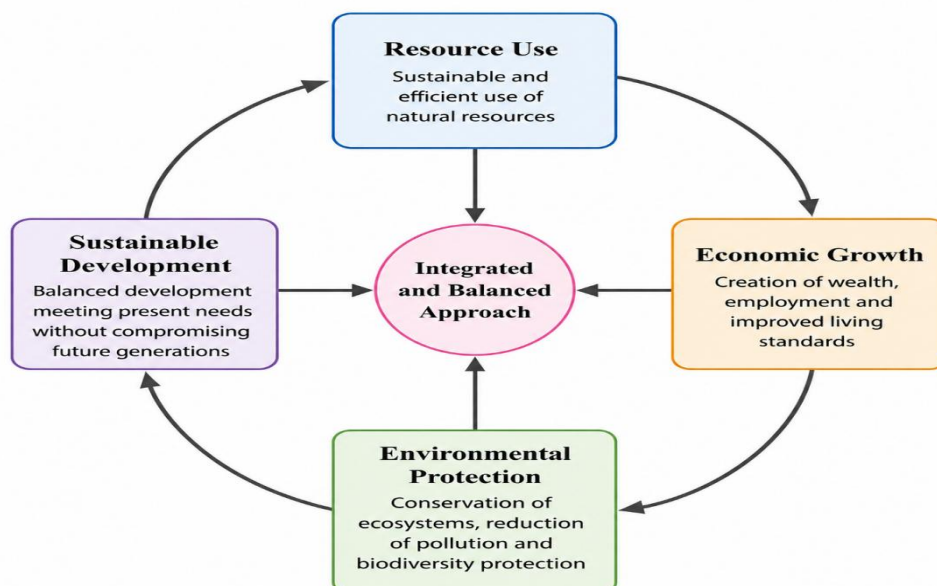


Fig. 5: Relationship between Economy, Resources and Sustainable Development

4.5 Technology, GIS and Remote Sensing

Modern technology has become an important component of environmental conservation and management. Technologies such as GIS, remote sensing, satellite imagery, climate modelling and environmental monitoring systems help analyse environmental changes more effectively.

Remote sensing techniques are widely used for forest mapping, land degradation studies, urban expansion analysis and disaster monitoring. GIS-based planning also supports flood management, biodiversity conservation and watershed development. Technological innovations further contribute to renewable energy development, waste management and pollution control.

India has increasingly adopted digital and technological approaches for environmental planning and natural resource management. The integration of science and technology therefore strengthens environmental decision-making and conservation strategies.

4.6 Public Policy and Environmental Governance

Environmental conservation depends greatly on effective governance and policy implementation. Environmental policies provide legal and institutional frameworks for resource protection, pollution control, biodiversity conservation and sustainable development.

India has introduced several environmental laws and policies such as the Environment Protection Act (1986), Forest Conservation Act (1980), Wildlife Protection Act (1972) and National Action Plan on Climate Change (NAPCC). These policies aim to reduce environmental degradation and promote sustainable development practices.

Table 5: Major Environmental Policies and Acts in India

Policy/Act	Year	Major Focus
Wildlife Protection Act	1972	Wildlife conservation
Forest Conservation Act	1980	Forest protection
Environment Protection Act	1986	Pollution control and environmental protection
Biological Diversity Act	2002	Biodiversity conservation
National Action Plan on Climate Change	2008	Climate change mitigation and adaptation

The above table shows that environmental governance in India involves multiple legal and institutional measures for conservation and sustainable management. However, effective implementation, monitoring and public participation remain important challenges in many regions.

5. Environmental Conservation Practices in India

5.1 Forest and Wildlife Conservation

India has adopted several measures for the conservation of forests and wildlife to maintain ecological balance and biodiversity. Forests play an important role in climate regulation, soil conservation, water management and habitat protection. However, increasing deforestation and habitat destruction have threatened many plant and animal species across the country.

To address these challenges, the Government of India has introduced various forest and wildlife conservation programmes. Protected areas such as national parks, wildlife sanctuaries and tiger reserves have been established for biodiversity protection. Programmes like Project Tiger and Project Elephant have contributed significantly to wildlife conservation and habitat management.

5.2 Protected Areas and Biosphere Reserves

Protected areas are important tools for conserving biodiversity and maintaining ecosystem stability. India has developed a large network of protected regions including biosphere reserves, national parks, conservation reserves and community reserves. These protected areas help conserve endangered species, forests, wetlands and ecological habitats.

The Sundarban Biosphere Reserve, Nilgiri Biosphere Reserve and Nanda Devi Biosphere Reserve are some important examples of conservation initiatives in India. These regions protect biodiversity while also supporting research, ecological monitoring and sustainable livelihood practices.

Table 6: Major Protected Areas and Biosphere Reserves in India

Protected Area/Biosphere Reserve	State/Region	Major Importance
Sundarban Biosphere Reserve	West Bengal	Mangrove ecosystem and Royal Bengal Tiger
Kaziranga National Park	Assam	One-horned rhinoceros conservation
Gir National Park	Gujarat	Asiatic lion habitat
Nilgiri Biosphere Reserve	South India	Rich biodiversity and forest ecosystem
Nanda Devi Biosphere Reserve	Uttarakhand	Himalayan biodiversity conservation

The above table shows that India possesses diverse protected ecosystems which contribute significantly to biodiversity conservation and ecological sustainability.

5.3 Community-Based Conservation Practices

Community participation has become an important component of environmental conservation in India. Local communities, especially tribal and rural populations, have traditionally depended on forests, rivers and natural resources for livelihood and survival. In many regions, local knowledge and traditional conservation practices have helped maintain ecological balance.

Joint Forest Management (JFM) programmes encourage cooperation between forest departments and local communities for forest protection and sustainable resource use. Community participation has also been effective in watershed management, wetland conservation and biodiversity protection.

The Chipko Movement in Uttarakhand is one of the well-known examples of community-based environmental conservation in India. The movement highlighted the importance of public participation and environmental awareness in protecting forest resources.

5.4 Environmental Education and Awareness

Environmental education plays a major role in promoting sustainable development and conservation awareness among people. Educational institutions, government agencies, NGOs and media organisations contribute to spreading environmental awareness related to pollution, climate change, biodiversity and sustainable resource management.

In India, environmental education has been introduced at different educational levels to increase awareness among students and communities. Campaigns related to cleanliness, waste management, afforestation and water conservation have also improved public participation in environmental activities.

Awareness programmes are especially important in urban and industrial regions where environmental pollution and resource consumption are increasing rapidly. Educated and informed communities are more likely to participate in sustainable environmental practices and conservation initiatives.

5.5 Sustainable Development Goals and India

The Sustainable Development Goals (SDGs) adopted by the United Nations provide a global framework for sustainable development and environmental protection. Several SDGs are directly related to environmental conservation, including climate action, clean water and sanitation, life below water and life on land.

India has undertaken various programmes and policy initiatives to achieve sustainable development goals through renewable energy development, afforestation, climate adaptation, biodiversity conservation and pollution control measures. Programmes such as Swachh Bharat Mission, National Solar Mission and Namami Gange reflect efforts towards environmental sustainability and resource management.

Table 7: Major SDGs Related to Environmental Sustainability

SDG Number	Goal	Environmental Relevance
SDG 6	Clean Water and Sanitation	Water resource protection
SDG 7	Affordable and Clean Energy	Renewable energy development
SDG 11	Sustainable Cities and Communities	Sustainable urban planning
SDG 13	Climate Action	Climate change mitigation
SDG 14	Life Below Water	Marine ecosystem conservation
SDG 15	Life on Land	Forest and biodiversity conservation

The above table indicates that environmental conservation is closely linked with global sustainable development goals and long-term ecological security.

6. Challenges to Sustainable Environmental Management

6.1 Population Pressure and Resource Depletion

Rapid population growth has increased pressure on forests, water resources, land and energy in India. Expansion of settlements, agriculture and infrastructure has accelerated environmental degradation and resource depletion in many regions.

6.2 Industrialisation and Environmental Pollution

Industrialisation has contributed to economic growth but has also intensified air, water and soil pollution. Mining, thermal power plants, manufacturing industries and urban-industrial expansion have created serious ecological problems in several parts of the country.

6.3 Deforestation and Biodiversity Loss

Deforestation, habitat destruction and overexploitation of natural resources continue to threaten biodiversity in India. Forest clearance for agriculture, mining and infrastructure development has reduced ecological stability and endangered many plant and animal species.

6.4 Climate Change and Environmental Vulnerability

Climate change has increased the frequency of floods, droughts, cyclones, heatwaves and other environmental disasters in India. These climatic changes affect agriculture, water resources, biodiversity and livelihood systems, especially in vulnerable regions.

6.5 Weak Policy Implementation and Governance Issues

Although India has several environmental laws and conservation policies, weak implementation and inadequate monitoring often reduce their effectiveness. Illegal mining, pollution and environmental degradation continue in many areas because of administrative and institutional limitations.

6.6 Lack of Environmental Awareness

Limited public awareness regarding pollution control, waste management, biodiversity conservation and sustainable resource use remains a major challenge. Environmental education and community participation are still insufficient in many rural and urban regions.

6.7 Urbanisation and Unplanned Development

Rapid urbanisation has increased environmental stress in Indian cities through pollution, waste generation, traffic congestion and loss of green spaces. Unplanned urban growth often creates long-term ecological and public health problems.

Overall, sustainable environmental management in India faces ecological, social, economic and institutional challenges. Addressing these issues requires integrated planning, effective

governance, public awareness and multidisciplinary approaches for long-term environmental sustainability.

7. Strategies and Recommendations

7.1 Strengthening Multidisciplinary Environmental Research

Environmental problems are complex and interconnected. Therefore, research and environmental planning should involve multiple disciplines such as Geography, Ecology, Sociology, Economics and Environmental Science. Integrated research can improve understanding of climate change, biodiversity loss, pollution and resource management from different perspectives.

7.2 Sustainable Resource Management

Natural resources such as forests, water, minerals and land should be utilised in a sustainable manner to reduce environmental degradation. Afforestation, watershed management, rainwater harvesting and eco-friendly agricultural practices can help maintain ecological balance and improve long-term resource sustainability.

7.3 Promotion of Renewable Energy

Increasing use of renewable energy sources such as solar and wind energy is essential for reducing pollution and greenhouse gas emissions. Expansion of clean energy infrastructure can support environmentally sustainable economic development and reduce dependence on fossil fuels.

7.4 Environmental Education and Public Awareness

Environmental awareness should be strengthened through educational institutions, media, NGOs and community programmes. Awareness regarding pollution control, biodiversity conservation, waste management and climate change can encourage environmentally responsible behaviour among people.

7.5 Community Participation and Local Governance

Local communities should actively participate in environmental conservation and resource management activities. Community-based conservation programmes and local governance institutions can improve environmental protection and strengthen sustainable development at the grassroots level.

7.6 Strengthening Environmental Policies and Climate-Resilient Planning

Effective implementation of environmental laws and policies is necessary for sustainable environmental management. Climate-resilient planning, disaster preparedness, pollution control and sustainable urban development should be given greater importance in environmental governance and development planning.

Overall, environmental conservation and sustainable development in India require coordinated efforts involving science, technology, policy and community participation. A multidisciplinary

approach is essential for achieving long-term ecological sustainability and environmental security.

8. Conclusion

Environmental conservation and sustainable development are closely interconnected and have become major concerns in India due to increasing environmental degradation, climate change, pollution and resource depletion. The study highlights that environmental problems are multidimensional in nature and therefore require a multidisciplinary approach involving Geography, Ecology, Sociology, Economics, Technology and Environmental Policy.

The analysis shows that India faces serious challenges such as biodiversity loss, deforestation, industrial pollution, climate vulnerability and unplanned urbanisation. These environmental problems affect not only ecosystems but also human health, livelihood and socio-economic development. The study further emphasises that environmental conservation requires scientific planning, community participation, effective governance, environmental awareness and sustainable resource management.

The paper also points out that protected areas, renewable energy development, environmental education and climate-resilient planning are important for achieving sustainable development. The integration of modern technologies with local knowledge and community participation can strengthen long-term environmental management in India.

Overall, the study suggests that sustainable environmental management can only be achieved through coordinated and multidisciplinary efforts at different levels. Strengthening environmental governance, public awareness, interdisciplinary research and sustainable development practices will be essential for ensuring ecological balance and environmental security in the future.

However, the study has certain limitations. The paper is mainly conceptual and based on secondary sources of information. It does not include detailed field-based analysis or advanced statistical methods. Future studies may incorporate regional case studies and empirical investigations for deeper understanding of environmental conservation and sustainable development in India.

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**The Status of Women's Empowerment Through Workforce Participation
in Jharkhand Over the Past Decade**

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Abstract: Female labour force participation is a crucial indicator of women's economic empowerment and overall economic development. But women's participation rates vary considerably across countries for various reasons. While the Indian economy is expanding rapidly, women's workforce participation is declining. In India, the male work participation rate (WPR) is about 53.3%, whereas the female WPR is approximately half, at 25.5%, according to the 2011 Census. Similar to India, Jharkhand has a male workforce participation rate of approximately 53–54% and a female workforce participation rate of 25–26%. This paper examines trends and patterns in the women's employment structure in Jharkhand over the years, focusing on their influence on women's empowerment, particularly among tribal women. We all know that Jharkhand is a tribal dominated state, and tribal women play a crucial role in the Jharkhand economy. This paper is based on qualitative and quantitative data collected from secondary sources. The data used in this study are from the Periodic Labour Force Survey (PLFS) across all available rounds (2017-18 to 2022–2023), the 2011 census of India, Jharkhand Economic Survey, recent articles, etc. The research indicates significant disparities in labour force participation between India and Jharkhand. The ongoing study displays the findings through multiple tables and graphs. This research highlights the reasons for reduced female workforce participation and indicates how tribal women differ from others in Jharkhand.

Keywords: Empowerment; Workforce Participation; Tribal Women; Economic Development; Census 2011; PLFS

1. Introduction

Gender equality and women's empowerment are integral to the Sustainable Development Goals. Goal 5 focuses on closing the gender gap and providing equal opportunities for all. Women and girls represent half of the world's population; therefore, half of the world's

potential lies in them. However, gender inequality persists everywhere, which stagnates societal progress. From the past to the present, much evidence points to the fact that women have been exploited and discriminated against in many ways. In Indian patriarchal society, women have often been forced to play a secondary role within their households. They do not always have the right to make decisions on their own. The government has introduced many policies, legal rights, and schemes to promote women's empowerment. True women's empowerment can be achieved only through women's participation in the workforce.

The researcher emphasised that having access to resources (material, human, and social) is an obligatory precondition for empowerment, as resources increase the ability to exercise choice (Naila Kabeer, 1999). Berta Esteve-Volart (2004) examines the social norms and restrictions prevalent in society that constitute the primary obstacles to women's employment. Many times, women participate in economic activities, but these activities remain unrecognised and undervalued. Ellina Samantroy (2020) concludes that women's workforce participation in India is declining due to increased domestic responsibilities. In most states in India, female participation has grown faster in rural areas among married women, but in some states, the presence of children has dampened the growth of female workforce participation (Shamika Ravi and Mudit Kapoor 2024). In India, gender inequalities exist across every sphere, including agriculture, occupations, education, health, and politics (I. Sundar 2017). Without the eradication of these inequalities, women can never achieve empowerment. Swati Dutta (2016) highlights that more women are engaged as unpaid agricultural labourers as household agricultural landholding increases. A similar kind of scenario is found in Jharkhand. Women are primarily employed in low-paid jobs, such as casual labour and self-employment. Tanuka Endow (2022) found, through her primary survey database, that workforce participation in rural districts of Jharkhand is comparatively low, and a significant gender gap exists between men and women. The majority of women in Jharkhand have a medium level of empowerment. Various factors, including marriage, education, occupation, and annual income, influence empowerment. (Sudha Suman and Jhanara 2024). Sudha Kumari and Renu Bose (2024) observe, based on their survey, that women employed in government organisations are more empowered than those in non-government organisations, because work in government organisations is more secure.

Based on the existing literature, we find that most studies focus either on women's workforce participation or on women's empowerment separately, and fewer studies have examined trends in women's workforce participation and their influence on women's empowerment over the past years in a state like Jharkhand. The present study examines women's workforce participation and its influence on empowerment together, and analyses the trends and extent of women's workforce participation in Jharkhand over the past years. The research area of this study is Jharkhand. The reason for choosing Jharkhand is that it is a tribal-dominated and underprivileged state, whose socio-economic structure is quite different from that of other states in India.

2. Data Sources and Methodology

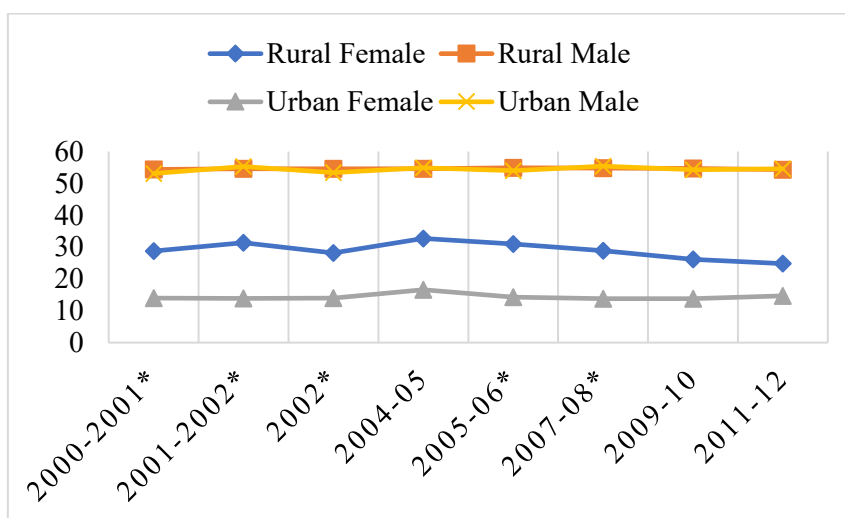
The present study is based entirely on secondary data sources. The data have been collected from the following secondary sources:

- Census of India, 2011
- Periodic Labour Force Survey (PLFS) reports from 2017–18 to 2025–26
- Jharkhand Economic Survey, 2025
- Scholarly books related to women’s studies, labour economics, and empowerment
- Peer-reviewed journals
- Academic research articles
- Government reports and publications
- Credible websites and online databases

This study uses both qualitative and quantitative research methods. The data were systematically sorted, organised, and analysed. Tables, charts, and diagrams were created in MS Excel to clearly show the results. These visuals make it easier to see trends, comparisons, and patterns about female labour force participation and women’s empowerment.

3. Main Findings and Discussions

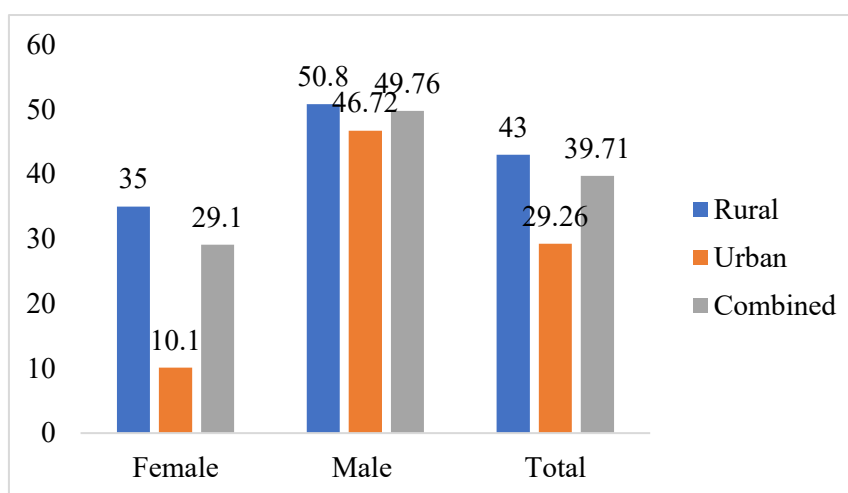
According to the 2011 Census, 25.51% of women in India participate in the workforce, compared to 53.26% of men. The rural sector has a slightly higher female participation rate, about 25%, while the urban rate is around 15%. Over time, female participation has decreased in rural areas but stayed about the same in urban areas. Male participation rates have not changed much in either area. Fig 1 shows workforce participation rates in India from the 2001 and 2011 censuses for both rural and urban areas. While male participation remains steady, a significant gender gap persists in workforce participation. This is because female labour force participation, though improving over the years, still lags behind male participation



Source: Census 2011

Fig. 1: Trends in Workforce Participation in India

A similar scenario is also found in Jharkhand. If we look at fig 2, we see that, according to the Census 2011, Jharkhand’s workforce participation is also not up to par. About 29 per cent of females are engaged in the workforce, with 35 per cent in rural areas compared to 10 per cent in urban areas.



