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Status of Agriculture and Pathway to Sustainable Agricultural Development in the South Bihar Plain

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ABSTRACT: *Agriculture in the South Bihar Plain, though vital for food security and rural livelihoods, faces persistent challenges such as fragmented and uneconomical landholdings, overdependence on erratic monsoons, and stark district-level disparities in irrigation. The region's vulnerability to recurrent floods and droughts, coupled with soil degradation and low adoption of organic and climate-resilient practices, further undermines sustainability. Market and infrastructural gaps constrain farmers' capacity to diversify and modernize. To address these issues, sustainable pathways must focus on revitalizing traditional water systems like Ahar–Pyne alongside promoting micro-irrigation and efficient water management, while encouraging crop diversification, agroforestry, and climate-smart technologies such as drought- and flood-tolerant crop varieties. Policy realignment toward natural and organic farming, capacity-building for smallholders, and the expansion of farmer producer organizations are crucial for strengthening resilience. Digital and precision agriculture, supported by government initiatives, can improve resource use and market linkages. In conclusion, the region requires a multi-pronged approach that integrates technological innovations, ecological balance, and socio-economic inclusivity to transform agriculture from a subsistence-based system into a sustainable and competitive sector, ensuring long-term productivity and rural prosperity.*

KEY WORDS*: Sustainable Agricultural, Climate-resilient practices, Net Irrigated Area, Agroforestry, Biodiversity, Food Security.*

1. INTRODUCTION:

Sustainable agricultural development focuses on enhancing food production while preserving environmental integrity, economic viability, and social equity for current and future generations. It integrates practices like crop rotation, organic farming, integrated pest management, agroforestry to maintain soil health, reduce chemical inputs, and enhance biodiversity. By leveraging renewable resources, improving water efficiency, and adopting climate-resilient crops, sustainable agriculture mitigates environmental degradation and adapts to climate change. Socio-economically, it supports smallholder farmers through fair trade, local market development, and capacity-building, ensuring food security and rural livelihoods. For instance, the use of precision agriculture technologies optimizes resource use, reducing waste and emissions[1]. This holistic approach balances productivity with ecological and social considerations, fostering resilient food systems. Sustainable agricultural development is a global priority to address food security, environmental degradation, and socio-economic challenges amid a projected population of 9.7 billion by 2050[2]. Globally, sustainable agriculture integrates practices like agroecology, climate-smart agriculture, and precision farming to enhance productivity while minimizing environmental impacts. For instance, climate-smart agriculture promotes resilience and reduces greenhouse gas emissions through practices like conservation tillage and integrated nutrient management, with the World Bank supporting climate-smart agriculture initiatives in countries like Bangladesh and Ethiopia to align with Sustainable Development Goals (SDGs)[3]. In sub-Saharan Africa, smallholder farmers adopt agroforestry and organic farming to combat soil degradation and climate variability, though challenges like limited access to credit and technology persist. In contrast, technocentric approaches in developed nations, such as Agriculture 4.0 with digital tools and genetic modification, boost yields but risk excluding small farmers due to high costs[4]. Sustainable agricultural development in India is critical for ensuring food security, environmental conservation, and socio-economic stability in a country where agriculture employs nearly 40% of the workforce and supports a population projected to reach 1.64 billion by 2050. The Green Revolution of the 1960s and 1970s transformed India into a food grain exporter through high-yielding varieties, chemical fertilizers, and irrigation, but it also led to soil degradation, groundwater depletion, and biodiversity loss[5]. To counter these challenges, sustainable practices like agroforestry, crop