Source: Periodic Labour Force Survey (PLFS), Ministry of Statistics and Programme Implementation, GoI

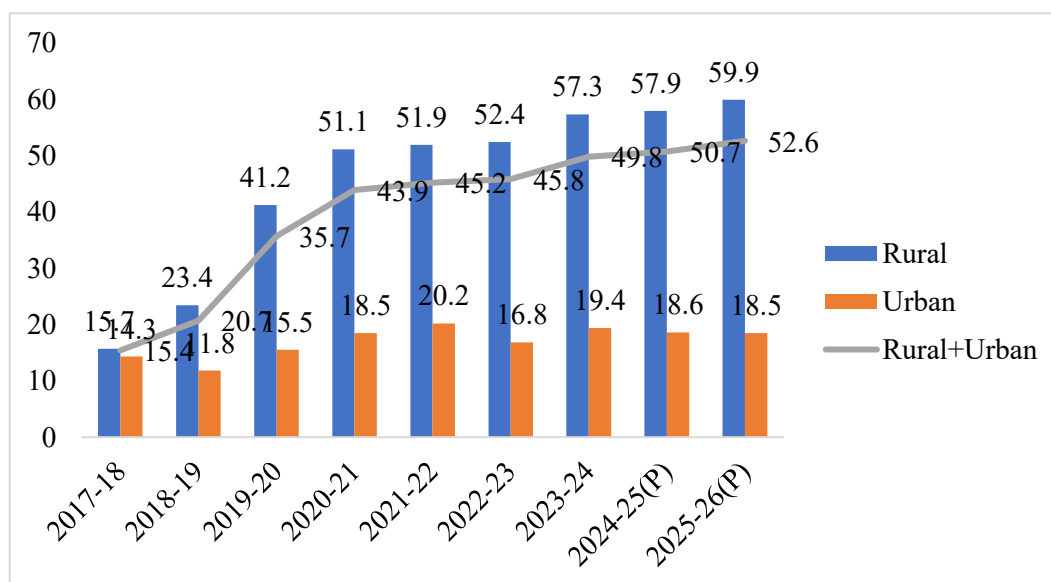
Fig. 2: Workforce Participation Rate in Jharkhand

Table 1: Labour Force Participation Rate (PS+SS) for Persons Aged 15 Years and Above: Jharkhand and All India, 2017-18 to 2023-24 (in percent)

Year	Jharkhand			All India		
	Male	Female	Person	Male	Female	Person
2017-18	73.9	15.4	45.1	75.8	23.3	49.8
2018-19	76.4	20.7	47.4	75.5	24.5	50.2
2019-20	76.9	35.7	55.9	76.8	30.0	53.5
2020-21	78.9	43.9	61.6	77.0	32.5	54.9
2021-22	79.3	45.2	61.9	77.2	32.8	55.2
2022-23	78.6	45.8	61.9	78.5	37.0	57.9
2023-24	78.3	49.8	63.8	78.8	41.7	60.1

Source: Periodic Labour Force Survey (PLFS), Ministry of Statistics and Programme Implementation, GoI

Table 1 provides a comparison of workforce participation between Jharkhand and all-India based on PLFS data across different rounds. The data show that since 2017–18, there has been a sharp and sustained increase in female labour force participation, particularly in rural areas. The reasons include increased involvement of women in agriculture and allied activities, as well as various public employment programmes. On the other hand, improvements in urban employment are insufficient, and there is a significant disparity in workforce participation between urban and rural women. The reason is that urban jobs are skill-oriented, and women have limited access to them. Figure 3 also shows that female labour force participation has increased each year in both areas, but the increase is more significant in rural areas than in urban areas. In rural areas, female participation rose from 15.7% in 2017–18 to 57.3% in 2022–23. It is estimated that in 2025–26 it will reach 59.9%. However, in urban areas, the rate of increase is very slow.



Source: Periodic Labour Force Survey (PLFS), Ministry of Statistics and Programme Implementation, GoI

Fig. 3: Labour Force Participation Rates in different regions of Jharkhand

Figure 4 shows that the unemployment rate for females in rural areas declined from 3.7% in 2017–18 to 0.1% in 2020–21 and thereafter remained constant at 0.1%. In urban areas, the unemployment rate has also been decreasing, but it is still higher than in rural areas. The rate of decline is higher in rural areas compared to urban areas. This indicates limited employment opportunities in urban areas, while females are increasingly actively involved in farming-related activities. The decline in rural unemployment does not imply that rural women are entering high-quality or higher-paid jobs; in reality, they cannot afford to remain unemployed for long and need to work to escape poverty. On the other hand, in the urban sector, the demand for formal, skill-oriented managerial jobs is higher, and these jobs are dominated by males, which leads to discrimination against females.

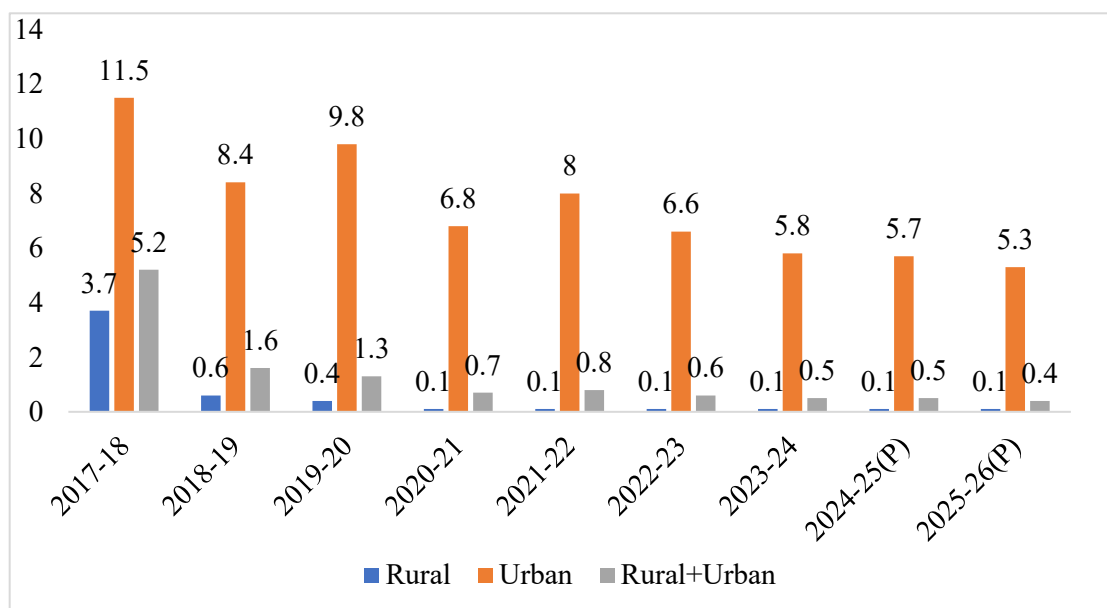
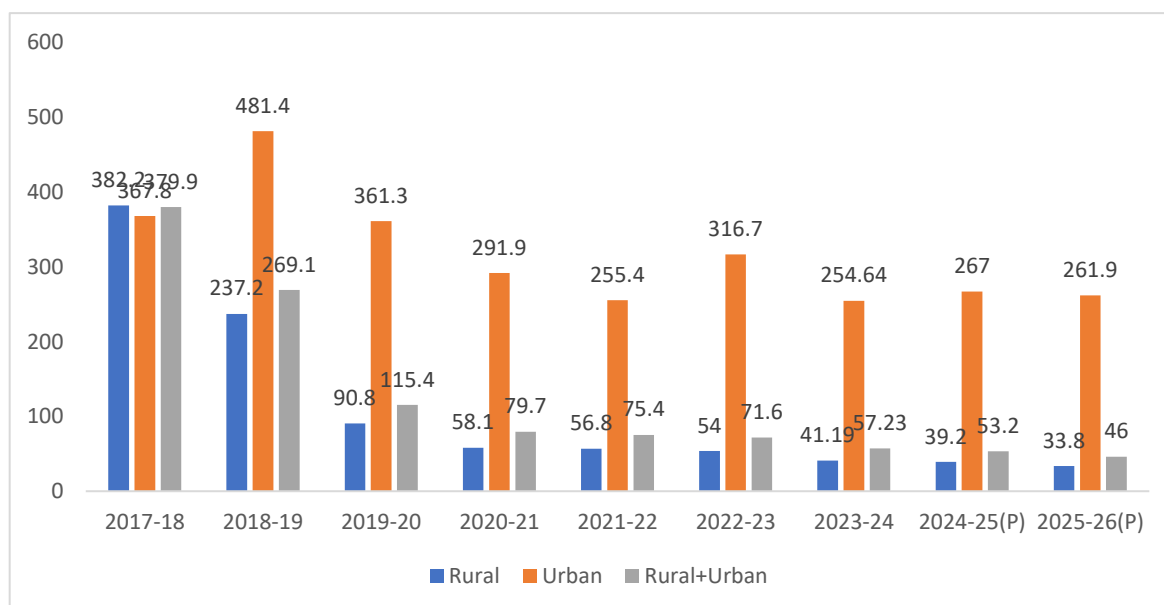


Fig. 4: Unemployment Rate of Females in Different Regions

Figure 5 shows that the gap between male and female average earnings is decreasing each year in both rural and urban areas. However, the rate of decrease is much higher in rural areas; it declined from Rs. 382.2 in 2017–18 to Rs. 41.19 in 2023–24, and the projected value for 2025–26 is Rs. 33.8. Urban areas also show improvement, with the difference decreasing from Rs. 379.9 in 2017–18 to Rs. 46 in 2025–26.



Data Source: Periodic Labour Force Survey (PLFS), Ministry of Statistics and Programme Implementation, GoI

Fig. 5: Difference Between the Male and Female Earnings in Different Regions

Table 2: Percentage Distribution of Female Workers in Usual Status by Employment Type

Year	Sector	Self emp.	Own account	Helper	Regular wage	Casual labour
2017-18	Rural	78.1	18.6	59.5	6.9	15
	Urban	25.4	15.3	10.1	46.9	27.7
	Total	69	18	51	14	17
2018-19	Rural	78.3	22	56.3	10.7	11
	Urban	31.7	16.9	14.8	45.6	22.7
	Total	73	21	51	15	12
2019-20	Rural	88.6	16.6	72	4.9	6.6
	Urban	53.9	24.8	29.1	39.2	6.9
	Total	86	17	68	7.9	6.6
2020-21	Rural	90.1	19.8	70.2	3.5	6.4
	Urban	48	25.7	22.3	39.4	12.6
	Total	86.5	20.3	66.1	6.6	6.9
2021-22	Rural	88.6	20.8	67.8	3.1	8.2
	Urban	56.4	35.1	21.3	38.7	4.9
	Total	86	22	64	6.3	8
2022-23	Rural	90.3	27.8	62.4	2.4	7.3
	Urban	55.7	24.1	31.5	38.1	6.2
	Total	88	28	61	4.7	7.2
2023-24	Rural	89.3	29.1	60.1	5.1	5.6
	Urban	55.5	31.9	23.6	34.8	9.7
	Total	86.5	29.3	57.5	7.3	5.9
2024-25 (P)	Rural	89.4	33.1	56.2	4.5	6
	Urban	59.4	31.1	28.2	34.2	6.5
	Total	87.2	33.2	55	6.4	6.1
2025-26 (P)	Rural	89.3	36.6	52.6	5	5.7
	Urban	61.5	31.9	29.6	32.7	5.8
	Total	87.4	36.4	52.1	6.4	5.7

Source: Periodic Labour Force Survey (PLFS), Ministry of Statistics and Programme Implementation, GoI

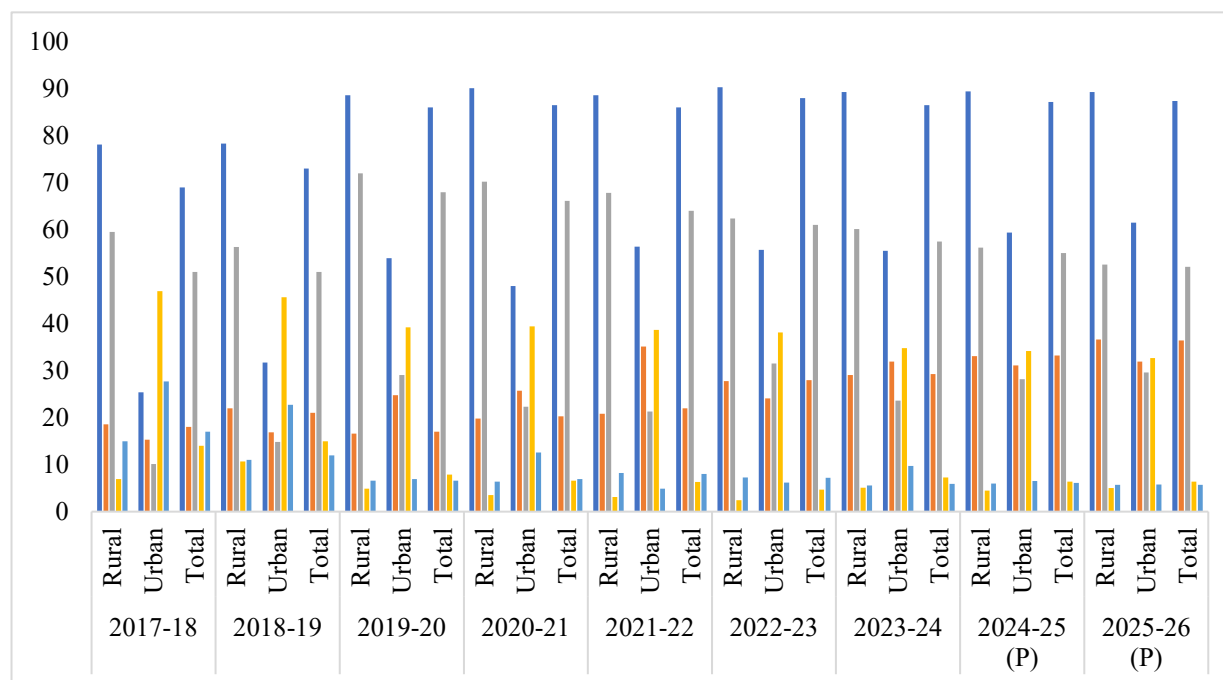


Fig. 6: Percentage Distribution of Female Workers in Different Regions

The above table and figure highlight that females participate in different types of work, but rural female workers are far more concentrated in self-employment. This points to a strong reliance on family-based, often unpaid, domestic work and on agricultural and allied activities.

Women remain engaged in domestic duties because no other member is available to take them on. This is the most common reason. Besides this, there are some social and religious constraints, and sometimes they cannot afford to hire someone to help them with domestic duties. (PLFS study. Some women choose to do domestic duties, while others are forced to do so due to a lack of alternative work. This is higher among urban women. The concentration of female workers in agriculture points to both constraints (e.g., limited access to non-farm employment, mobility, or skills) and the importance of improving conditions and productivity in agriculture for women. Promoting female participation in the secondary and tertiary sectors may require targeted skilling, childcare support, and more inclusive hiring practices. Urban areas are service-driven, with low-skilled, household-based activities that lack diversification into formal and knowledge-intensive sectors. We observe that the maximum number of rural women are engaged in the self-employment sector. Its percentage increases from 78 per cent to approximately 90 per cent. A good percentage of women are also engaged as helpers. Over the period 2017-18 to 2025-26, the average percentage is almost 60 per cent. Rural women’s contribution in the own-account, casual labour, and regular wage sectors is relatively very low. Urban women’s contributions to the self-employment sector also increase, but they are lower than in rural areas. In other sectors, urban women’s contributions are not very high, yet they are greater than those of rural women.

4. Position of Women in Jharkhand with respect to Empowerment

The different rounds of PLFS data and the Census data of 2011 show that female workforce participation in Jharkhand has been increasing over the years. The participation rate among rural women is higher than that of urban women. However, urban women have also shown some improvement. This indicates that not only in Jharkhand but across India, women, especially rural women, play an important role in the economy. Their contribution strengthens women's empowerment. They are now contributing to the family income, which helps uplift their confidence level. They can also participate in family decision-making.

Their financial independence helps them gain control over their lives. In our patriarchal society, women can find their own identity and existence. The unemployment rate and gender wage gap have also declined. This implies that women are increasingly participating in the workforce. Despite this progress, the gender gap persists, especially in the urban sector, where women are often offered low-paid and temporary work.

5. Recommendations

To increase the female participation rate and to strengthen women's empowerment, the following recommendations are given:

- a) Education is an important aspect, so the government should give more focus on female education and should reduce the obstacles that limit women's access to education.
- b) Women's participation in the workforce is low because of the lack of availability of work. Thus, the government and the private sector should create job opportunities for women.
- c) In the urban sector, most of the jobs are skill-oriented in nature, where women face difficulties accessing the jobs due to a lack of proper skills and training. The government should provide skill development programmes and training for women.
- d) To reduce gender discrimination in wages, the government should ensure equal wages for equal work.
- e) Safety and security measures should be given to the women in their workplace so that they feel free to join in work force.

6. Conclusion

The analysis of PLFS data across 2017–18 to 2025–26 shows that, in Jharkhand, although a gender gap in workforce participation exists, women's participation is increasing, especially in rural areas. Jharkhand is a tribal-dominated state, and most tribal women play an important role in tribal society. They engage in agricultural, forest-based, and animal husbandry activities to support their families' livelihoods. However, in urban areas, female participation is lower than in rural areas. Men still dominate urban jobs.

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Extractivism, the Environment, and Land Rights in the Nickel Mining Sector of Zambia

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Abstract: *This study examined the environmental, social, and economic implications of nickel mining in Zambia, with a focus on sustainable land use, tenure security, and community livelihoods. Guided by three objectives, the research assessed the environmental impacts of nickel mining, particularly land degradation, water quality, and broader ecosystem effects; explored how land acquisition and resettlement practices have influenced tenure security and community rights; and explored the socio-economic outcomes of mining in terms of employment, income generation, and equitable benefit distribution. The study adopted a qualitative research design, using semi-structured interviews with community members, civic leaders, and affected households. Thematic analysis was employed to identify emerging patterns and perspectives. The findings revealed that nickel mining has exacerbated environmental challenges, including poor water access, soil degradation, and cracks in houses due to blasting. Resettlement processes disrupted tenure security, with inadequate housing, poor infrastructure, and unfulfilled promises of social services, leading to worsening poverty among displaced households. Socio-economic benefits were limited, with employment opportunities being inaccessible to locals due to nepotism and external recruitment. Overall, the study concludes that nickel mining has contributed more to environmental damage and community marginalization than to sustainable local development.*

Keywords: *Nickel mining, resettlement, livelihoods, environment, tenure security*

1. Introduction

Zambia's political economy has long been shaped by mineral extraction, with copper historically forming the backbone of national revenue, and more recently nickel emerging as a

strategic resource in the country's economic diversification agenda (Mwitwa, German, Muimba-Kankolongo, & Puntodewo, 2012). Since independence, mining has dominated Zambia's export earnings and fiscal revenue, providing the government with substantial capacity to implement development projects while simultaneously exposing the economy to the volatility of global commodity markets (World Bank, 2019). Despite its celebrated role as an engine of growth, the mining sector has often fallen short of delivering inclusive development outcomes, particularly in rural and peri-urban communities located near mining operations. These communities frequently bear the brunt of extractive activities, experiencing land dispossession, social dislocation, and environmental degradation, even as national economic indicators record growth (Chinene, Maimbo, Banda, & Msune, 2024; Moyo, 2007). The paradox of resource-led development in Zambia, therefore, mirrors broader patterns in sub-Saharan Africa, where extractivist models of growth often generate profound social and ecological tensions.

The concept of extractivism provides a critical lens for understanding these dynamics. Extractivism denotes the large-scale removal of natural resources for export, primarily geared toward meeting external market demands rather than fostering local development or diversification (Alonso-Fradejas, 2021). In practice, extractivist projects are characterized by limited downstream processing, weak linkages to domestic industries, and highly uneven distribution of economic benefits. Beyond economic inequities, extractivism is associated with severe environmental impacts, including deforestation, soil erosion, water pollution, and the depletion of arable land (Moyo, 2007; Shivji, 2009). The expansion of mining into areas governed by customary land regimes intensifies conflicts over tenure security, as statutory mining licenses often override community-based landholding systems, undermining livelihoods, cultural practices, and local governance structures (Nzara, 2018). Such tensions reflect the persistent contradictions of capitalist resource exploitation, where patterns of dispossession and accumulation resemble a contemporary form of primitive accumulation, what Moyo, et al., (2012) describe as a "new scramble" for African resources, driven by both global and semi-peripheral actors seeking to extract surplus from local populations while reshaping land and labor relations.

The Munali Nickel Mine in Mazabuka District exemplifies these tensions in Zambia. Commissioned in the late 2000s, the mine was positioned as an opportunity to diversify the national mineral base beyond copper, yet its operations rapidly became entangled in disputes over land acquisition, resettlement compensation, and environmental management (Mungu, *The relationship between mining and local community development: The case of Munali nickel mine in Southern Zambia*, 2017). While some resettled households benefited from expanded landholdings or improved infrastructure, others experienced insecure tenure, diminished agricultural productivity, and relocation to environmentally unsuitable areas. These divergent outcomes illustrate the uneven social and economic benefits of extractivist projects, highlighting the limits of Zambia's mineral-led development paradigm when confronted with customary tenure systems and vulnerable local ecologies (Chinyemba & Simbeye, 2025). The Munali case thus provides a lens to interrogate broader governance questions: how statutory and customary institutions mediate resource extraction, the socio-environmental trade-offs

involved, and the mechanisms through which communities negotiate rights and livelihoods amidst capitalist accumulation pressures.

Despite growing recognition of these challenges, significant knowledge gaps remain in understanding the intersection of land rights, environmental sustainability, and socio-economic benefits in Zambia's mining sector. Existing studies have predominantly focused either on macroeconomic contributions of mining (Bebbington, et al., 2018; World Bank, 2019) or on environmental impacts in isolation (Alonso-Fradejas, 2021). Less attention has been paid to the structural processes through which extractive capital shapes land tenure security, environmental integrity, and local livelihoods concurrently, particularly in the context of semi-peripheral accumulation dynamics and globalized mineral markets (Moyo, et al., 2012). This study addresses this gap by examining the Munali Nickel Mine as a case study, seeking to generate insights on the systemic mechanisms of resource dispossession, environmental degradation, and uneven socio-economic outcomes.

The research is guided by three interrelated objectives. First, it aims to assess the environmental impacts of nickel mining in Mazabuka, focusing on land degradation, water quality, and broader ecosystem effects that influence sustainable land use. Second, it examines how land acquisition and resettlement practices affect tenure security and community rights, exploring the linkage between statutory regulations and customary landholding arrangements. Third, it investigates the socio-economic outcomes of mining, including employment, income generation, and the equitable distribution of benefits, to understand the broader implications for local development and livelihoods. By addressing these objectives, the study situates the Munali experience within broader debates on extractivism, resource governance, and community resilience, highlighting the tensions and opportunities inherent in Zambia's mineral-based development model.

Ultimately, the study contributes to ongoing scholarly and policy discussions on the governance of mineral wealth in Africa, foregrounding the lived experiences of affected communities alongside institutional and policy analyses. By critically engaging with issues of land rights, environmental sustainability, and socio-economic justice, this research advances knowledge on how extractivist economies can be reconciled with equitable and sustainable development, offering lessons for Zambia and other resource-dependent countries across the continent.

2. Conceptual & Theoretical Underpinnings

Extractivism as a critical concept emerges from political ecology, ecological economics, and Latin American dependency theory, where it has been employed to describe modes of resource exploitation tied to global capitalist expansion (Acosta, 2017; Bebbington et al., 2018; Durante et al., 2021). Unlike narrow accounts of mining as an economic activity, extractivism is understood as a structural condition: it positions resource-rich but industrially peripheral economies like Zambia as suppliers of unprocessed raw materials for metropolitan centers of

accumulation. This creates what Warnecke-Berger and Ickler (2025) describe as *enclave economies*, islands of intensive capital extraction within broader landscapes of marginalization.

At its core, extractivism embodies a paradox. On the one hand, mining generates foreign exchange and contributes to national GDP, aligning with Zambia's diversification agenda; on the other, its gains are distributed unevenly, with disproportionate costs borne by rural communities adjacent to mining sites (World Bank, 2019). The case of the Munali Nickel Mine in Mazabuka exemplifies this tension. Its reopening in 2008 was celebrated as a milestone for Zambia's re-entry into global nickel markets, yet it also introduced disputes over land acquisition, displacement, and ecological damage. Such contradictions reveal extractivism as a deeply political phenomenon, entangled with questions of land rights, environmental justice, and community livelihoods (Mungu, 2017).

To explore further these dynamics, this study employs Marx's theory of Primitive Accumulation as its sole theoretical anchor. This framework provides the critical tools to examine how extractive projects like Munali reproduce capitalist relations through dispossession, coercion, and the restructuring of land and labor systems.

Marx (1867/1976) developed the concept of primitive accumulation to explain the violent historical processes that facilitated the rise of capitalism. Contrary to liberal accounts that portrayed capitalism as the outcome of gradual thrift and trade, Marx argued that it emerged through coercive expropriation of the peasantry, forced separation of producers from means of subsistence, and legal codification of private property. Primitive accumulation was not simply an economic shift but a political and social transformation underpinned by violence, law, and state power (Ekman, 2012).

While rooted in the historical enclosure of common lands in Europe, primitive accumulation has been extended by contemporary scholars to analyze ongoing dispossession in the Global South. Harvey (2003) reconceptualized it as accumulation by dispossession, showing that capitalism continually requires fresh frontiers of expropriation to sustain accumulation. Further demonstrating how state power, international capital, and local elites orchestrate these processes, often through legal reforms, privatization, and securitization (Fontes, 2017).

In the Zambian context, primitive accumulation is evident in the relationship between state mineral governance and customary land tenure. The Mines and Minerals Development Act (1995) empowers the state to allocate mineral rights to corporations, even on customary land, without requiring meaningful consent from affected communities (Chinyemba & Simbeye, 2025). This legal framework reflects the dual role of the state: formally the guardian of national resources but functionally the enabler of corporate access to land. Customary tenure, often undocumented and communally managed, becomes highly vulnerable to encroachment. As Mudenda (2006) argues, compensation schemes rarely capture the cultural, social, and livelihood values embedded in land, reducing dispossession to monetary transactions that inadequately address the depth of community loss.

In the Munali case, households were displaced and resettled under terms framed as development opportunities, yet the underlying dynamic mirrored Marx's description of

coercion. Here, coercion was not necessarily physical violence but the bureaucratic and legal apparatus that legitimized corporate claims while undermining customary rights. This reflects what Comaroff and Comaroff, (2007) identify as the *violence of law*, the deployment of legal and administrative instruments to render dispossession both lawful and seemingly inevitable.

Thus, primitive accumulation provides the analytical foundation for this study. It situates land dispossession not as incidental to mining but as constitutive of extractivism. It highlights how capital accumulation at Munali was predicated on separating communities from their means of production, land, water, and ecological systems, under the guise of national development. By foregrounding these dynamics, the framework illuminates the structural inequalities and conflicts that define extractive capitalism in Zambia.

3. Land and Mining in Zambia: An overview

The history of mining in Zambia cannot be separated from the country's broader struggles over land, resource governance, and development. Mining has for more than a century shaped Zambia's political economy, subordinating agriculture, restructuring land relations, and entrenching a resource-dependent development model. At its core, Zambia's experience exemplifies the paradoxes of extractivism: mineral wealth has enabled ambitious national projects and periods of prosperity, yet it has also produced cycles of dependency, displacement, ecological degradation, and social inequality.

Zambia's dual identity as both an agrarian society and a mineral-rich state has long been marked by tensions over which sector should form the backbone of development. Prior to the discovery and expansion of copper mining in the early twentieth century, agriculture was the dominant livelihood for the vast majority of Zambians, sustained largely under customary tenure systems and geared towards subsistence farming (Phiri, 2021). The colonial state, however, privileged mining over agriculture, facilitating the development of the Copperbelt through foreign capital while relegating African farmers to marginal lands and labour reserves (Ferguson, 1999).

At independence in 1964, Zambia inherited this structural imbalance. Copper production, concentrated in the Copperbelt, accounted for the bulk of government revenues, foreign exchange earnings, and formal employment (World Bank, 2019). The government's fiscal reliance on mineral rents entrenched the prioritization of mining over agriculture, despite agriculture's central role in food security and rural livelihoods. Policy and public investment were channeled disproportionately towards the mining sector, while agriculture was underfunded, poorly mechanised, and left largely in the domain of customary land tenure (Mudenda, 2006).

The subordination of agriculture to mining has had profound consequences. While mining generated significant state revenue, its enclave character limited linkages to the broader economy (Bebbington et al., 2018). Agriculture, meanwhile, remained underdeveloped and vulnerable, leaving rural communities on the periphery of mineral-led growth. This imbalance

continues to shape Zambia's development trajectory, reinforcing the dominance of extractivism while undermining efforts at diversification.

The structural dominance of mining was reinforced by the presence of giant mining cooperatives and conglomerates. During the colonial era, two firms, Anglo American Corporation and the Rhodesian Selection Trust, controlled the vast majority of copper production in Northern Rhodesia (now Zambia), creating a duopolistic structure that monopolised mineral wealth (Chinyemba & Simbeye, 2025). These corporations not only controlled production and exports but also exerted political influence, shaping colonial labour policies, wage structures, and land allocation.

The Copperbelt thus became an economic and political epicentre, drawing migrant labour from across Zambia and neighbouring countries. Mining companies established company towns, controlled housing, health, and education services, and reinforced a paternalistic form of social order that tied workers' lives to corporate structures (Larmer, 2010). While mining created an African working class with strong trade unions, the distribution of benefits remained unequal, with rural areas excluded from the dividends of mining prosperity.

The ascendancy of Kenneth Kaunda after independence marked an attempt to reconfigure this colonial legacy. Under the philosophy of "Zambian Humanism," Kaunda envisioned a developmental state that would mobilise mineral rents for social and economic transformation. The Mines and Minerals Development Act of 1969 was a turning point, transferring control of mineral rights to the state and paving the way for the nationalisation of mining assets. By the mid-1970s, Zambia Consolidated Copper Mines (ZCCM) emerged as the state-owned giant controlling copper production (Chinene et al., 2024).

Nationalisation was celebrated as a reclaiming of sovereignty over natural resources and a mechanism for redistributing wealth. Copper revenues were directed towards expansive social investments: free primary education, subsidised health care, rural electrification, and infrastructure development (Saasa, 2003). Kaunda's government also expanded parastatal enterprises, using mineral rents to diversify into sectors such as manufacturing and transport.

Yet this strategy carried inherent risks. The economy became deeply dependent on copper revenues, accounting for more than 90 percent of foreign exchange earnings by the early 1970s. When global copper prices collapsed in the mid-1970s, Zambia's fiscal base eroded. The overreliance on mining, combined with underinvestment in agriculture, exposed the structural fragility of the extractivist model (Acosta, 2017). Although mining wealth initially financed redistribution, the absence of sustained agricultural development left rural communities marginalised, widening the urban-rural divide.

By the 1980s, Zambia faced mounting debt, fiscal crises, and economic stagnation. The state's inability to sustain ZCCM operations, coupled with pressure from the International Monetary Fund (IMF) and World Bank, ushered in neoliberal structural adjustment policies. The 1990s marked the era of privatisation, where ZCCM assets were sold off at undervalued rates to foreign investors (Fraser & Lungu, 2007).

This wave of privatisation reversed the gains of nationalisation. Mining revenues to the state plummeted as new investors negotiated tax holidays, royalty exemptions, and profit repatriation agreements. For instance, mining companies often paid royalties as low as 0.6 percent, among the lowest in the world, undermining Zambia's fiscal sovereignty (Chinyemba & Simbeye, 2025). While privatisation restored production capacity and attracted foreign capital, it eroded the state's developmental role and weakened its ability to capture mineral rents for social investment.

The return of multinational dominance also reconfigured labour relations. Workforce retrenchments accompanied privatisation, undermining trade unions and eroding worker protections. Communities that had once benefitted from ZCCM's social services were left vulnerable, as private mining companies dismantled the welfare functions previously provided by the state-owned enterprise (Larmer, 2010).

Land has been a recurring arena of conflict in Zambia's mining history. The country's dual tenure system, statutory and customary, has created enduring tensions. While statutory law grants the state ownership of all minerals, customary tenure governs the land on which most rural Zambians live and farm. This arrangement has created structural vulnerabilities: communities with insecure tenure rights are frequently displaced when mining concessions are issued, often without adequate consultation or compensation (Chu, 2015).

The Mines and Minerals Development Act of 1995 codified the supremacy of mining rights, enabling corporations to acquire land even in customary areas. Communities displaced under such arrangements often faced development-induced displacement, losing not only their land but also their cultural and livelihood bases. Compensation packages were frequently inadequate, reflecting the commodification of land rather than its broader social and ecological value (Mudenda, 2006).

The Munali Nickel Mine in Mazabuka exemplifies these dynamics. Located in a predominantly agricultural district, the mine's establishment required significant land acquisition, displacing farming households and disrupting agricultural production. While some resettled households received larger plots or improved infrastructure, others reported insecure tenure, reduced productivity, and unsuitable relocation sites. Such uneven outcomes highlight the contradictions of extractivist development, where national economic gains often come at the expense of local livelihoods.

Mining in Zambia has left a profound environmental footprint. Copper, cobalt, and nickel extraction have contributed to deforestation, soil erosion, water contamination, and air pollution. Mining towns such as Kitwe, Mufulira, and Kabwe remain symbols of environmental injustice. Kabwe, in particular, has been identified as one of the most polluted towns in the world, with lead contamination affecting generations of residents (UN-Habitat, 2017). The long-term health consequences, respiratory illnesses, neurological damage, and waterborne diseases, represent what Nixon (2011) terms "slow violence," where harm accumulates invisibly over time.

Environmental degradation also intersects with agriculture, as polluted rivers and soils undermine food security and rural livelihoods. Effluents from mining operations contaminate water sources used for irrigation and human consumption, reducing agricultural productivity and increasing public health risks. These ecological impacts illustrate the inseparability of mining from broader environmental justice debates in Zambia.

Successive governments after Kaunda have struggled to balance the imperatives of mining-led growth with the demands of equitable development and ecological sustainability. Efforts to renegotiate development agreements, raise royalty rates, and improve regulatory oversight have often been constrained by weak state capacity, corruption, and corporate lobbying (Durante et al., 2021).

Civil society organisations, faith-based groups, and local movements have increasingly questioned whether Zambia's extractivist model is sustainable. They highlight the persistent issues of inadequate compensation for displaced communities, weak enforcement of environmental standards, and the limited redistributive impact of mining revenues (Warnecke-Berger & Ickler, 2025). At the same time, agriculture remains underdeveloped despite its potential to serve as a foundation for diversification, food security, and rural employment.

The history of land and mining in Zambia reveals a trajectory where mining has consistently superseded agriculture in state policy, fiscal reliance, and national identity. From the colonial dominance of giant mining cooperatives to Kaunda's nationalisation project, the neoliberal privatisation of the 1990s, and contemporary struggles over land tenure and environmental justice, the extractivist model has produced both wealth and precarity.

While mining has financed important social programs and enabled moments of prosperity, it has also entrenched dependency, displacement, and ecological harm. The Munali Nickel Mine in Mazabuka, alongside the broader Copperbelt experience, epitomises the paradoxes of extractivism: wealth creation for some, dispossession and slow violence for others. The unresolved dilemmas of taxation, land rights, and environmental regulation underscore the urgent need for a more balanced development strategy that recognises both the historical significance of mining and the necessity of revitalising agriculture as a pathway to inclusive and sustainable development.

4. Methods

This study adopted a qualitative exploratory research design, selected for its strength in uncovering social meanings, community experiences, and institutional dynamics that shape the relationship between extractivism, land rights, and environmental change in Zambia. Unlike quantitative approaches that seek numerical generalization, the qualitative design allows for a nuanced and contextual understanding of how the Munali Nickel Mine in Mazabuka has influenced livelihoods, governance, and ecological systems. This orientation is consistent with Creswell's (2014) argument that exploratory qualitative designs are particularly suited for examining under-researched issues in complex socio-political environments.

The research population was conceptually defined to include communities in Mazabuka directly affected by the Munali Nickel Mine, state institutions responsible for regulating extractive industries, corporate actors involved in mining operations, and civil society organizations engaged in advocacy on land and environmental rights. Given the study's reliance on secondary sources, a purposive sampling strategy was employed to identify a body of texts that best represented these perspectives. The "sample size" thus consisted of 15 interview respondents and a carefully curated set of documents, including Environmental and Social Impact Assessments (ESIAs), parliamentary records, corporate disclosures, government policy papers, community testimony reports, and peer-reviewed scholarship. Selection was based on relevance, credibility, and capacity to illuminate the study's central themes.

Data collection relied on documentary analysis as the primary interview instrument. Secondary data from peer-reviewed articles from databases such as Scopus and Google Scholar provided the theoretical and empirical foundations of extractivism research, while policy documents and archival records from the Zambia Environmental Management Authority (ZEMA) and the Ministry of Mines offered insights into the regulatory environment. Civil society submissions and community testimony reports provided counter-narratives that highlighted lived experiences often omitted from official accounts. Corporate reports and disclosures were also examined, but critically assessed for silences and selective framing. This wide range of instruments allowed the study to capture diverse voices and institutional standpoints.

For data analysis, the study employed thematic content analysis for both primary and secondary data collection, drawing on Braun and Clarke's (2006) six-step framework. Interviews were transcribed and documents were read repeatedly and coded inductively, with recurring issues clustered into themes such as land-use change and displacement, environmental degradation, governance and corporate accountability, and community agency. Through this iterative process, connections and contradictions across different data sources were identified. In order to enhance rigor, triangulation was applied by cross-referencing insights from government, corporate, and civil society documents, consistent with Moon's (2019) methodological emphasis on validating qualitative interpretations.

Throughout the process, the study adopted a critical interpretive stance, recognizing that qualitative data may not be neutral but are shaped by power relations and institutional interests. This lens, informed by political ecology and postcolonial theory, allowed for deeper interrogation of how extractivist narratives are constructed, whose voices are amplified, and whose experiences are marginalized. While the absence of primary fieldwork presents a limitation, it was addressed by drawing extensively on secondary testimonies, independent evaluations, and archival sources that capture local voices.

5. Discussion of Results

This section presents the discussion of findings from interviews conducted with community members living around the Munali Nickel Mine in Mazabuka. The discussion is structured around the three objectives guiding the study and interpreted through thematic analysis.

Respondents' experiences illuminate how environmental impacts, land and resettlement practices, and socio-economic outcomes intersect in shaping livelihoods and rights in the context of extractivism.

5.1 Environmental Impacts of Nickel Mining in Mazabuka

A consistent theme emerging from the interviews concerns environmental degradation linked to nickel mining operations. Respondents described deteriorating agricultural conditions, inadequate access to clean water, and ecological damage such as soil infertility and house cracks caused by blasting. Respondents 1, 2, and 8 highlighted how farming has become increasingly difficult: *“Over the years, farming has become hard and deteriorating. Our animals graze from far and we have no adequate water... the same place we use to drink water, animals use the same.”* These accounts align with wider studies documenting how mining disrupts agricultural systems through soil depletion, deforestation, and contamination of water resources (Moyo, et al., 2012).

Farmers repeatedly emphasized the decline in soil fertility, with crop yields falling significantly since the onset of mining. Respondents described how farming activities now require greater effort, yet the outcomes remain poor. The replacement of fertile customary land with degraded resettlement areas has led to a situation where communities are unable to sustain their traditional livelihoods. This mirrors evidence from Acosta (2017), who argues that extractivism undermines agrarian economies by prioritizing external demand for minerals over local food systems.

Water emerged as one of the most pressing environmental concerns. Communities reported relying on a single pump for both human and livestock consumption. Although some respondents acknowledged the presence of about six dams, many expressed dissatisfaction with their condition, noting they were poorly built and inadequately maintained: *“The dams were not built properly.”* Such inadequacy exacerbates existing challenges of drought and climate variability, leaving households vulnerable to food and water insecurity. This finding reflects Durante et al. (2021), who emphasize that mining-related water infrastructure projects often fail to meet long-term community needs.