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rotation, organic farming, and integrated pest management are being promoted, with only 2% of India's 140 million hectares of net sown area under organic farming and 800,000 farmers adopting natural farming. States like Sikkim and Andhra Pradesh lead in organic and natural farming, supported by initiatives like the National Mission for Sustainable Agriculture (NMSA), which funds programs such as Rainfed Area Development and Sub-Mission on Agroforestry[6]. However, adoption remains low due to high initial costs, limited market access, and insufficient long-term impact data, particularly for practices like biodynamic agriculture. Climate-resilient agriculture addresses water scarcity in regions like northwestern India, using geospatial and AI tools to enhance water-use efficiency and adapt to erratic rainfall. Despite progress, challenges include small landholdings, inadequate irrigation, and overreliance on chemical inputs, with subsidies for chemical fertilizers far outweighing investments in biofertilizers. Scenario analyses project that meeting future food demands by 2030 may require agricultural land expansion and intensification, risking biodiversity losses unless sustainable practices are scaled up[7]. Policies like the Soil Health Card scheme and Pradhan Mantri Fasal Bima Yojana aim to improve soil management and provide financial security, but gaps in extension services and infrastructure hinder widespread adoption. A comprehensive strategy integrating technological innovation, capacity building, and market access is essential for scaling sustainable agriculture across India's diverse agro-climatic zones, ensuring economic viability, environmental health, and social equity.

Sustainable agricultural development in Bihar, a state where agriculture employs over 80% of the population and contributes significantly to its economy, focuses on addressing challenges like low productivity, climate vulnerability, and small landholdings while promoting environmental and economic resilience. Bihar's agricultural landscape, dominated by smallholder farmers with average landholdings of 0.39 hectares, faces issues such as soil degradation, flood-drought cycles, and limited mechanization[8]. Initiatives like the Bihar Agricultural Roadmap (2017–2027) emphasize sustainable practices, including organic farming, integrated nutrient management, and climate-resilient crops like flood-tolerant rice varieties (e.g., Swarna-Sub1). The state has promoted System of Rice Intensification (SRI) and zero-tillage farming, increasing yields by 20–30% in some districts while reducing water and input costs. Programs like the Jal Jeevan Hariyali Mission aim to enhance water conservation through farm ponds and check dams, addressing Bihar's dependence on monsoon rains and groundwater depletion. The recent approval of a Digital Agriculture Directorate seeks to integrate technology for crop forecasting, data-driven planning, and timely delivery of farmer benefits, enhancing precision agriculture. However, challenges persist, including inadequate irrigation (only 68% of cultivable land is irrigated), low adoption of organic practices due to high transition costs, and limited access to credit and markets. Agroforestry and crop diversification, supported by schemes like the Sub-Mission on Agroforestry, are gaining traction in districts like Vaishali and Samastipur to improve soil health and farmer incomes. Despite these efforts, fragmented landholdings, weak extension services, and climate impacts like recurring floods in north Bihar hinder scalability. A multi-pronged approach—integrating technology, policy support, and farmer training—is essential to advance sustainable agriculture in Bihar, ensuring food security and environmental sustainability[9].

2. STUDY AREA:

The South Bihar Plain is an integral part of the middle Gangetic Plain, known for its fertile alluvial soils and agrarian economy. It extends an area of 41870 k.m.^{2}, lies between 24^0 12' 50" N latitude to 25^0 10' N latitude and 83^0 46' E longitude to 87^0 38' E longitude. This plain lies south of the Ganges River, which forms its northern boundary, separating it from the North Bihar Plain. To the south, it is bordered by the Chota Nagpur Plateau. The eastern boundary of the South Bihar Plain extends toward West Bengal, while the west merges into the plains of Uttar Pradesh. This plain is made up by seventeen districts i.e., Buxar Aurangabad, Rohtas, Kaimur, Bhojpur, Patna, Gaya, Jehanabad, Arwal, Nawada, Nalanda, Sheikhpura, Munger, Lakhisarai, Jamui, Bhagalpur, and Banka.