Respondents living closer to the mine reported severe impacts on housing structures, with one noting: *“People who are closer experience house cracks due to mine blasts.”* These structural damages, while not immediately life-threatening, accumulate over time and represent what Nixon (2011) terms “slow violence” environmental harm that erodes communities' resilience in invisible and delayed ways. Beyond structural hazards, blasting also creates dust, noise, and vibrations that further reduce the quality of life.

Underlying these environmental concerns is a shared perception of neglect from both the mine and the government. Respondents like R1 strongly came out: *“There is no help, the mine and the government are not helping.”* This reflects a governance gap, where regulatory bodies fail to enforce environmental safeguards, leaving communities to bear the costs. The contradiction is striking: while the Munali Nickel Mine was promoted as part of Zambia's diversification strategy, its operations have diminished ecological resilience and undermined food security.

Overall, the environmental impacts show how mining creates a paradox: while contributing to national revenue, it simultaneously erodes the ecological base that sustains local communities.

5.2 Land Acquisition, Resettlement, and Tenure Security

The second objective examined how land acquisition and resettlement have affected tenure security and community rights. The findings show widespread dispossession and precarious outcomes. Respondents emphasized that resettlement disrupted agricultural livelihoods, destroyed social cohesion, and undermined tenure security.

One group of respondents explained: *“We were shifted... we are suffering with the settlement area we were given. Even the roads here are very bad. They removed us from our areas, including our farm lands and our crops are growing badly.”* This reflects a process of coerced displacement, consistent with Marx’s concept of primitive accumulation, where communities are separated from their means of production. The relocation severed ties to fertile lands and replaced them with degraded plots prone to flooding.

Resettlement was characterized by unfulfilled promises. Communities reported being given houses that were already deteriorating: *“These houses are not in good condition now, there are leakages, they have cracks.”* Moreover, critical infrastructure such as electricity and water tanks was never delivered: *“We have no electricity, no water tanks despite this being the promise the mine made.”* This pattern is consistent with Mudenda (2006), who argues that compensation often focuses on symbolic compliance with legal frameworks rather than on meeting displaced communities’ long-term needs.

A recurring grievance concerned the quality of resettlement land. Respondents explained: *“The mine brought more problems, we are unable to farm here, the soil is bad. When it rains, the farms get flooded and crops die.”* Such conditions highlight the gap between statutory approaches to compensation, which focus on plot size, and customary understandings of land as a holistic resource tied to fertility, identity, and livelihood security (Nzara, 2018).

Some respondents noted having legal titles to their land *“This is my land and I have title”* yet their security remains fragile. This shows the dominance of statutory frameworks, such as the Mines and Minerals Development Act (1995), which prioritize mineral rights over customary or individual tenure rights. Even titled landowners face displacement when state and corporate interests align.

Taken together, these findings show that resettlement deepened vulnerability rather than securing sustainable livelihoods. Far from improving living conditions, it entrenched inequalities and marginalized communities under the guise of development.

5.3 Socio-Economic Outcomes of Mining

The third objective investigated the socio-economic effects of mining, focusing on employment, income, and distribution of benefits. The interviews highlighted widespread disillusionment, as initial promises of prosperity gave way to exclusion and precarious livelihoods.

Respondents consistently expressed frustration at their exclusion from mining jobs. As one explained: *“The people in our village don’t benefit from the jobs in the mines, they recruit people from the Copperbelt. Recruitments are based on corruption and favoritism.”* Civic leaders confirmed their marginal role, limited to casual labor placements. This exclusionary dynamic undermines the legitimacy of the mine and reflects broader governance issues in Zambia’s mining sector.

Although some locals initially gained jobs, these were unstable. Respondents 3, 5, and 7 recalled: *“When the mine started, a lot of people got employed. But over time, a lot lost their jobs.”* Frequent changes in ownership led to retrenchments, forced leave, and delayed payments. As one group explained: *“People have been put on forced leave, others laid off... those lucky are called back.”* This instability mirrors the enclave economy model, where mining creates short-lived opportunities disconnected from sustainable local development (Warnecke-Berger & Ickler, 2025).

Beyond employment, socio-economic contributions were minimal. Respondents recalled that the only meaningful benefits were the construction of a clinic and school during the mine’s establishment: *“The last help they gave was when opening the mine... after that no help has come.”* This reflects a one-off, compliance-driven approach to corporate social responsibility, rather than sustained community investment (Fraser & Lungu, 2007).

Instead of alleviating poverty, mining-induced resettlement forced households into precarious labor markets. Displaced people often resorted to low-paid farm work: *“People are forced to go work in farms owned by the whites to make ends meet.”* This demonstrates how mining can worsen rather than improve living standards, creating cycles of dependency and downward mobility.

The findings also highlight unequal outcomes. A small minority benefited from employment or slightly better land allocations, while the majority reported worsening poverty. This reflects the extractivist pattern where profits are captured by corporations, elites, and external actors, while local communities shoulder the social and environmental costs (Bebbington et al., 2018).

5.4 Synthesis

Across the three objectives, the findings show a coherent pattern: the Munali Nickel Mine has imposed significant environmental costs, undermined tenure security through resettlement, and delivered limited socio-economic benefits to local communities. Rather than enabling sustainable and inclusive development, the mine has reproduced the contradictions of extractivism, growth for the national economy but dispossession and precarity for host communities.

Through the lens of primitive accumulation, these outcomes reflect the structural logic of extractivism in Zambia: state-backed resource extraction that prioritizes corporate access over community rights, displaces local livelihoods, and externalizes environmental costs. The Munali case exemplifies how capitalist accumulation requires not only physical resources but also the reconfiguration of land, labor, and ecological systems, often at the expense of marginalized rural populations.

These findings reinforce calls for rethinking Zambia's mineral-led development model. Without stronger regulatory frameworks, meaningful community participation, and equitable benefit-sharing mechanisms, extractivist projects will continue to reproduce cycles of dispossession, inequality, and ecological harm. The challenge, therefore, lies in reconciling resource extraction with environmental justice, land rights, and socio-economic inclusivity.

6. Conclusion

This study explored the environmental, social, and economic impacts of nickel mining in Mazabuka, with the aim of understanding how mining activities intersect with sustainable land use, community rights, and local development. The findings have shown a complex reality in which the anticipated benefits of mining are overshadowed by its adverse consequences on the environment, tenure security, and socio-economic well-being of local communities. From an environmental perspective, the evidence demonstrated that mining operations have significantly contributed to land degradation, water scarcity, and broader ecosystem disruptions. Farmers in the study area reported declining soil fertility, reduced crop yields, and the collapse of grazing opportunities, making agricultural livelihoods increasingly unsustainable. Water resources, shared between humans and livestock, were inadequate and poorly managed, with some communities relying on a single pump or makeshift dams for survival. Furthermore, the blasting activities associated with mining were linked to the physical destruction of houses, further eroding the quality of life for communities living in proximity to the mine.

On the social dimension, the study highlighted how resettlement and land acquisition practices undermined tenure security and disrupted community livelihoods. While some households were given houses upon resettlement, these were poorly constructed, lacking basic amenities such as electricity and water tanks, and have since deteriorated with cracks, leakages, and structural weaknesses. More importantly, resettlement not only stripped people of their original lands but also displaced them into areas with poor soil quality and inadequate infrastructure, leaving them worse off than before. The unfulfilled promises of social support services, including better roads, water facilities, and electricity, have further entrenched discontent among communities. The sense of neglect and betrayal by both the mine and government institutions has fueled a perception of dispossession and marginalization, thereby intensifying the vulnerability of resettled households.

Economically, the study found that the benefits of nickel mining were not equitably shared. Employment opportunities were limited and often inaccessible to local residents due to corruption, favoritism, and the recruitment of labor from outside the community, particularly from the Copperbelt Province. This exclusion from mining jobs, despite the presence of the mine in their locality, has deepened the poverty of local households, forcing many to depend on subsistence farming under deteriorating environmental conditions or to seek casual labor in nearby farms owned by private individuals. The instability of employment within the mine, marked by frequent layoffs, forced leave, and changes in ownership, further demonstrates the

fragile nature of mining-related livelihoods. The absence of consistent and meaningful corporate social responsibility initiatives from the mine, beyond initial infrastructure such as schools and clinics, reinforces the view that mining has failed to contribute to sustainable community development in Mazabuka.

The study has strongly shown that while nickel mining in Mazabuka was expected to drive development, it has instead intensified environmental degradation, weakened community land rights, and failed to deliver meaningful economic empowerment. The research highlights the urgent need for stronger regulatory frameworks that prioritize environmental sustainability, equitable benefit-sharing, and protection of community rights in the mining sector. Furthermore, genuine engagement with local communities, inclusive employment practices, and the fulfillment of resettlement promises are critical to restoring trust and mitigating the adverse impacts of mining. Without such reforms, nickel mining risks perpetuating cycles of poverty, dispossession, and environmental decline, rather than serving as a catalyst for sustainable local development.

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Climate Change Adaptation Strategies Adopted by Farmers in the Small-Scale Farming Sector of Zambia: A Scoping Study

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Abstract: *The study focused on climate change and its influence on the behavioural adaptation of smallholder farmers in rain-fed agricultural systems in Sub-Saharan Africa, particularly Zambia. The purpose of the study was to examine how climate change shapes the behaviour, adaptation strategies, and livelihood decisions of smallholder farmers. Increasing climate variability, recurrent droughts, and declining agricultural productivity in Zambia have created the need to better understand farmer adaptation behaviour and the factors influencing resilience. The study adopted a qualitative scoping review design using secondary data from peer-reviewed articles, policy documents, institutional reports, and empirical studies. A thematic narrative synthesis approach was used for data analysis. The findings revealed that farmers are adopting various climate adaptation strategies such as drought-resistant crops, crop rotation, planting-date adjustments, livelihood diversification, and integrated farming systems. However, adaptation is limited by socio-economic inequalities, weak institutional support, poor extension services, and financial constraints. The study suggests that policymakers and development practitioners should strengthen extension services, improve access to climate information and financial support, and promote locally appropriate climate-smart agricultural interventions. The study contributes to the literature by integrating behavioural, livelihood, innovation, and resilience perspectives to explain farmer adaptation while identifying important research gaps within the Zambian context, especially at district level.*

Keywords: *Climate change; smallholder farmers; adaptation; farmer behaviour; resilience; livelihood diversification; drought-resistant crops*

1. Introduction

Climate change has become one of the greatest problems that face the world today. The effects of climate change can be felt across both developed and developing countries through the changing temperature trends, increase in extreme weather events, and the unpredictability of climatic trends (Alotaibi , 2023). At a global level, agriculture becomes vulnerable to climate change due to its dependence on climatic factors like rainfall and temperature trends (FAO, 2022). This way, climate change becomes a socio-economic and behavioural problem that determines the decision-making processes for farmers about what crops to grow and how to allocate their land resources (FAO, 2022). Farmers around the globe have started adjusting their farming activities according to climate change by applying innovations in technology, irrigation, and climate-smart agriculture practices. Nevertheless, the adaptive capabilities of farmers vary significantly based on the level of economic development, institutional support, and resource availability (Cano & Campos , 2024).

The effects of climate change are especially significant in sub-Saharan Africa, given the high reliance of agriculture in the region on rainfall, poor irrigation facilities, and socio-economic vulnerability (Emediegwu, et al., 2022). Indeed, the agricultural production system in the region is particularly sensitive to variations in rainfall patterns, long droughts, and rising temperature levels, which have become more pronounced in the past decades. Climate changes directly affect farm productivity, livestock productivity, and food security at the household level (Angwaomaodoko, 2024; Ngoma, et al., 2021). The problem is compounded by the low ability of small farmers to adapt to the changes owing to factors such as the lack of financial resources, poor extension services, and lack of supportive policies. In essence, climate change not only reduces agricultural productivity in sub-Saharan Africa but exacerbates existing vulnerabilities. Against this background, farmer behaviour emerges as an essential topic for analysis.

It is noted that one of the regions where the effects of climate variability were particularly profound included recurrent droughts, unpredictable rain cycles, and frequent mid-season dry periods in Southern Africa (Abebaw, 2025; Kekana, et al., 2025). The above factors contributed significantly to the difficulties in producing key staple crops such as maize that plays a dominant role in the agriculture of this part of the world. Based on available research evidence, many farmers now have to reevaluate the way of growing crops since the climate has become much more stressful for crop production. However, the ways in which farmers respond to these challenges greatly differ from one farm to another. While some decide to adapt to the situation by using drought-resistant crops, diversifying income sources, and combining livestock farming and crop production, others continue using traditional farming methods due to either cultural or financial limitations (Mubanga and Ferguson, 2017).

Climate change has now emerged as an important factor constraining agricultural production in Zambia, specifically in Southern Province, where agriculture is dependent on rainfall alone. The region faces increased variability in rainfall, delays in the timing of the onset of the rains, early termination of the rainy season, and droughts. All these factors affect the agricultural cycle, leading to lower productivity levels (Abebaw, 2025; Asfaw, et al., 2017; Kekana, et al.,

2025). It is important to note that small-scale farmers are the most affected groups, being constrained by lack of resources and conventional means of production. Such climatic factors affect how the farmers behave, therefore changing their crops, planting seasons, land management techniques, and other aspects of their livelihoods (Chintu, et al., 2011). Some farmers now grow drought-resistant crops like sorghum, millet, and cassava, whereas other farmers continue using maize even though the crop is not drought resistant.

The primary issue arising from the literature review is how the small-scale farmers perceive and react to the stresses caused by the climate. The adaptation process is not simply a matter of changing techniques, but a process driven by personal perception, social norms, economics, and policies. While some small-scale farmers can adapt positively by engaging in novel farming techniques, other farmers are unable to adapt due to structural factors like lack of access to inputs, extension support, and finances (Ngoma et al., 2021).

The scope of this review will therefore attempt to chart the existing body of literature on the link between climate change and the behaviour of smallholder farmers from the global, regional, and local levels. The review is informed by key theories such as Theory of Planned Behaviour, Diffusion of Innovations, Sustainable Livelihood Approach, and resilience theory. At the same time, the gap in the empirical body of work is identified, particularly in the Zambian context where the localized research on the topic is lacking. This will set the stage for discussing how the present research fits into wider debates on the issue of climate adaptation and rural livelihoods among scholars.

2. Literature Review

The literature on climate change and smallholder farmers highlights that adaptation behaviour is influenced by multiple social, economic, psychological, and environmental factors. Researchers increasingly view farmers' responses to climate change as a complex process shaped by individual decision-making, institutional support, livelihood conditions, and environmental uncertainty. This is especially important in rain-fed agricultural regions such as Southern Africa, where climate variability directly affects farming systems.

One important theoretical perspective is the Theory of Planned Behaviour (TPB), which explains that human behaviour is guided by behavioural intentions influenced by attitudes, social norms, and perceived control (Ajzen, 1991). In agricultural studies, TPB has been widely used to understand farmers' willingness to adopt climate-smart practices such as drought-resistant crops and conservation agriculture. Studies indicate that farmers are more likely to adopt innovations when they believe such measures are beneficial and socially accepted (Bosnjak et al., 2020). However, TPB mainly focuses on individual thinking and pays less attention to structural barriers such as poverty, limited market access, weak extension services, and institutional failures.

The Diffusion of Innovations (DOI) Theory further explains how agricultural technologies spread within farming communities. According to Rogers (2003), adoption depends on factors such as relative advantage, compatibility, complexity, and observability. Empirical studies

from Southern Africa show that peer learning, demonstration plots, and extension services significantly influence adoption of drought-resistant crops and climate-smart technologies (Oyetunde-Usman & Shee, 2023; Ngoma et al., 2021). Nevertheless, DOI has also been criticised for underestimating structural inequalities and financial limitations that restrict adoption among poor rural farmers.

The Sustainable Livelihoods Approach (SLA) provides a broader understanding of adaptation by linking farmer behaviour with livelihood assets and institutional conditions. Chambers and Conway (1992) and DFID (1999) identified five forms of capital: human, social, natural, financial, and physical capital. Households with better access to these resources are generally more capable of adopting climate-resilient practices, while poorer households often remain vulnerable due to lack of credit, inputs, and institutional support. Studies from Zambia also confirm that livelihood assets strongly influence adoption behaviour and adaptive capacity among smallholder farmers (Ngoma et al., 2021).

Resilience Theory further contributes by viewing farming systems as dynamic social-ecological systems capable of adaptation and transformation. According to Folke (2006), resilience refers to the capacity of systems to absorb disturbances and maintain essential functions. Farmers respond to climate stress through crop diversification, livestock integration, and water conservation practices.

Overall, the reviewed literature suggests that farmers' adaptation behaviour cannot be explained through a single theoretical perspective. Climate adaptation is shaped by the interaction of behavioural intentions, innovation diffusion, livelihood resources, institutional support, and resilience capacity within vulnerable agricultural systems.

3. Methods

The current study employed the use of the scoping review research methodology to map and interpret the existing research literature related to climate change and the behaviour of smallholder farmers. The use of a scoping review method was appropriate because of the multidisciplinary nature of the subject matter, which includes climate science, agricultural economics, rural development, and behavioural science. The methodology does not seek to critically evaluate the quality of studies but rather provides an overview of the available literature and major themes related to the topic.

The review process followed a structured framework adapted from existing scoping review approaches proposed by Arksey and O'Malley (2005) and Tricco et al. (2018). The process involved identification of the topic scope, study identification, study selection, data extraction, organisation of findings, and thematic synthesis. Unlike systematic reviews, scoping reviews emphasise inclusiveness and flexibility in data collection and interpretation.

3.1 Data Collection

All secondary data used in the study were collected from electronic academic databases, institutional repositories, journal indexing services, policy reports, and academic publishers'

databases. These sources were selected to obtain literature related to climate change, agriculture, adaptation behaviour, and rural livelihoods, especially in Sub-Saharan Africa.

Two major approaches were used during the literature search process, including keyword searches and manual citation searches. Keywords such as “climate change,” “farmer behaviour,” “adaptation,” “drought,” “rainfall variability,” “crop adoption,” “livelihood diversification,” and “smallholder agriculture” were used individually and in combination to identify relevant literature. Backward and forward citation searches were also conducted to identify influential studies.

The inclusion criteria focused on scholarly articles that: i) Assessed the effects of climate change on agriculture, ii) Examined the behaviour of farmers in adapting to climate change, and iii) Related to Sub-Saharan Africa, particularly Southern Africa and Zambia.

Both peer-reviewed and non-peer-reviewed sources such as policy documents and institutional reports were included to provide broader understanding of adaptation policies and practices. Articles from different periods were also considered to examine changes in adaptation discourse over time.

The first stage of the scoping review involved defining the scope of the review in relation to the primary research question concerning the behavioural responses of smallholder farmers to climate change. The review mainly focused on three important adaptation themes identified from previous empirical studies: adoption of drought-resistant seeds, adjustment of planting dates, and crop rotation strategies.

The second stage involved identification of relevant studies through detailed desk-based research. Literature was obtained from peer-reviewed journal articles, working papers, institutional documents, and policy literature. Important empirical studies included works by Lunduka et al. (2017), Martey et al. (2020), Oyetunde-Usman and Shee (2023), Katengeza et al. (2018), and Wossen et al. (2017) on drought-resistant crops; Guido et al. (2020), Mangani et al. (2023), and Muyiramy (2020) on planting-date adaptation; and Thierfelder and Patrick (2010), Shah et al. (2021), and Thierfelder et al. (2024) on crop rotation and soil management practices.

The third stage involved the selection and analysis of studies. The selected studies were required to focus on smallholder farmers, climate-related adaptation behaviour, and empirical evidence. Literature focusing exclusively on large-scale commercial agriculture without empirical analysis was excluded from the review.

The fourth stage involved data charting and organisation. Relevant information from selected studies was extracted into a structured analytical framework. Key information included study location, research design, adaptation strategy, sample characteristics, major findings, and drivers or barriers influencing farmer behaviour. This process helped compare findings across different geographical and methodological contexts.

The final stage involved synthesis and presentation of findings through narrative analysis rather than statistical aggregation. The review identified similarities, differences, and gaps within the

literature. Many studies reported positive impacts of drought-resistant crops and adaptive farming strategies on agricultural productivity and food security. However, inequalities in access to technology, climate information, extension services, and institutional support were also widely observed.

The review further noted that while changes in planting dates were widely adopted, their effectiveness often depended on access to reliable climate information and extension support. Similarly, crop rotation and soil management practices showed positive outcomes but faced implementation challenges in resource-constrained rural settings.