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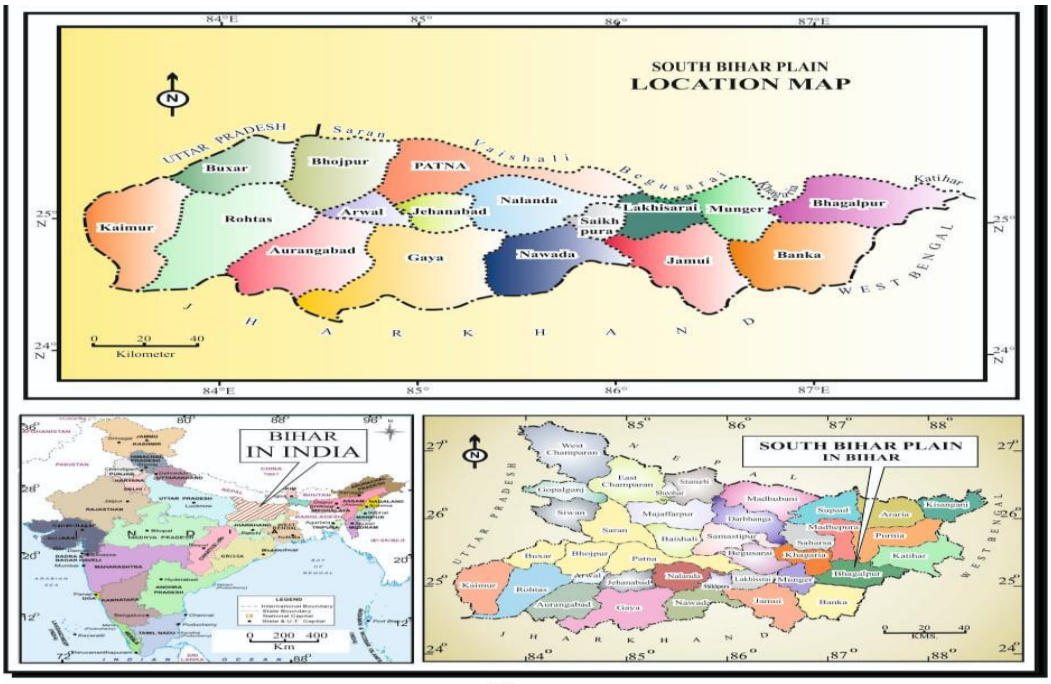

Fig.

The topography of the South Bihar Plain is predominantly flat, with elevations ranging from 50 to 150 meters above sea level, though it gently slopes from the south to the north toward the Ganges. The plain is formed by the deposition of alluvial sediments brought down by the Ganges and its tributaries. These rivers have played an important role in shaping the landscape, creating a fertile expanse ideal for agriculture. According to the census of 2011 total population of this plain is 37651927 and density of population is about 899 persons per k.m.^{2}. However, challenges such as overpopulation, and land fragmentation persist, impacting sustainable development in this agriculturally rich and geographically vital plain of Bihar.

3. REVIEW OF LITERATURE:

Sustainable agriculture research globally emphasizes a paradigm shift from yield maximization to balancing productivity, ecological health, and socio-economic equity, with scholars stressing agroecology, crop diversification, and conservation agriculture as pathways to resilient food systems (FAO, 2021)[10]. Climate-smart agriculture and precision farming are widely promoted, though challenges of cost, technology access, and smallholder marginalization persist (Pretty, J., et al., 2018)[11]. In India, the Green Revolution, though transformative, caused ecological stress through soil degradation, water depletion, and biodiversity loss (Nature, 2023)[12]. To address this, national policies such as the National Mission for Sustainable Agriculture, Soil Health Card Scheme, and promotion of natural farming highlight the shift toward sustainability (Government of Bihar 2023)[13]. M.S. Swaminathan have long advocated "evergreen revolution" models that integrate science, technology, and ecological principles to ensure food security with environmental safeguards (Swaminathan, 2010)[14]. Region-specific studies, such as Singh (2014)[15] on Bihar's smallholder challenges and Singh & Jha (2020)[16] on climate-resilient crops in eastern India, highlight the constraints of fragmented landholdings, low mechanization, and high climate vulnerability. Bihar's Agricultural Roadmap (2017–2027) and Jal Jeevan Hariyali Mission seek to promote SRI, zero tillage, and water conservation, with IWMI (2024)[17] reporting yield gains and input cost reductions. In the South Bihar Plain, Rohtas and Kaimur dominate in cereal output, Gaya and Banka reflect high forest dependency, Patna shows urban encroachment on farmland, and Bhagalpur has horticultural potential—underscoring the need for localized sustainable strategies.