The scoping review did not aim to establish causal relationships or quantify effect sizes. Instead, the review focused on providing a broad understanding of existing knowledge and identifying areas requiring further investigation, especially in under-researched regions such as Zambia.

3.2 Data Analysis

Thematic synthesis was employed for analysing the selected literature. Statistical aggregation was not used because the main purpose of the study was to identify patterns, theories, and empirical findings related to climate adaptation behaviour among smallholder farmers.

The selected studies were systematically coded and compared based on study location, research methodology, theoretical framework, adaptation practices, and key conclusions. Major themes identified from the analysis included adaptation behaviour, determinants of adaptation, institutional support, social networks, livelihood assets, and barriers related to policy and market access.

The review also examined the application of theoretical frameworks such as the Theory of Planned Behaviour, Diffusion of Innovations Theory, Sustainable Livelihoods Approach, and Resilience Theory within empirical studies. This helped explain both the behavioural dimensions of adaptation and the broader socio-economic conditions influencing farmers' responses to climate change.

In line with the principles of scoping reviews, the study did not critically evaluate the methodological quality of individual studies. Instead, emphasis was placed on identifying the scope of existing evidence and recognising important research gaps related to climate adaptation and smallholder farming systems.

3.3 Ethical Considerations

As a desk-based study relying entirely on secondary sources, the research did not involve direct interaction with human participants. Therefore, issues related to consent, confidentiality, and participant harm were minimal. However, ethical standards were maintained through proper citation, acknowledgement of all academic sources, and transparency in literature selection and analysis. These measures ensured academic integrity, credibility, and avoidance of plagiarism.

4. Results

The empirical studies carried out in Sub-Saharan Africa have always pointed out that climate change is among the main factors that lead to changes in small-scale agricultural systems. Climate variability in terms of drought, unpredictable rainfall, and warming trends have occurred frequently and intensely, thereby creating an environment of uncertainty in rain-fed agricultural systems (Omokpariola et al., 2025; FAO, 2012). In this regard, small-scale farmers have found themselves forced to make necessary adjustments in their behaviour due to the changes in the environment, although there have been variations in these adjustments.

A commonly reported response to climate change includes the changes in choice of crops due to the presence of recurrent droughts and rainfall variability. According to Ngoma et al. (2021), recurrent drought and rainfall variations in Zambia have caused farmers to conduct experiments and adopt drought-resistant crops such as sorghum, millet, cassava, sweet potatoes, and groundnuts. These drought-resistant crops are believed to be more water-tolerant and less sensitive to rainfall variability than maize, a crop that is vulnerable to water stress. According to Mubanga and Ferguson (2017), recurrent failure of maize crops in Southern Zambia has prompted farmers to seek other crops, even though maize still occupies an important position due to cultural and economic reasons.

Nevertheless, although there is increased awareness about such climate-smart crop types, the diffusion process appears to be inconsistent and fragmented. According to empirical evidence, adoption is largely contingent on the availability of extension services, input subsidies, and financial capital (Sekaran et al., 2021; Rapiya et al., 2025). Families having higher exposure to agricultural infrastructure are more willing to adopt advanced seed types and introduce crop diversification, while those living in far-off and resource-scarce areas continue to rely on conventional maize systems.

A third important dimension of adaptation highlighted in the literature is the adjustment of planting times according to rain fluctuations. Farmers regularly shift planting times in order to account for delays in the rainy season or avoid dry spells during the middle of the season. However, this practice relies mostly on farmers' empirical observations, since climate information systems are still underdeveloped in most rural communities. Although there are instances where farmers have effectively implemented earlier planting practices and staggered planting patterns to reduce risks, there are also other cases of repeated losses suffered by farmers because of the irregularity of rain patterns (Ngoma et al., 2021).

Diversification of livelihood has become one of the important coping mechanisms in sub-Saharan Africa. It has been found out that there is an increasing tendency among rural households to adopt agricultural livelihood together with other non-agricultural sources of income like petty trade, casual labour, and other forms of entrepreneurial ventures (Bwalya, 2023; Stadtbäumer et al., 2022). Diversification increases the chances of survival for the household through spreading risks among various sources of income, which reduces reliance on weather-dependent agriculture as a source of livelihood. Livestock rearing is another crucial means in areas where drought prevails.

Even then, diversification cannot be practiced by all communities. Studies show that people from poor backgrounds tend to resort to coping mechanisms which generate very little income because they lack access to resources including capital, skills, and markets (Bwalya, 2023). In this regard, though diversification helps certain individuals to become resilient, it can exacerbate inequalities as asset-rich and asset-poor farmers remain at opposite ends of the economic spectrum.

The use of crop rotation and soil fertility enhancement techniques has been found to play a critical role in climate change adaptation efforts. Continuous planting of maize alongside soil degradation and depletion of organic matter content have resulted in decreased productivity in Southern African regions (Thierfelder et al., 2024; Descheemaeker et al., 2016). In this case, some have started using rotation methods where legumes such as peanuts and cowpeas are planted to improve nitrogen content and moisture conservation in soils.

However, the application of crop rotation has been inconsistent because of conflicting land uses, lack of knowledge, and immediate need for livelihood support. In many instances, the primary consideration for most farmers has been food security rather than soil conservation, which has continued to lead to the practice of monoculture despite the decrease in soil fertility levels. This shows the complexities involved in making decisions when resources are scarce.

The combination of water and livestock management practices has also become common among farmers as an adaptation strategy considering the climatic stresses being experienced. According to studies carried out on the integrated crop-livestock system, decreased pasture availability and water shortages have compelled farmers to embrace rotational grazing and water management techniques (Manono & Gichana, 2025; Rapiya et al., 2025). The main objective of these techniques is to ensure that resource utilization is efficient and that nutrients are recycled. Livestock plays a key role in these agricultural systems by offering income to farmers and protecting them from climate-related risks (Descheemaeker et al., 2016).

Zambia has experienced the necessity of adaptive livestock management due to the increased problem of water shortages and drying up of surface water sources. There is an increasing trend towards altering livestock herds, using various livestock types, and developing water storage facilities where feasible (Bwalya et al., 2024; Kalapula & Mweemba, 2018). Unfortunately, such adaptation measures may not be easily achieved due to financial limitations and lack of infrastructure, especially in rural districts like Choma.

Nevertheless, while these adaptations have been documented in the literature, several structural factors exist which hinder the implementation of climate-smart agriculture practices. Perhaps one of the most significant barriers is the poor performance of agricultural extension services. Many rural communities suffer from inadequate extension services due to understaffing, underfunding, and uneven distribution of extension officers (Rapiya et al., 2025).

The preference for agriculture based on culture is another factor that impacts decision-making in the sector. Maize is highly valued in Zambia culturally and as a diet, making its production dominant despite its susceptibility to droughts. The cultural inclination makes it difficult for

farmers to completely adopt other crops, even when empirical evidence suggests that the crops are resilient to climatic shocks.

Financial capital is another challenge that prevents households from fully adopting new farming techniques. Farmers require enough financial resources to invest in seeds that have improved characteristics, irrigation technology, and livestock management. Financial constraints make it difficult for households to improve agricultural productivity (Ngoma et al., 2021).

Inconsistency in agricultural policy implementation affects the extent to which households adopt new agriculture practices. For instance, the input subsidy program that aims to diversify crop production and ensure resilience is rarely consistent. Implementation challenges include inefficiency, delayed implementation, and inadequate coverage (Rawlins & Kalaba, 2020).

To sum up, the empirical data indicate that although small-scale farmers in sub-Saharan Africa have been actively adopting different adaptation techniques, such as crop diversification, change in sowing times, livelihood diversification, fertilization, and livestock and water integration, the results vary significantly depending on several factors. Adaptation not only depends on environmental factors but also depends on socio-economic position, institutional resources, culture, and policies. In addition, despite the growing significance of the social side of adaptation, especially gender aspects and community-level natural resource management, there is still much to investigate in this regard (Sekaran et al., 2021; Bwalya et al., 2024).

Table 1: Selected Empirical Studies on Climate Change Adaptation and Livelihood Diversification

Author(s)	Study Area	Method / Design	Respondents	Major Indicators	Source
Ngoma et al. (2021)	Zambia	Panel data analysis	Smallholder farmers	Climate shocks, resilience, climate-smart practices	<i>Climatic Change</i>
Bwalya (2023)	Zambia	Case study	Rural households	Income diversification, food security	University of Zambia
Beyene et al. (2023)	Ethiopia	Quantitative survey	Pastoral households	Poverty, diversification, livestock ownership	<i>Cogent Social Sciences</i>
Stadtbäumer et al. (2022)	Zambia	Simulation modelling	Smallholder farmers	Adaptation strategies, income stability	<i>Agriculture & Food Security</i>

Sekaran et al. (2021)	Global	Systematic review	Published studies	Sustainability, food security	<i>Journal of Agriculture and Food Research</i>
Rapiya et al. (2025)	Sub-Saharan Africa	Review study	Published studies	Soil fertility, income diversification	<i>Agriculture</i>
Manono & Gichana (2025)	Sub-Saharan Africa	Literature review	Published studies	Pasture management, resilience	<i>Earth</i>
Descheemaeker et al. (2016)	Sub-Saharan Africa	Systems analysis	Smallholder systems	Productivity, adaptation	<i>Regional Environmental Change</i>
Kalapula & Mweemba (2018)	Zambia	Qualitative case study	Pastoral communities	Indigenous knowledge, resilience	<i>World Journal of Sociology and Anthropology</i>
Bwalya et al. (2024)	Zambia	Quantitative survey	379 households	Livestock ownership, adaptation	<i>Frontiers in Sustainable Food Systems</i>
Rawlins & Kalaba (2020)	Zambia	Policy analysis	National context	Policy effectiveness, maladaptation risks	<i>African Handbook of Climate Change Adaptation</i>
Asfaw et al. (2017)	Ethiopia	Econometric analysis	Smallholder farmers	Income sources, access to finance	<i>Development Studies Research</i>

Table 2: Climate Change Adaptation Strategies among Smallholder Farmers in Sub-Saharan Africa

Adaptation Strategy	Key Authors	Evidence Type	Main Focus	Level
Crop diversification and drought-tolerant crops	Ngoma et al. (2021); Oyetunde-Usman & Shee (2023)	Empirical / Review	Adoption of sorghum, millet, cassava, legumes to reduce drought risk	Household / Farm
Planting date adjustment	Guido et al. (2020); Mramba & Mafwela (2025)	Empirical	Adjustment of planting calendars based on rainfall variability	Farm

Livelihood diversification	Bwalya (2023); Beyene et al. (2023)	Empirical / Modelling	Income diversification through trade, labour, livestock, and small businesses	Household
Livestock-based adaptation	Bwalya et al. (2024); Manono & Gichana (2025)	Empirical / Review	Herd diversification, grazing management, livestock as buffer assets	Household / Community
Soil fertility management and crop rotation	Thierfelder & Wall (2010); Aslam et al. (2024)	Experimental / Empirical	Improved soil fertility, moisture retention, and crop productivity	Farm
Integrated crop–livestock systems	Descheemaeker et al. (2016); Sekaran et al. (2021)	Review / Conceptual	Improved resilience, productivity, and nutrient cycling	Farm / System
Policy and institutional support	Rawlins & Kalaba (2020); FAO (2022)	Policy / Review	Role of extension services, credit access, and adaptation policies	Institutional

5. Discussion

However, it is evident from the reviewed literature that behaviour exhibited by farmers in face of climate change is not simply an outcome of their reaction to stressors in the environment, which include factors like water scarcity, unpredictable rainfall, and increase in temperatures. In fact, this behaviour turns out to be an outcome of a complex adaptive phenomenon that involves multiple elements including behavioural intent, institutions, social and economic structures, and ecological processes. In other words, farmers do not act merely due to climate stresses but take decisions based on a variety of other factors too.

The Theory of Planned Behaviour is important in explaining how and why farmers intend to adopt or not adopt certain agricultural practices depending on their resilience to climatic conditions. According to this theory, behavioural intention is guided by three factors, which include attitude towards the intended behaviour, subjective norms, and perceived behavioural control. The explanation can be used to understand how farmers show willingness to adopt drought-resistant seeds or change planting times whenever there is a change in weather patterns. Nonetheless, from the literature, a common limitation of this theory is that it makes assumptions about people's ability to make sound judgments because they have the capacity to decide independently. The reality in most smallholder agriculture settings is that people experience constraints such as limited availability of quality seeds, no credit facilities, poor extension services, and uncertain input systems. As a result, it would be very difficult for

intention to result in behavioural change where there are limited resources available for adoption.

Another contribution to the comprehension of behavioural change that can be gained from applying the Diffusion of Innovations Theory lies in the process through which farmers adopt agricultural innovations. Relative advantage, compatibility with the status quo, simplicity, trialability, and observability have all been shown to play an important role in influencing farmers' choices when adopting innovations. In fact, empirical studies have found that farmers are very much inclined to use resilient crops after they witness successful results in their neighbours or after they experiment with demonstration plots through extension services. Social learning, therefore, is crucial in lowering uncertainty and motivating farmers to innovate. The problem with the Diffusion of Innovations Theory is that it takes for granted that farmers will have equal access to information and innovations, which does not happen. In fact, unequal access to extension services, input subsidies, and market channels has resulted in certain farmers being constantly placed in the position of early adopters whereas others have no access whatsoever to innovation networks.

However, the sustainable livelihoods approach fills these lacunas through its focus on the asset base of the household, rather than on individual decision-making processes. The approach makes it clear that the behaviour of the farmers is strongly influenced by their asset base in terms of five types of capital – human, social, financial, physical, and natural. A diversified asset base makes it easier for a household to withstand shock and undertake adaptation measures like diversifying crops, livestock inclusion, and diversified income generation. Conversely, an asset-poor household tends to remain locked in a survival mode, making it difficult for them to adapt.

In this regard, resilience theory builds upon this knowledge by presenting adaptation as an interactive, iterative, and non-linear process. Adaptation is not seen as a final product or end goal, but rather a dynamic interaction between the social and ecological systems continuously. Resilience theory also points out that natural events such as droughts not only affect agricultural production but may also result in system changes within the means of livelihood, institutions, and farming systems. The significance of resilience theory lies in its ability to explain how climate shock, when recurring, results in permanent changes in cropping, farming systems, and rural livelihood structures.

One of the major takeaways from the literature is that adaptation must be thought of as more than simply the adoption of new technology or practice. Adaptation entails the reshaping of entire livelihood systems in reaction to new ecological and socioeconomic circumstances. Farmers frequently employ several approaches at once, ranging from changes in planting times to crop rotation, introducing livestock, taking up alternative occupations, and altering their soil and water management approaches. Yet, empirical analyses of these different approaches typically consider each approach independently, instead of analysing the interplay between them as part of larger livelihood systems.

Another critical point to note is the fact that behaviour change tends to be highly situational and influenced by socio-cultural and historical factors that are deeply entrenched. For instance, despite increased instances of drought in Choma District, maize still predominates in farming systems. Apart from agronomical advantages, other considerations such as culture, eating habits, and agricultural history have a significant influence on the choice of the crop. The district's agriculture policy has been centred on maize farming due to input programs that encourage farmers to grow the crop. Hence, despite sorghum, millet, cassava, and groundnuts being more resilient to drought than maize, their uptake has remained limited.

Consequently, one could draw from the literature that there is a need for a holistic approach to studying farmer behaviour in the face of climate change, which should incorporate insights from multiple theories and frameworks to account for the interrelationship between the individual, the social, the institutional, and the ecological. Furthermore, it is critical to recognize the fact that adaptation processes are heterogeneous, dependent on contextual factors, and reflective of past agricultural history.

6. Implications for Future Research

In terms of methodological considerations, there is a necessity for future research to incorporate theoretical perspectives from behavioural sciences, livelihood frameworks, and resilience theory. Therefore, researchers would have a chance to investigate the interplay between psychological predispositions, social environment, and natural surroundings and their impact on farmers' decision-making process.

Moreover, it is important for future investigations to conduct more empirical work within Zambian territory by paying attention to the differences between adaptation patterns at the district level rather than making general assumptions about the whole nation. As mentioned above, longitudinal analysis might be helpful in investigating adaptation behaviours.

Methodologically, it is important for future studies to make further efforts in utilizing mixed methods design, especially such designs as exploratory sequential and abductive approaches. These methods would enable scholars to refine their hypotheses and theories by using field data. Additionally, more emphasis should be put on incorporating qualitative information into quantitative models.

Lastly, while future research should address questions related to the adoption of resilient technologies and innovations, there should also be an analysis of their sustainability.

7. Conclusion

Climate change has been shown to exert influence on smallholder farmers' behaviours through a range of related mechanisms including psychological intention, social diffusion, livelihood assets, and resilience dynamics. By employing the Theory of Planned Behaviour, Diffusion of Innovations Theory, Sustainable Livelihoods Approach, and resilience theory, an effective conceptual framework for exploring climate change adaptation among smallholder farmers has been established.

There have been empirical observations of rising adoption of climate-resilient crops, changing planting time schedules, livelihood diversification, and integrated resource management practices. Nevertheless, these adaptation practices remain hindered by structural barriers as well as socio-cultural issues.

Several gaps in the literature have emerged throughout the review, including inadequate theorization, lack of localized data, and insufficient focus on behavioural dynamics. These aspects need to be addressed to ensure further advancements in both research and policymaking with regards to enhancing the adaptive capacities of smallholder farmers, especially within Choma District.

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Assessment of Socio-Demographic Profile and Occupational health Risk of the Brick Kiln Workers in Dinajpur District, Bangladesh

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Abstract: *Brick kilns industries are one of the fastest-growing yet informally recognized sectors in Bangladesh, significantly contributing to both economic development and environmental degradation. However, these industries pose severe occupational health risks to workers, who often come from marginalized socio-economic backgrounds. This study aims to assess the socio-demographic status of brick kiln workers and analyze the occupational hazards they face. A field survey was conducted during November and December 2022, covering nine brick kilns in Bochaganj upazila (sub district) under the district of Dinajpur. Using a simple random sampling method, 100 workers were selected for the study. Descriptive statistical analysis was employed to evaluate the collected data. The findings reveal that 85% of the workforce consists of males with low level of formal education, while 84% of workers earn less than 7000 BDT per month. The study also identifies significant health concerns among the workers, with 30 % suffering from whooping cough, followed by both 18 % experiencing headaches and injuries. 12 % of them reported suffering from high blood pressure. To reduce the occupational health risks, the study underscores the necessity of stringent policy interventions, improved workplace monitoring and enhanced labour welfare initiatives at the government level.*

Keywords: Brick field, Brick field workers, Socio-Demographic status, Health Hazards, Dinajpur, Bangladesh

1. Introduction

In Bangladesh, fired brick fields are among the most essential building suppliers (Luby *et al.*, 2015). Bangladesh has ranked as the world's fourth-largest manufacturer of bricks (Rahman 2022). Approximately 8122 brick kilns can be found all over the country. Bangladesh manufactures between 23-32.4 billion bricks annually (Siddik *et al.*, 2021). Bangladesh's

expanding population will require the building of 4 million new homes annually (Barua *et al.*, 2010). About 8122 brickfields in Bangladesh are legal, but there are many more that are not. The unlawful brickfields lack the necessary equipment to operate and a valid license to maintain the field's integrity (Rahman, 2021).

Socio-Demographic status involves variables such as gender, age, income, education, employment, marital status, ethnicity etc. (Melgar *et al.*, 2010). In Bangladesh, every single economic, social, and other component is steadily rising over the years. Bangladesh's current GDP is 7.25%, and its per-capita income is around 2824 USD (BBS, 2022). Infrastructure development is one of the main problems across the nation as a result of the increasing macroeconomic stability. Bangladesh's construction sector has been growing at a pace of roughly 5.28% (Asadullah & Chakravorty, 2019). The construction industry has grown at a rate of roughly 5.28% during the past few years (Liu *et al.*, 2023). Every infrastructure development endeavor starts with a brick. One percent of the nation's GDP is contributed by the brick industry, which also employs about 1 million people (Ahmed, 2019). Over 20 billion bricks may be produced annually in the existing brick kilns (Nath *et al.*, 2018). The Department of the Environment (DoE) and the Bangladesh Brick Making Owners Association (BBMOA) claim that new brick kilns were erected in 1930. In terms of lowering agricultural land, deforestation, air pollution, and GHG emissions, coupled with other social problems like labor rights and gender violence at work, this sector is currently seen as one of the alarming sectors (Hossain *et al.*, 2019). Total annual amount of CO₂ emission for six divisions: Dhaka, Chittagong, Rajshahi, Khulana, Sylhet and Barisal are 8.862 Mt/year, 10.048 Mt/year, 12.783 Mt/year, 15.250 Mt/year, in the year of 2002, 2005, 2007 and 2010, respectively. Humans are quite concerned about the percentage of CO₂ emissions that have increased geographically during the past ten years (Imran *et al.*, 2015). The greatest source of GHG emissions in the nation over the past few decades has reportedly been the brick industry (Saha & Hosain, 2016). Brick kilns are now responsible for 58% of all PM_{2.5} pollution generated in the city of Dhaka. During the dry season, the proportions significantly higher (Khaliquzzaman *et al.*, 2020). The socio-demographic condition of brick kiln workers revealed that the majority of workers are male respondents with low education levels, with 91.79% getting monthly pay less than 15000 BDT and experiencing serious health and environmental challenges (Sajan *et al.*, 2017). A study found that 70% of respondents to a questionnaire survey 64% were male, and 36% were female, while 38% respondents were illiterate and 10% were graduates (Tusher *et al.*, 2019).

An enormous number of brick kilns are using firewood illegally as fuel. A study finds that, about 30% of Bangladesh's brick kilns are defective (Eil *et al.*, 2020). The current production of red bricks (clay burned) uses top soil from farms. Typically, the top soil the upper 6 to 24 inches of the agricultural field is needed for the traditional brick-making process (Fatema & Hossain, 2022). Research findings indicated that more than 100 core tones of agricultural topsoil are required for bricklaying every year. Everyday about 690 acre of agricultural land is transforming into non-agricultural land all over the country (Hossain *et al.*, 2022). Brick field provide a livelihood for thousands of unskilled workers across the country. The seasonality of work attracts workers and landless farmers (Hossain *et al.*, 2019). The demographic and health aspects of brick kiln workers are not clearly known from various published research papers and

book. As a result, ongoing research has been conducted to find out these issues. Thus this research attempts to show the scenario of the socio demographic status and health hazards of brick field workers.

The workers work long hours and do manual hard work in brick field. During work, they have to carry various heavy loads. Thus, they most often suffer from muscle raises (Guttikunda *et al.*, 2012). These disorders are caused by strenuous exercise, rigid working postures, frequent bending and twisting, lifting, pushing and pulling, repetitive tasks, vibrations and psychosocial stress (Das, 2014). Apart from these problems, workers suffer from various ailments such as skin allergies, eye irritation, tuberculosis and joint disease. They suffer from asthma, chronic obstructive pulmonary disease, silicosis, and more from exposure to dust particles (Hunashal, 2013). The majority of brick kiln workers in the proximity of these facilities were found to be affected by numerous illnesses, such as asthma, weariness, headaches, eye irritation, and other conditions, indicating that the pollutants from brick kilns may be a contributing factor in these conditions (Saha *et al.*, 2020).

It was found that 14.3% of workers did not exhibit pale, chilly skin symptoms; but migrant workers employed temporarily exhibited the condition in 85.7% of cases, and fatigue symptoms were found in all cases when 82.2% of workers were assessed by brick kiln experts (Gogoi, & Hazarika, 2016). It was shown that a maximum 96.8% of responders had tinges on their hand's palms or their eye's conjunctiva, which indicated nutrient deficiencies, vitamin D deficits, iron shortcomings, headaches, common cold, diseases, insufficient sleep, and anemia (Gogoi, & Hazarika, 2016). There are usually no clean drinking water or sanitation facilities in all around brick field area (Saha *et al.*, 2020). Brick kilns lack the availability of normal medical amenities, clean drinking water, and sanitary facilities (Sajan *et al.*, 2017). The health of those who work in brick kilns is poor, with 96.7% indicating some sort of complaint, with musculoskeletal, respiratory, and skin issues being the most prevalent (Kazi & Bote, 2019). A research in South India discovered that 9.4% of brick kiln migrant workers experienced chest symptoms, with illiteracy, alcohol misuse, and excessive smoking being important risk factors (Thomas *et al.*, 2014). The brick kilns business in Pakistan releases toxic gasses that threaten human health and the environment, and it is advised that innovative technology be used to mitigate negative impacts and eliminate harmful emissions (Khan *et al.*, 2019).

Another study indicates that because of their dangerous working circumstances, over 11% of brick kiln workers have health issues; yet, only 7% of these workers are receiving care, and the remaining 4% do not have access to medical supplies or care (Kumari, 2018). According to the survey, asthmatic disease is one of the main factors affecting worker health, while other factors have a negative impact on local resident's health in brick kiln locations (Saha *et al.*, 2020). Brick kilns are used to prepare, process, and bake bricks. It offers employment in a variety of sub-occupations to practically everyone. The majority of brick manufacturing field workers are uneducated and from lower socio-economic strata (Kainth, 2009). Brick field workers do not receive appropriate payment or access to healthcare (Darain *et al.*, 2015). Brick field workers have poor dietary habits, and since they work in a challenging environment, they are highly susceptible to various health problems (Rizwan, 2021). The goal of this study is to examine the

socio-demographic status and health hazards of this unorganized sector. This research is to evaluate how brick fields affect the health of brick field workers, specifically their socio-demographic status and the factors that influence their health.

2. Methodology

This study employs a mixed-method approach, incorporating both primary and secondary data to comprehensively assess the socio-demographic status and occupational health hazards of brick kiln workers in Dinajpur District, Bangladesh. Primary data were collected through a structured questionnaire survey conducted during November and December 2022. Through the questionnaire survey, the socio-demographic status of the respondents, and their physical problems due to working in brick kilns were brought out. The final questionnaire is based on a compromise between the need for the data and the respondent's capacity to provide it. Certain statistical and operational factors, including the nature of the data sought the method of collection and the need for respondents' units to process and tabulate the data, were taken into account when designing the questionnaire.

2.1 Selection of study area and respondents

Brick making industry is currently a fast-growing sector in Bangladesh. It provides employment opportunities to people at a given time of the year. There were about 8122 brick fields in the country. Of these, there are only 45 hybrid Hoffmann and 86 tunnels Kilns. The rest were zigzag method (BBS, 2022). In the brick field a large amount of wood and coal is used as fuel. There are 17 brick kilns in Bochaganj upazila (Sub-district) under Dinajpur district. Of them 9 Brick fields were selected in which nearly 10,000 public relations people who do their promotional work, both men and women make up the research population. Figure 1 represents the Map of study area. Questionnaires of 100 workers of 9 brick kilns from Bochaganj upazila have been surveyed based on random selection from among these brick kilns.

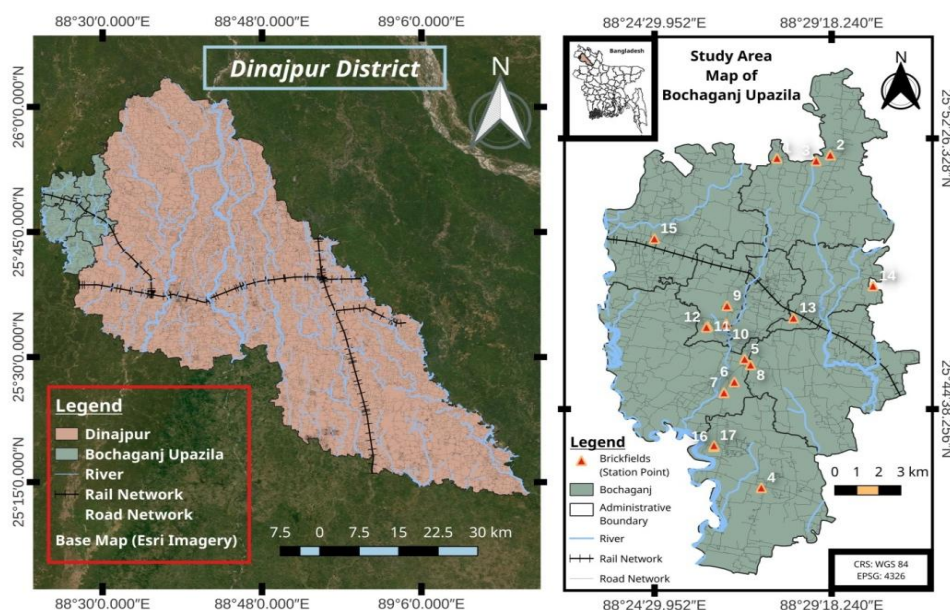


Fig. 1: Location Map of the study Area

2.2 Sampling technique and sample size

Data for the study were purposefully gathered from respondents who were working and available during the survey. There will be a random selection of 100 workers from the 9 distinct brick fields in the study region. The sample for this research was calculated using the 95% confidence level of Taro Yamane’s formula (Yamane, 1973). The following is a demonstration of Taro Yamane’s calculating formula.

$$n = \frac{N}{1 + Ne^2}$$

Where, N= Total population, e= Error and n= Sample size

Using the above formula, the calculated sample size of the research is 100. The following table presents the distribution of sample along with coordinates of the location of the brick field.

Table 1: Location of the Sample Site

Brick Field No	Latitude	Longitude	Respondent
1	25.864585	88.463713	12
3	25.863312	88.481439	11
5	25.768026	88.435231	12
7	25.751880,	88.439746	11
9	25.793657,	88.441109	11
12	25.783339,	88.431809	10
14	25.803202,	88.507170	11
16	25.725935,	88.435148	12
17	25.726546,	88.435231	10
Total			100

Source: Primary Data

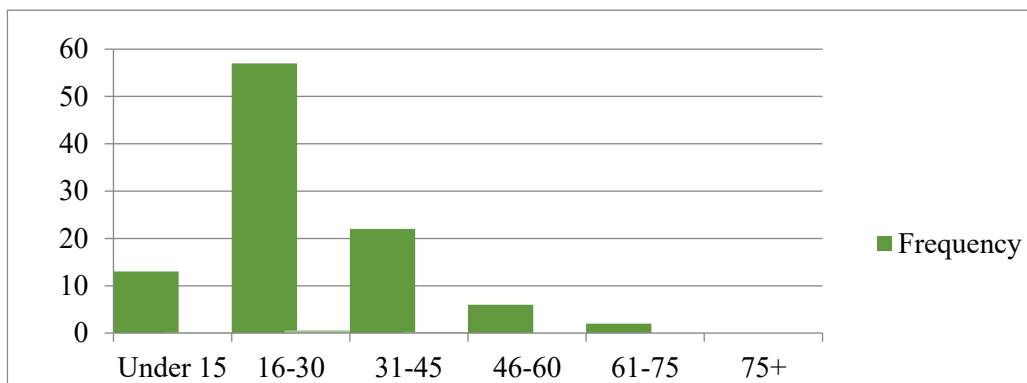
3. Results and discussion

3.1 Socio-demographic Status of the Bick Kilns workers

Age factor

Most of the responders in Bochaganj upazila were older than 16 years of age. 80% of the responders were in the 16 to 45 age range. 8% of responders were in the 46–75 age range. A large number of young individuals are obliged to work in this dangerous profession due to severe unemployment and poor levels of education. The age ranges of (61-75) and (75+) are represented by 2% and 0%, respectively (Figure 2).

A study by Gogoi and Hazarika (2015) showed that 56.3 % of the workers in brick kilns are between 31 and 60 years of age. Besides, 19 to 30 years old workers are 34.2 %. A study finding show that the highest number of respondents (41.79%) belonged to the age of group 31-35 years, followed by the age group of 26-30 (31.59%), 36-40 (19.15%), 20-25 (5.72%) and only 1.74% of male respondents were more than 40 years (Sajan *et al.*, 2017)

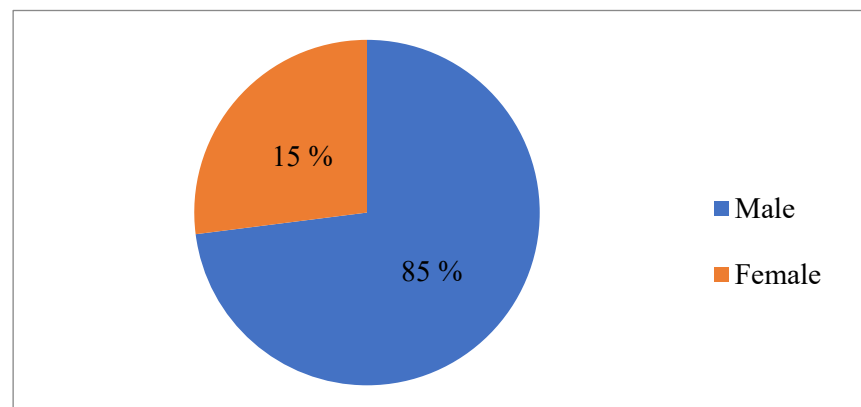


Source: Primary Data

Fig. 2: Age Factor

Sex factor

According to the figure 3, men make up the majority of responders (85%), while women make up 15%. Working in the brick industry requires physical strength and the right kind of energy to endure the hard conditions. Because women are inherently weaker than men, this job targets a relatively small number of women. A study by Gogoi and Hazarika (2015) also found that 87.9 % were male and 12.1 % were female. Another study on brick field workers health of 402 interviewees contained 269 (66.92%) males and 133 (33.08%) females, ranging in age from 20 to >40 years (Sajan *et al.*, 2017).

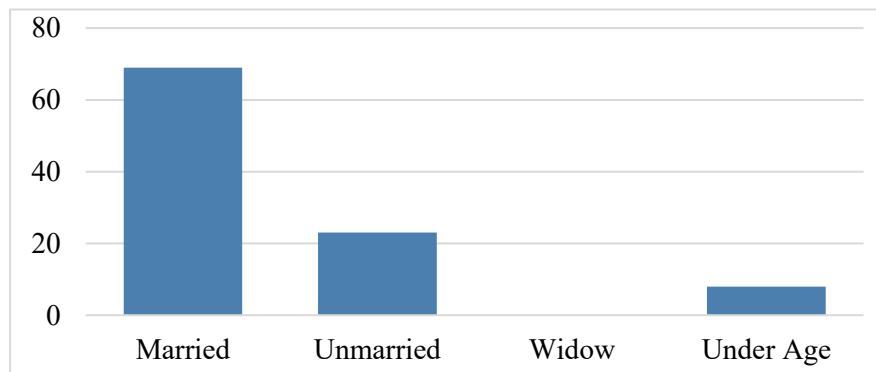


Source: Primary Data

Fig. 3: Sex Factor

Marital status

With a few exceptions, the majority of responders in the study population are married. Due to a lack of education and appropriate social awareness, the majority of respondents (65%) don't have any proper knowledge regarding marriage. Additionally, they typically originated from rural areas where early marriage is a widespread practice. From the data on marriage, about 8 percent of the respondents got married before the appropriate age which is called under age marriage (Figure 4).

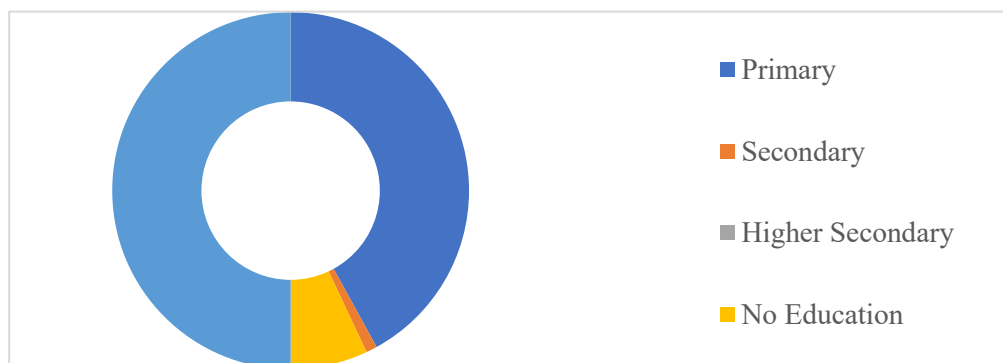


Source: Primary Data

Fig. 4: Marital Status of the Respondents

Educational Status

According to field survey, 84% of the respondents have basic level education, with the exception of 14% of respondents who are illiterate (Figure 5). Another study on the brick field workers health found that 9.7% of the sampled workers were uneducated and pursued primary (72.64%) and secondary (17.66%) levels of study (Sajan *et al.*, 2017)



Source: Primary Data

Fig. 5: Education Qualification of the Respondents

Main Occupational Status

When the respondent had no option to work in the brick field, majority of them worked as farmers. Workers work in brick kilns for 3 to 4 months a year. During the remaining months of the year, they are busy with various economic activities. 57 % of them are engaged in agriculture. Apart from this, thirty percent people work as day labor. Rest of them earns their living as housewives, fishermen or business (Table 2).

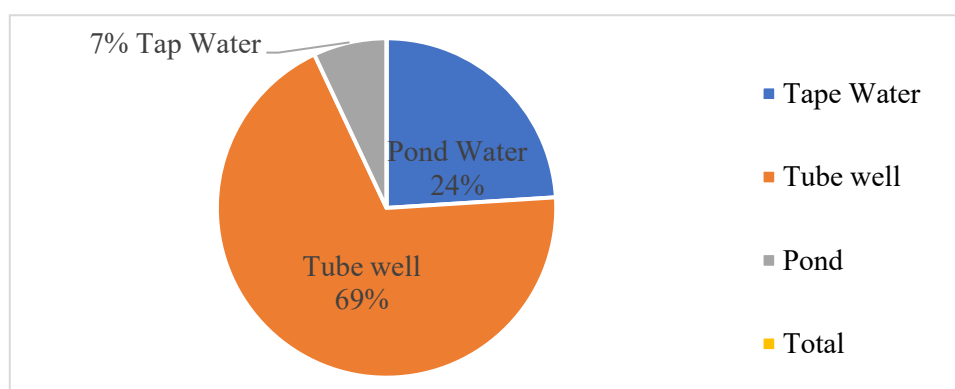
Table 2: Occupation Types

Occupation	Frequency	Percentage
Agriculture	57	57%
Business	3	3%
Day labor	30	30%
Housewife	5	5%
Fisherman	5	5%
Total	100	100%

Source: Primary Data

Availability of Drinking Water

The majority (69%) of drinking water comes from tube wells. The workers source of drinking water is a tube well, which is almost always present in brick fields. And the workers use neighboring ponds and tap water for bathing and washing, which equals 24% and 7%, respectively (Figure 6). In a study on the effect of brick industry on water, total solids, dissolved oxygen, Calcium, hardness, and total hardness were estimated. These were found in significant quantities in the water around the brick fields (Khan, & Vyas, 2008). Another study found that majority of workers (98.01 %) do not have access to clean water and (90.80 %) do not have proper sanitation facilities (Sajan, *et al.*, 2017).



Source: Primary Data

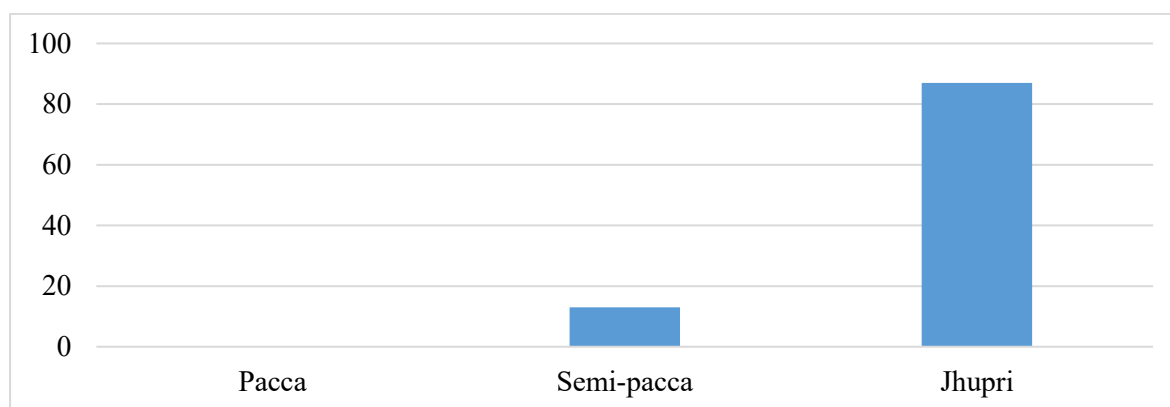
Fig. 6: Drinking Water Availability

A study by the International Agency for Research on Cancer found sulfur dioxide in water sources around brick kilns. Ingestion of these SO₂ amplified pulmonary resistance, and changes

in metabolism, resulting in chronic exposure to inflammation and increased secretion of mucosal tissues which causes cancer (WHO, 1979; Toyokuni *et al.*, 2017). In a study on the effect of brick industry on water, total solids, dissolved oxygen, Calcium, hardness, and total hardness were estimated. These were found in significant quantities in the water around the brick fields (Khan & Vyas, 2008). Another study found that majority of workers (98.01 %) do not have access to clean water and (90.80 %) do not have proper sanitation facilities (Sajan *et al.*, 2017).