4. OBJECTIVES:

The objectives of this study as follows:

- Assess Agricultural Productivity: Evaluate the current status of agricultural productivity in the South Bihar Plain, focusing on major crops like cereals, pulses, and oilseeds across 17 districts.
- Analyse Land Use Patterns: Examine the land use patterns in 2022-23 to understand the distribution of net sown area, forest cover, fallow lands, and non-agricultural land use in the region.

- (iii). Evaluate Irrigation Coverage: Investigate the extent and disparities in net irrigated area across districts to identify gaps in irrigation infrastructure and water management practices.
- (iv). Identify Key Challenges: Highlight major constraints to sustainable agriculture, such as fragmented landholdings, soil degradation, monsoon dependency, and inadequate market infrastructure.
- (v). Promote Climate-Resilient Practices: Propose the adoption of climate-smart agricultural techniques, including flood- and drought-tolerant crop varieties, to enhance resilience against climate variability.
- (vi). Encourage Crop Diversification: Advocate for diversification from cereal-dominated systems to high-value crops like fruits, vegetables, and pulses to improve farmer incomes and food security.
- (vii). Integrate Technology and Policy: Promote digital agriculture, precision farming, and supportive policies like subsidies for biofertilizers and expanded credit access to ensure sustainable agricultural transformation.

5. DATABASE AND METHODOLOGY:

The present study is based on both secondary and limited primary data. Secondary data were collected from the Directorate of Economics and Statistics, Government of Bihar, district statistical handbooks, agricultural department reports, and ICAR publications for the year 2022–23. Primary insights were supplemented through field observations and informal discussions with farmers in selected districts. Data were analyzed to assess land use, irrigation patterns, and crop coverage of cereals, pulses, and oilseeds. Statistical tools such as percentages, averages, growth rates, and cropping intensity indices were applied to identify trends and variations. Comparative analysis across districts was undertaken to highlight disparities in production and irrigation coverage. Qualitative assessment of policies and sustainable practices such as crop diversification, agroforestry, and water management is also included. The methodology emphasizes both quantitative and qualitative approaches to provide a holistic understanding of agricultural development.

Status of Agriculture in South Bihar Plain

The South Bihar Plain is a productive agricultural hub due to its fertile Gangetic alluvial soil and favourable semi-arid climate. Agriculture forms the backbone of the region's economy, engaging over 75% of the population. Major crops include rice, wheat, pulses (like moong and arhar), and vegetables such as potato, onion, and cauliflower. Despite its potential, agriculture faces challenges like small landholdings (91% under one hectare), outdated farming techniques, and inadequate market infrastructure, leading to post-harvest losses. The region benefits from the traditional Ahar-Pyne irrigation system, which mitigates erratic monsoons, though 57% of cultivated land relies on surface water-based irrigation, making it monsoon-dependent. Following data highlights the actual scenario of status of agriculture in south Bihar plain.

TABLE NO. 1
SOUTH BIHAR PLAIN: LANDUSE PATTERN -2022-23 (Area in Hectare)

DISTRICTS	GEOG. AREA	FOREST	BARREN & UNCUL. LAND	AREA PUT TO NON AGRI. USES	CULTL. WASTE LAND	PERMANENT PASTURE	MISC. TREES & GROVES	OTHER FALLOW	CURRENT FALLOW	N.S.A.
KAIMUR	342447	113039	19256	35170	1840	117	2343	890	801	168991
AURANGABAD	330011	18764	16410	59948	1721	536	682	1192	24218	206540
BUXAR	166999	0	2180	18514	601	15	798	669	4993	139229
ROHTAS	390722	66723	16831	53512	952	84	2977	189	613	248841
BHOJPUR	237339	0	6702	33446	580	49	1922	112	390	194138