Availability of Sanitary Systems

Modern sanitary systems are not present in brick field's area. The majority (88%) of brick workers lack access to contemporary sanitary facilities. They consequently experience a variety of illnesses that are directly related to sanitary systems. Nearly 88% of the respondents complained about having to use the Jhupri type toilet every day. A single toilet is used by numerous individuals (Figure 7). According to a survey, the majority of workers reside in subpar home with an unhealthy (Jhupri) environment (Sajan *et al.*, 2017).



Source: Primary Data

Fig. 7: Sanitary Systems of the Respondents

4. Causes and Incidence of Disease among Brick Field Workers

4.1 Causes of Diseases

According to the results of field survey, roughly 50% of the study area is afflicted with ailments brought on by dust and sand. They are used to work in and dust environment. In addition, 18% of the respondents reported health problems due to incaution and sound. Moreover, some blamed work pressure and poor sanitation (Figure 8). Based on research conducted in developing nations, brick kilns burn tires, fuel gas, and coal. These sources of air pollution include CO_x, SO_x, NO_x, and suspended particulate matter, all of which have negative health effects on people (Ismail *et al.*, 2012).

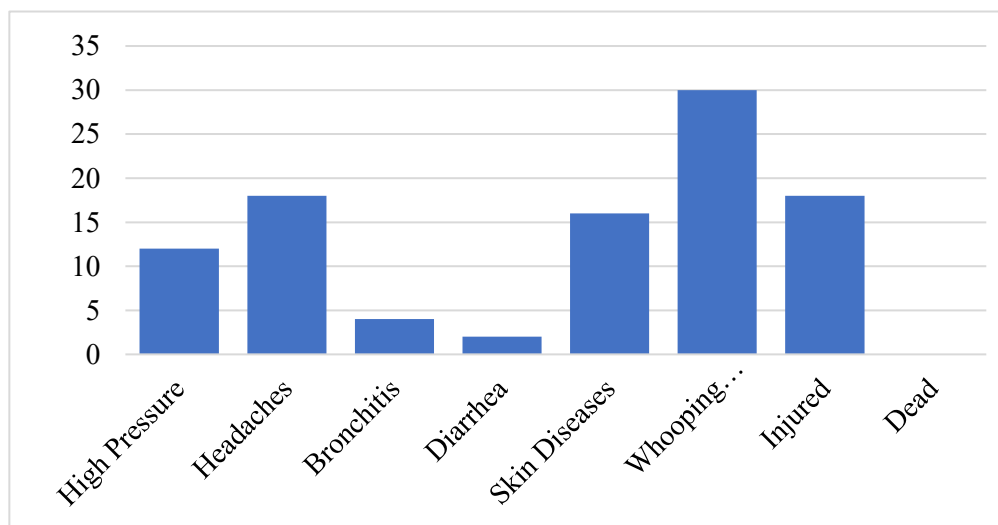


Source: Primary Data

Fig. 8: Causes of Diseases

4.2 Impact of Brick Field on worker's Health

Field Survey findings indicate that, workers are most affected by whooping cough (30 %). Headaches and injuries at work accounted for 18 percent of cases. Besides, 16 percent of skin diseases, 12 percent of high blood pressure, 4 percent of bronchitis and 2 percent of diarrhea cases are recorded (Figure 9).



Source: Primary Data

Fig. 9: Consequence of Disease in Brick Fields

A study on brick field in Indian perspective reveals that 21% of respondents had stage 1 hypertension, 7.3% had hypotension, and 6.2 % had stage 2 hypertension, whereas 33.7 % of respondents had prehypertension, 31.8 % had desirable or normal blood pressure (Gogoi1 & Hazarika, 2015). In this study 27.2% of respondents reported not having a fever, cold, or cough, while 72.8% of respondents reported having these illnesses. Their results found that, 50.4% of the respondents reported having a persistent cough that was accompanied by chest pain and sputum that had bronchitis symptoms. 49.6% of respondents said they had not noticed any bronchitis symptoms. Before starting work in the brickfield, 75.2% of the respondents had

diarrhea. However, 24.8% of the respondents claimed that they did so either before or after reporting for duty didn't experience diarrhea. 86 % of the respondents reported having skin conditions, while the remaining 14 percent had no complaints. The majority of respiratory illnesses and symptoms are caused by occupational risk factors, and lung disease accounted for 29.6% of workers with chronic obstructive pulmonary disease. Nasal congestion affected 68.7% of the respondents. In addition, 32.1% of respondents reported experiencing physical harm as a result of mishaps during work in brick kilns. After starting work in brick kilns, seasonal illnesses struck 77.6% of the workforce. Another study found that, Ninety five percent (95%) of respondents from the affected area reported having a respiratory illness or the common cold within the previous 12 months. 36% of respondents in the control region and 72% of respondents in the brick kiln area believed that the diseases were caused by brick kilns, respectively (Joshi, & Dudani, 2008). Another study shows that skin diseases and eye problems of the workers are 10% and this number is increasing day by day (Jerin, et al., 2017). Skin diseases, asthma, headaches problem are common disease among the workers and the residents lived nearby of brick field. Joshi & Dudani's health survey in Nepal clearly demonstrated that residents who live close to brick kilns are more likely to have illnesses brought on by kiln pollution than those who live farther away (Joshi & Dudani, 2008).

4.3 Injuries among the brickfield Workers

A large proportion (16%) of the respondents suffered head injuries while working in brick fields. Fingers and hands were injured rate same like as 10%. They also suffered neck, backbone, shoulder, ankle, back, and foot spinal, hip, and foot injuries during work which percentages are refer to the figure separately (Figure 10).

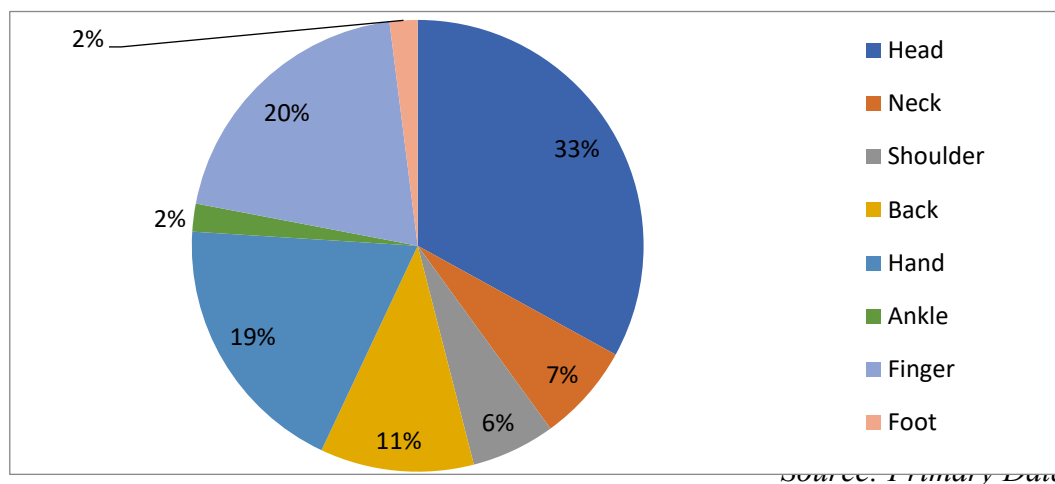


Fig. 10: Types of Injuries

About 20% of brick field workers experience back and muscular pain, and as the hands and feet are the primary body parts that enable workers to retain their range of motion during activities, these organs are harmed as a result (Rizwan, 2021). A study showed that in case of injury of the brick field workers, hands (59%), legs 53 percent, knees 19 percent were injured.

Apart from these organs like neck, shoulder, knee, wrist, finger, ear, hip, elbow, back and ankle also suffered during working at brick field (Sajan, *et al.*, 2017).

4.4 Initiatives for the Improvement of Brick Filed Worker's Health Condition:

According to the field survey data, if the workers get any illness or injury, in most cases they have to get treatment at their own expense or at their own initiative (85%). In this case, among others, the owners of brick field's help in some cases (10%) with some money and some NGOs (5%) take the initiative to provide treatment. The owner is not concerned with the physical improvement of the brick field laborers. Some NGOs assist the workers with their medical needs. Survey findings confirm 10% of the workers receive care from the owners. 85% of the employees are responsible for covering their own medical expenses. Owners of brick factories do not care about worker's living standards. A study found that nearly 90% of brick field workers do not have health insurance. As a result, if they suffer any accident during work, they have to pay the medical expenses on their own. This affects the family's income. Brick field owners do not take any plans or initiatives to take care of their workers. There were very few workers who benefited from the government at various times (Saha, *et al.*, 2020). This research shows that brick field workers do not have health insurance. So, those who are injured are treated at their own expense. As a result, their families are also suffering financial losses.

5. Conclusion

The rate of brick production is increasing day by day due to rapid population growth all over the world. This increase in the rate of brick production is detrimental to the human health, environment, society and economy of the country due to its harmful effects. The demands of bricks for building new infrastructure will tend to increase in future. The study found that among the respondents, males were more (85%) than females working in the bricklaying. In terms of age, most (90%) workers are between 16 to 45 years old. Number of married men (65%) is higher than all others. Moreover, 84% of their education is up to primary level and a large proportion of them are involved in agriculture during the rest of the year. Regarding the availability of drinking water, 69% of them drink water from tube wells and their sanitation system is very unhealthy. Incidence of whooping cough occurs 30% among brick field workers, headache and injury in 18%. Besides, 16 percent of skin diseases, 12% of high blood pressure, 4% of bronchitis and 2% of diarrhea cases are recorded. Dust-sand and sound pollution have been found to be the cause of these diseases. Brick field workers (33%) suffered also head injuries followed by 20% hands and 19% fingers respectively.

The findings also indicate that in most cases (85%) if injured, they get treatment at their own expense. Government agencies such as the Department of Environment (DOE) should also set standards and limits for harmful smoke emission rates from brick kilns. These efforts by the Government of Bangladesh and brick kiln owners will help control the harmful effects which in turn will help reduce the damage to the environment and human health. Initiatives for reducing health impact and injuries to body must be taken in the brick field industries. Relevant policies are urgently required in this regard.

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Challenges of Municipal Waste Management System Using an Integrated Approach: A Case Study of Kolkata

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Abstract: *The issue of Municipal Solid Waste Management (MSWM) in Kolkata, a densely populated and rapidly urbanizing city in India, presents significant challenges due to increasing waste generation and limited capacity for effective waste handling. This study examines key aspects of Kolkata's MSWM, such as waste generation rates, composition, collection, and treatment methods. Current challenges include inadequate infrastructure, insufficient financial resources, lack of land for disposal, and limited public awareness. These issues are compounded by ineffective regulatory enforcement and technology constraints, further impeding sustainable practices. The environmental and health risks of unmanaged waste—such as water contamination, air pollution, and heightened disease risk—disproportionately impact vulnerable communities. Additionally, this study highlights the potential of public private partnerships (PPPs) to enhance waste management, though challenges in private sector engagement remain. Emphasizing the often-overlooked role of informal sector workers, such as ragpickers, the study suggests their integration into formal waste systems to improve efficiency and inclusivity. Ultimately, the paper advocates for decentralized waste processing units and a strengthened recycling industry to address Kolkata's pressing MSWM needs, contributing to sustainable urban development in fast-growing cities.*

Keywords: *urbanization, biodegradable, population growth, solid waste, ragpickers, recycling*

1. Introduction

West Bengal is undergoing a rapid transformation from an agrarian economy to one increasingly driven by industry and services. Kolkata, with a population exceeding one million, serves as a major hub for business and industrial activities. The city's unique blend of tropical wet, tropical dry, subtropical humid, and mountain climates affects consumption habits and seasonal waste generation patterns, spanning winter, summer, monsoon, and autumn seasons. However, there is a noticeable gap in comprehensive studies analyzing these regional and

seasonal variations in waste generation, which are essential for effective municipal solid waste management (MSWM) in urban areas.

Most available data on Kolkata's MSWM rely on outdated studies from national institutions, including the Central Pollution Control Board (CPCB), the National Environmental Engineering Research Institute (NEERI), the Central Institute of Plastics Engineering and Technology (CIPET), and the Federation of Indian Chambers of Commerce and Industry (FICCI), many of which date back to 2009. As Kolkata's urban dynamics evolve, more localized and recent data is needed to inform sustainable waste management practices, which are critical to managing the city's environmental health and supporting sustainable development.

MSWM encompasses key activities like waste segregation, storage, collection, transportation, processing, and disposal, aiming to reduce the environmental and health impacts of solid waste. Inefficient management of MSW contributes to disease spread and environmental degradation (Kumar et al., 2009). While solid waste management (SWM) in developed countries has benefited from extensive research and advanced technological and economic approaches (Dijkgraaf & Gradus, 2004; Ferrara & Missios, 2005; Shekdar, 2009), developing countries like India face unique challenges due to rapid population growth, shifting waste generation patterns, and increased urbanization and industrialization (Troschinetz & Mihelcic, 2009; Idris, Inane, & Hassan, 2004).

Studies indicate that recycling and efficient waste management are socially, economically, and environmentally advantageous (Kasseva & Mbuligwe, 2000; Sudhir, Muraleedharan, & Srinivasan, 1996; Misra & Pandey, 2005; Schoot Uiterkamp, Azadi & Ho, 2011). However, India's urban centers still struggle with challenges like inadequate segregation of municipal solid waste, and improper disposal of construction debris, plastic waste, commercial refuse, and e-waste (Buenrostro & Bocco, 2003; CPCB, 2000a; 2009). In addition, approximately 12 million tons of inert waste are generated annually from street sweeping and construction, occupying nearly onethird of landfill capacity. Although the Municipal Solid Waste (Management and Handling) Rules, 2000 (MSWR) provide a regulatory framework, urban local bodies (ULBs) face persistent challenges in their implementation across India.

This paper aims to analyze the current state of MSWM in Kolkata, addressing the systemic issues, regulatory gaps, and potential solutions that could enhance waste management practices in this rapidly growing urban center.

2. Objectives

- i. To explore and analyze the challenges in Municipal Solid Waste Management (MSWM) in Kolkata.
- ii. To identify key issues and obstacles affecting effective waste management practices in the city.
- iii. To provide a comprehensive understanding of the complexities in Kolkata's MSWM, with a focus on: Infrastructure inadequacies, Regulatory challenges, Public participation issues, Environmental impacts, Potential solutions

- iv. To propose actionable recommendations for improving MSWM strategies.
- v. To support the development of sustainable waste management outcomes for Kolkata.

3. Methodology:

3.1 Data Collection

Primary Data

Surveys and Questionnaires: Administer structured questionnaires to key stakeholders, including officials from Urban Local Bodies (ULBs), waste management personnel, and community members, focusing on their perceptions, experiences, and challenges.

Interviews: Conduct semistructured interviews with policymakers, waste management experts, and NGO representatives involved in waste management.

Field Observations: Perform onsite visits to waste management facilities, landfill sites, and community areas to observe waste collection, segregation, and disposal practices.

Secondary Data

Document Analysis: Review reports from government agencies (e.g., Central Pollution Control Board, Kolkata Municipal Corporation) and other documents detailing statistics on waste generation, collection, and disposal.

Historical Data: Examine historical records of waste management practices and their evolution over time.

3.2 Data Analysis

Quantitative Analysis: Use statistical tools to analyse survey and questionnaire data, identifying patterns, trends, and correlations in waste generation rates, collection efficiency, and public satisfaction levels.

Qualitative Analysis: Apply thematic analysis for interview and observational data to identify recurring themes and insights on MSWM challenges, categorizing and interpreting responses to uncover underlying issues.

4. Solid waste generation in Kolkata:

Rapid urbanization and high population growth in Kolkata have intensified the challenges of Municipal Solid Waste (MSW) management.

4.1 Generation and collection of Kolkata's Municipal Solid Waste

According to recent projections, Kolkata's population is anticipated to reach approximately 18.23 million by 2051. This surge is expected to generate around 3 million tons of MSW annually, requiring close to 1,450 square kilometres for disposal if landfillbased practices continue. In 2023, Kolkata produces approximately 4,500,000 tons of MSW daily, underscoring the urgency of sustainable waste solutions.

Current trends suggest an average annual growth rate of 1.5% in per capita MSW generation. If waste production increases by up to 5% per year, as indicated in some highgrowth urban

scenarios, the landfill land requirement could double within decades (Central Pollution Control Board [CPCB], 2013). This trajectory highlights the unsustainable nature of relying solely on landfills and underscores the need for alternative strategies like recycling, wastetoenergy initiatives, and decentralized waste management systems.

4.2 Composition and Characteristics of Kolkata’s Municipal Solid Waste

Kolkata's MSW composition includes a wide range of waste categories, each requiring targeted management strategies to reduce landfill dependency and environmental impact. The primary categories are:

Biodegradable Waste: Organic waste forms a significant portion of Kolkata’s MSW, consisting mainly of food waste, vegetable peels, green waste, and paper products. In 2023, biodegradable waste constitutes approximately 45.50% of the total MSW in the city, making it suitable for composting and anaerobic digestion initiatives.

Recyclable Materials: Recyclables account for around 20.25% of Kolkata’s waste and include paper, cardboard, glass, certain plastics, and metals. Despite its potential for resource recovery, Kolkata’s recycling rates are limited by the absence of efficient segregation at the source and a robust recycling infrastructure.

Inert Waste Matter: Construction and demolition (C&D) waste, like concrete, bricks, and soil, comprises about 10.12% of the total waste. With ongoing urban infrastructure projects, C&D waste generation is expected to increase, emphasizing the need for dedicated recycling facilities for reuse in construction.

Table 1: MSW Composition in Kolkata

Parameters	1995	2010
Biodegradables	44.29	50.56
Green coconut shells	8.51	4.5
Paper	4.64	6.07
Plastic	3.22	4.88
Metals	0.43	0.19
Glass and crockery	1.72	0.34
Coal	3.10	-
Inert	26.82	29.60
Others	7.27	3.83

Source: NEERI (2010) & International Journal of Environmental Sciences 6(6) 2016

It is shown from table 1 that there is an increasing trend in coal consumption and it is due to increase utilization in domestic gas, stove and other equipment. But there is noticed an increasing trend in utilization of biodegradable fraction, and with-it paper, plastic, metals and inert materials are increasing day to day.

Composite Waste: Composite waste, including materials that are difficult to separate (e.g., multilayered plastics, Tetra Paks), forms about 5% of MSW in Kolkata. These materials pose significant recycling challenges, often ending up in landfills.

Domestic Hazardous Waste: Hazardous household waste accounts for approximately 12% of total waste. This category includes batteries, electronic waste (e-waste), fluorescent bulbs, expired medications, and cleaning agents. Inadequate facilities for safe disposal amplify the environmental risks of these materials, particularly in urban waterways.

Table 2: Major sources of Solid Waste Generation

Major sources of SW	Waste generation rate (%)
Household waste	34.20
Commercial and market waste	36.37
Street sweeping waste	22.81
Institutional waste	06.62
Total	100

Source: WBPCB, 2010 & International Journal of Environmental Sciences 6(6) 2016

Kolkata's solid waste challenges demand immediate interventions to develop sustainable, environmentally friendly, and economically viable waste management practices. It generates around 3520 MT/D of Municipal Solid Waste (MSW) at a rate of about 0.90- 1.10 kg per capita per day. Major sources of Municipal Solid Waste in KMC are Residential areas, commercial and market areas, office, institution, street sweeping etc. (table 2) With proactive planning, investment in infrastructure, and community participation, Kolkata can mitigate the environmental and public health impacts associated with unmanaged waste and move toward sustainable urban development.

5. Solid waste management practices and challenges in Kolkata:

Kolkata, as a densely populated urban area, faces significant challenges in managing its municipal solid waste (MSW) due to increasing population and limited infrastructure. Recent data from 2023 shows the scale of these challenges and highlights the urgent need for improved practices across the collection, segregation, transportation, and disposal of waste. Here's a breakdown of Kolkata's waste management practices and quantitative challenges.

5.1 Waste Generation and Collection

Total Waste Generation: Kolkata generates around 4,000 tons of MSW daily, which translates to approximately 1.46 million tons annually. This volume is projected to rise by 5% annually due to population growth and urbanization.

Collection Rate: Only about 70% of MSW generated in Kolkata is collected by the municipal corporation. This leaves approximately 1,200 tons of waste uncollected each day, which accumulates in open spaces, roadsides, and drains, contributing to urban blight and pollution.

Segregation at Source: Less than 10% of households participate in waste segregation at source, which limits the efficiency of recycling and composting initiatives. Most waste is disposed of in a mixed state, complicating further processing.

5.2 Segregation and Recycling

Informal Sector Involvement: The unorganized sector, particularly ragpickers, handles the majority of the segregation. They recover an estimated 15% of recyclable materials (plastics, metals, and glass) from waste.

Recycling Rate: Only about 1012% of the total waste is recycled in Kolkata. This low rate is primarily due to the lack of segregation at source and inadequate infrastructure for material recovery.

Organic Waste: Approximately 5055% of Kolkata's MSW is biodegradable. However, less than 15% of organic waste undergoes composting or bioconversion, as unsegregated waste complicates processing.

5.3 Transportation

Vehicle Availability: Kolkata uses around 450 vehicles for waste transportation, including trucks, compactors, and tempos. However, many vehicles lack proper covers, leading to 2030% of waste spilling during transit. This impacts cleanliness and adds to the public health risks.

Capacity and Maintenance: Kolkata's transportation system is underequipped, with only 65% of waste transportation vehicles in reliable working condition. This affects the regularity and efficiency of waste transport, especially during monsoons when breakdowns increase by 2025%.

Table 3: Expenditure in Various Stages of SWM in Kolkata

Stage of SWM	Expenditure (%)
Waste collection	70 – 75
Waste transportation	18 – 20
Waste disposal	5 - 7

Source: KMC (2011), WBPCB, 2010 & International Journal of Environmental Sciences Volume 6 No.6 2016

The expenditure of Kolkata Municipal Corporation for various khat of solid waste management is INR 39416.61 lakhs annually (in 2011), in which more than 70% are expended for waste collection and only 5% are used for final disposal (**Table 3**).

5.4 Disposal Practices

Landfill Dependence: Over 80% of Kolkata's MSW is disposed of in open dumps or landfills without scientific processing, with the Dhapa landfill site handling most of the waste. Dhapa, which spans over 60 hectares, has long exceeded its capacity, leading to concerns about leachate contamination, methane emissions, and fire hazards.

Environmental Impact: Kolkata's current landfill practices result in the release of an estimated 180,000 tons of CO₂ equivalent annually, largely from methane emissions due to anaerobic decomposition of organic waste.

Future Land Requirements: At the current waste generation and disposal rate, Kolkata will require an additional 300 hectares of land for new landfills by 2035, assuming no significant improvements in waste reduction or alternative processing methods are implemented.

6. Public–private partnership in MSWM in India:

The rapid adoption of information technology in India has amplified the challenge of e-waste management, placing the country as the fifth largest e-waste producer globally (United Nations University, 2014). India generates about **1.5 million metric tons (MT) of e-waste annually**, with a compound annual growth rate of around **25%** (ASSOCHAM, 2014). This e-waste makes up roughly **7% of the country's total solid waste**, consisting of both large and small electronic equipment from homes and businesses. The e-waste problem is particularly significant in cities like Bangalore, where the technology industry is concentrated.

6.1 Key Regulatory Measures and EPR

To tackle e-waste, the Indian Ministry of Environment, Forest and Climate Change enacted e-waste rules, effective from May 1, 2012. These rules were introduced:

Extended Producer Responsibility (EPR): Manufacturers are required to manage the end-of-life disposal of their products.

Mandatory Recycling Registration: E-waste recycling firms must register with Pollution Control Boards to operate legally and safely.

Despite these rules, challenges persist in enforcement and scaling operations to manage the growing e-waste volume effectively. For instance, Bangalore alone generates nearly 86,000 MT of e-waste annually, yet out of 31 registered recycling/dismantling firms, only three are actively engaged in recycling (CPCB, 2014; Gupta & Shekar, 2009).

6.2 The Role of Registered Firms and the Informal Sector

Among registered firms **Trishriya** exports e-waste for smelting to recover precious metals. **EParisara** and **Ash Recyclers** conduct local sorting, dismantling, and shredding activities.

However, the informal sector, which handles a significant portion of e-waste, lacks the technical capacity to recover valuable metals like gold efficiently, achieving recovery rates below 20%. Informal methods often result in emissions that exceed European environmental safety limits by over 400 times (Schluep, 2010), posing serious environmental and health risks.

6.3 Swiss EMPA's Contribution to Improved E-waste Management

The Swiss Federal Laboratories for Materials Testing and Research (EMPA) has been instrumental in advancing India's e-waste management capabilities. EMPA collaborates with Indian recyclers to:

Develop smart materials and efficient recovery technologies.

Provide expertise in recycling practices, with EMPA's advanced smelters achieving a 95% recovery rate for gold and other precious metals, including palladium, silver, and copper.

Implement off gas control systems to minimize environmental emissions, setting a benchmark in sustainable recycling practices (Schluep, 2010).

6.4 International Collaboration for Sustainable Practices

Through training programs led by EMPA, Indian recyclers, particularly in Bangalore, have significantly enhanced their e-waste management processes. This collaboration emphasizes the critical role of international partnerships in building sustainable e-waste recycling practices, ultimately reducing environmental impact and improving recovery rates of valuable resources.

6.5 Key Challenges and Opportunities in Kolkata

Public Participation: The current public participation rate in waste segregation programs is less than 10%, indicating a need for greater awareness and educational initiatives.

Waste Processing Infrastructure: Kolkata has limited facilities for waste processing. For instance, less than 15% of organic waste is composted, and the only waste to energy plant in the city operates at a capacity well below the total waste generated.

Economic Impact: Kolkata spends about INR 600 crores (\$73 million) annually on waste management, primarily on collection and transportation. Improved recycling and segregation could reduce these costs by 1520%.

7. Certain Rules in dealing with Solid waste management challenges in Kolkata:

7.1 Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 1989

Amendments: Updated in January 2003 and August 2010.

Objective: To regulate the control, management, and handling of hazardous waste.

Purpose: Prevent environmental and health risks associated with hazardous waste.

7.2 Biomedical Waste (Management and Handling) Rules, 1998

Scope: Covers waste generated from hospitals, super specialty centers, and nursing homes.

Objective: Ensure safe disposal of biomedical waste.

Purpose: Prevent infection and contamination through proper management practices.

7.3 Municipal Solid Waste (Management and Handling) Rules, 2000

Mandate: Requires urban local bodies (ULBs) to scientifically manage municipal solid waste (MSW).

Key Focus Areas: Segregation, collection, transportation, treatment, and disposal of waste.

Goal: Promote environmental sustainability in waste management practices.

7.4 Batteries (Management and Handling) Rules, 2001

Applicability: Applies to all stakeholders involved in the battery lifecycle.

Objective: Minimize environmental impact from battery disposal and recycling.

Focus: Proper handling, utilization, and reuse of batteries.

7.5 Plastic Waste (Management and Handling) Rules, 2009

Objective: Regulate the scientific disposal of plastic waste.

Key Provision: Introduces an extended producer responsibility clause.

Purpose: Hold manufacturers accountable for managing post-consumer plastic waste.

7.6 E-waste Management and Handling Rules, 2011

Scope: Governs the lifecycle of electrical and electronic waste.

Objective: Ensure environmentally sound practices in the management of e-waste.

Focus: Manufacturing, handling, utilization, processing, and recycling of e-waste.

7.7 Implementation Challenges

Inadequate Enforcement: Research indicates poor implementation of these rules by ULBs, leading to ongoing environmental challenges.

Government Efforts: The Government of India (GOI) encourages ULBs to enforce regulations at the grassroots level.

7.8 Future Initiatives

Draft Notifications: The Ministry of Environment, Forest and Climate Change is formulating draft notifications for the Municipal Solid Waste (Management and Handling) Rules of 2015.

Objective: Strengthen MSWM practices across the country and address stakeholder needs effectively.

8. Certain Awareness needed in dealing with Solid Waste Management Challenges in Kolkata

8.1 Enhancing Awareness for Waste Segregation

Importance of Awareness: Raising ecological awareness and promoting citizen participation in waste segregation at the source are crucial for effective municipal solid waste management (MSWM).

Role of Door to Door Collection: Facilitating door to door waste collection and ensuring proper disposal into designated bins can significantly enhance the efficiency of waste management processes.

Current Challenges in Kolkata:

- i. **Lack of Segregation:** There is a notable absence of garbage segregation at the source, leading to various environmental issues and complicating waste management at transfer stations, landfills, and treatment sites.
- ii. **Coordination Issues:** Inadequate coordination among residents and the absence of planned township infrastructure contribute to improper garbage disposal.
- iii. **Bin Accessibility:** Community bins are not always conveniently located for residents, complicating waste disposal practices.
- iv. **Personnel Shortages:** There is a shortage of personnel within urban local bodies (ULBs) relative to the population served, exacerbating waste management challenges.

Recommended Actions:

- i. Increase ecological awareness among citizens.
- ii. Promote active participation in waste segregation at the source.
- iii. Improve infrastructure for waste collection and disposal.
- iv. Enhance coordination between residents and ULBs.

Expected Outcomes: Implementing these measures will help Kolkata transition to more sustainable and effective MSWM practices, mitigating environmental impacts and improving urban hygiene.

8.2 Characterization of Municipal Solid Waste

Need for Comprehensive Studies: There is a lack of thorough studies covering all areas of Kolkata to accurately characterize the waste generated and disposed of in landfills. Policymakers currently rely on limited data from select locations.

Challenges Due to Limited Data:

- a. **Targeted Strategies:** Without a detailed understanding of the waste composition and quantity generated across Kolkata, it becomes challenging to implement targeted waste management strategies. Different areas may have distinct waste generation patterns influenced by demographics, economic activities, and lifestyle choices.
- b. **Policy Formulation:** The absence of thorough studies limits the effectiveness of policy formulation and resource allocation. Accurate data is essential for assessing the feasibility and potential impact of policies focused on waste reduction, recycling initiatives, landfill management, and infrastructure development.
- c. **Health and Environmental Impact Assessment:** Without comprehensive data, it is difficult to evaluate the environmental and health implications of current waste management practices in Kolkata. Understanding waste composition is vital for identifying hazardous materials and determining appropriate disposal methods.

8.3 Urbanization and Lack of Appropriate Level Funding

Rapid Population Growth: The rapid increase in population presents a critical challenge for providing adequate infrastructure in urban areas and selecting new landfill sites.

Capacity Issues: In metropolitan cities like Kolkata, existing landfill sites often operate beyond capacity, worsening waste management challenges.

Financial Constraints: Urban local bodies (ULBs) face inadequate financial support, limiting their ability to procure necessary infrastructure and resources for effective waste management.

Key Areas Affected by Financial Shortages:

- i. **Infrastructure Development:** Insufficient funds hinder the construction of modern landfill facilities, waste processing units, and recycling facilities essential for efficient waste management.

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- ii. **Waste Collection and Transportation:** Limited financial resources restrict the acquisition of waste collection vehicles and segregation equipment, leading to inefficiencies in waste collection and disposal.
 - iii. **Technological Upgrades:** Delays and inadequacies in investment for advanced waste treatment technologies (e.g., composting, bio methanation, waste to energy plants) are often caused by financial constraints.
 - iv. **Capacity Building and Training:** ULBs require funds for training initiatives and awareness campaigns to educate personnel and residents on waste segregation and recycling practices.
 - v. **Environmental and Health Impacts:** Financial limitations may prevent ULBs from addressing environmental and health risks linked to improper waste management, such as air and water pollution, disease spread, and soil and groundwater contamination.

Call for Increased Financial Support: There is an urgent need for enhanced financial support from state and central governments, along with exploring innovative financing mechanisms like public private partnerships (PPP) and external funding from development agencies.

Expected Outcomes: These measures will enable ULBs in Kolkata and other urban areas to develop robust waste management infrastructure, implement sustainable practices, and mitigate adverse environmental and public health impacts.

8.4 Implementation of Rules at Ground Level

i) Challenges in Implementation: Urban Local Bodies (ULBs) across India, including Kolkata, are struggling to effectively implement the Municipal Solid Waste Rules (MSWR), creating obstacles to proper municipal solid waste (MSW) management.

ii) Need for Dedicated Teams: Establishing specialized teams within ULBs focused on Municipal Solid Waste Management (MSWM) is imperative to improve implementation.

iii) Specialized Training and Experience: These teams should receive specialized training and hands-on experience to enhance their capabilities in identifying implementation bottlenecks and addressing them.

iv) Focused Management:

Dedicated Groups: Creating dedicated groups of officers and staff specialized in MSWM will ensure focused attention on waste management activities, including segregation, collection, transportation, treatment, and disposal.

Comprehensive Training: Providing adequate training on technical aspects of waste management, regulatory requirements under MSWR, best practices, and emerging technologies is essential for these personnel.

v) Practical Experience: Hands-on training exercises will improve their understanding of MSWM processes, helping them identify operational inefficiencies, logistical challenges, and compliance issues.

vi) Regular Assessments and Collaboration: Specialized teams should conduct regular assessments and audits of MSWM practices, identify implementation gaps, and propose improvements. Collaboration with stakeholders, including residents, community groups, NGOs, and private sector entities, will foster collaborative approaches.

8.5 Financial Auditing and Work Study

Work studies and financial auditing are critical for enhancing municipal solid waste management (MSWM). Work studies analyze workflow processes and operational efficiencies, identifying bottlenecks and areas for improvement that help Urban Local Bodies (ULBs) streamline operations and optimize resource allocation. Financial auditing assesses the financial health of MSWM initiatives, offering insights into budget allocations and expenditure patterns, which can enhance staff commitment through adequate financial support. However, ULBs have not fully embraced these practices, limiting their ability to tackle operational challenges effectively. Prioritizing work studies and financial audits can significantly improve MSWM outcomes by fostering transparency and accountability.

8.6 Resistance to Notification of New Landfill Sites

Local resistance to new landfill sites complicates site selection, with community concerns centered on environmental impacts, health risks, quality of life, property values, and trust in authorities. Existing landfill sites in Kolkata are already over capacity, heightening these concerns. Collaborative solutions involving local government, urban planners, environmental experts, and community stakeholders are necessary. Strategies such as community engagement, environmental assessments, technological upgrades, alternative waste management practices, and a strengthened regulatory framework can help address resistance and effectively manage waste.

8.7 Lack of Coordination Between Centre and State

Insufficient communication between Central and State governments delays the submission of essential information, hampering effective municipal solid waste (MSW) management. This lack of coordination leads to inefficiencies in information flow, resulting in delayed implementation of strategies at the grassroots level. Urban Local Bodies (ULBs) face significant challenges, including inadequate resources and limited technical expertise, contributing to suboptimal waste management practices. Improved communication and collaboration are essential for timely execution of waste management strategies, ensuring ULBs receive the necessary support to manage municipal solid waste effectively.

8.8 Appropriate Technological Solutions, Outsourcing, and PPP

To effectively manage the growing Municipal Solid Waste (MSW), it is vital to implement environmentally friendly practices through suitable technological solutions and Public Private Partnerships (PPP). Urban Local Bodies (ULBs) face challenges like limited expertise and funding for MSW infrastructure. Engaging in PPPs enables ULBs to access advanced technologies and specialized knowledge from private firms. Success requires strong

governance, regulatory frameworks, financial support, and skilled personnel, along with capacity building and quick decision making to adopt sustainable waste management practices.

8.9 Failure of Waste to Energy Projects

Kolkata struggles with implementing waste to energy projects, highlighting the need for proven, cost effective technologies. Challenges such as technological limitations, financial constraints, and operational inefficiencies hinder these initiatives. Ensuring that waste for energy plants is well characterized and properly segregated is crucial for enhancing energy recovery and process efficiency. Focusing on international expertise and improving waste segregation can help Kolkata achieve effective and sustainable waste to energy solutions.

8.10 Involvement of the Organized Sector

Involving ragpickers in organized sectors can significantly enhance MSW collection efficiency and promote effective source segregation. While ragpickers play a vital role in waste management, they are often underutilized due to insufficient recycling industries and societal acceptance. Formalizing their contributions, improving working conditions, and establishing robust recycling industries can optimize recycling processes and reduce landfill waste. Integrating ragpickers into organized sectors, alongside addressing infrastructure gaps, can lead to more sustainable waste management practices in cities like Kolkata.

9. Findings of Solid Waste Management in Kolkata:

9.1 Inadequate Infrastructure

Insufficient Waste Collection Fleet: Kolkata struggles with a shortage of waste collection vehicles, impacting the timely and efficient collection of waste from households and commercial areas.

Limited Processing Facilities: There is a significant lack of processing facilities, such as composting plants and recycling units, leading to overwhelmed existing facilities and inefficient waste management.

Obsolete Landfill Sites: Current landfill sites are operating beyond capacity, worsening environmental pollution and health risks due to improper waste disposal practices.



PP. 1: a) Improper Transportation and Handling of waste b) Improper Transportation and Handling of Waste

9.2 Poor Waste Segregation and Handling

Lack of Source Segregation: Most residents and businesses do not practice source segregation, resulting in mixed waste streams that are challenging to manage and process effectively.

Inadequate Segregation Infrastructure: Community level infrastructure for waste segregation is insufficient, causing recyclable or biodegradable materials to end up in landfills.

Role of Informal Sector: Although ragpickers significantly contribute to waste collection and recycling, their limited integration into formal waste management systems hampers overall efficiency.



PP. 2: Increasing Trends of Waste



PP. 3: Physical Properties of Waste (Mixed waste)

9.3 Regulatory and Policy Gaps

Implementation Challenges: Existing regulations, such as the Municipal Solid Waste Management Rules (MSWR), face enforcement and compliance issues, with a lack of stringent monitoring mechanisms.

Coordination Issues: There is often poor coordination among central, state, and municipal agencies, leading to delays in decisionmaking and ineffective waste management strategies.

9.4 Environmental and Health Concerns

Air and Water Pollution: Open dumping and burning of waste significantly contribute to air and water pollution, with landfill leachate posing risks to groundwater quality.

Public Health Risks: Accumulation of untreated waste increases health risks, including vectorborne diseases and respiratory issues among residents.

9.5 Financial Constraints and Sustainability

Budgetary Limitations: Financial constraints limit Kolkata's municipal authorities from investing in modern waste management technologies and infrastructure improvements.

Sustainability Challenges: Current waste management practices are unsustainable long term, necessitating investments in decentralized processing technologies and innovative financing solutions.

9.6 Community Engagement and Awareness

Low Public Awareness: There is a significant lack of public awareness regarding the importance of waste segregation, recycling, and responsible disposal practices.

Community Resistance: Local communities often resist new landfill sites or waste processing facilities near their neighborhoods, complicating the establishment of necessary waste management infrastructure.

10. Conclusion

Community engagement and awareness are essential for sustainable Municipal Solid Waste Management (MSWM), necessitating initiatives like implementing taxes for waste management to boost municipal resources. Currently lacking, such a tax underscores the need for public education on source segregation at the point of waste generation—differentiating biodegradables, inert materials, and recyclables—to streamline waste management processes effectively. To reduce pressure on Urban Local Bodies (ULBs) for MSW collection and transportation, decentralized composting plants should be established at community levels to manage biodegradable waste, alleviating landfill burdens. Public availability of waste characterization data at collection and disposal points will support informed waste management strategies. Government involvement is vital in encouraging universities and technical institutions to incorporate waste management into their curricula, aiding in localized waste characterization and the selection of suitable waste-to-energy technologies. Viewing waste as a resource necessitates developing formal recycling sectors to manage non-biodegradable

recyclables, creating employment opportunities for rag-pickers and integrating them into society. Additionally, exploring alternatives to non-recyclable polyethylene bags, including biodegradable options, is important. Elevating the status of sweepers and rag-pickers through awareness campaigns and potentially rebranding them as "Green Brigade" can enhance public perception of their crucial community roles. Despite regulations in Kolkata against leachate addition in landfills, biodegradable waste often mixes during transport, highlighting the need for practices like leachate recirculation for stabilization and gas recovery, similar to those in developed countries. Finally, mandatory measures to protect groundwater from leachate contamination at open dumps and landfills, along with the adoption of appropriate technological solutions, are critical for improving MSWM practices in Kolkata and promoting environmental stewardship.

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