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PATNA	317236	56	12369	80958	695	90	1309	9939	49109	162711
NALANDA	232732	4640	1160	47954	185	03	1320	1927	8658	166885
JEHANABAD	94043	637	3270	15271	129	72	746	496	39352	34070
GAYA	493774	77836	27541	73167	3233	2037	3944	30382	104964	170670
ARWAL	62631	0	2180	11561	82	125	944	1590	20295	25854
NAWADA	248732	63775	11237	35747	1089	854	729	5513	11589	118199
SHEIKHPURA	62084	0	1017	10843	215	0	330	1140	3028	45511
LAKHISARAI	128602	13445	7009	16256	683	46	488	5414	25142	60119
JAMUI	305289	92855	28567	44560	10281	1636	2143	19487	67401	38359
MUNGER	139793	28524	11436	32683	914	182	620	3131	20603	41700
BHAGALPUR	254300	78	22403	69055	2224	605	6710	6662	40304	106259
BANKA	305621	46310	42961	42879	7876	1044	7474	11687	32349	113041
TOTAL	4111355	526682	232529	681524	33300	7495	35479	100420	453809	2041117

Source: Directorate of Economics and Statistics, Government of Bihar- 2022-2023

Table number one shows the land use pattern in the districts of south Bihar plain. In the South Bihar Plain, land use patterns vary widely across Kaimur district spans 342,447 hectares with substantial forest cover at 113,039 hectares dominating the landscape, followed by a net sown area (NSA) of 168,991 hectares, while barren and uncultivable land is 19,256 hectares and non-agricultural uses claim 35,170 hectares, with minimal cultural waste, pastures, and fallows; Aurangabad covers 330,011 hectares, featuring limited forests at 18,764 hectares but high non-agricultural land at 59,948 hectares and NSA at 206,540 hectares, alongside notable current fallow of 24,218 hectares; Buxar, at 166,999 hectares, has no forests, minimal barren land at 2,180 hectares, non-agricultural uses at 18,514 hectares, and a strong NSA of 139,229 hectares with low fallows; Rohtas extends over 390,722 hectares with 66,723 hectares in forests, 16,831 hectares barren, 53,512 hectares in non-agricultural uses, and NSA at 248,841 hectares, showing balanced but low waste and pasture lands; Bhojpur's 237,339 hectares lack forests, with 6,702 hectares barren, 33,446 hectares non-agricultural, and NSA dominating at 194,138 hectares amid negligible pastures and groves; Patna, urban-influenced at 317,236 hectares, has negligible forests at 56 hectares, high non-agricultural land at 80,958 hectares, significant current fallow at 49,109 hectares, and NSA at 162,711 hectares; Nalanda covers 232,732 hectares with small forests at 4,640 hectares, 47,954 hectares in non-agricultural uses, NSA at 166,885 hectares, and minor fallows; Jehanabad's compact 94,043 hectares include minimal forests at 637 hectares, 15,271 hectares non-agricultural, unusually high current fallow at 39,352 hectares exceeding its NSA of 34,070 hectares, indicating potential underutilization; Gaya spans 493,774 hectares with 77,836 hectares in forests, 27,541 hectares barren, 73,167 hectares non-agricultural, high other fallow at 30,382 hectares and current fallow at 104,964 hectares, but NSA at 170,670 hectares; Arwal's 62,631 hectares have no forests, 11,561 hectares non-agricultural, current fallow at 20,295 hectares nearly matching NSA at 25,854 hectares; Nawada covers 248,732 hectares with 63,775 hectares forests, 35,747 hectares non-agricultural, NSA at 118,199 hectares, and moderate fallows; Sheikhpura's 62,084 hectares lack forests, with 10,843 hectares non-agricultural and NSA at 45,511 hectares dominating over low barren and waste lands; Lakhisarai spans 128,602 hectares with 13,445 hectares forests, 16,256 hectares non-agricultural, high current fallow at 25,142 hectares, and NSA at 60,119 hectares; Jamui's 305,289 hectares feature 92,855 hectares forests, 44,560 hectares non-agricultural, significant barren at 28,567 hectares and current fallow at 67,401 hectares, but low NSA at 38,359 hectares suggesting rugged terrain; Munger covers 139,793 hectares with 28,524 hectares forests, 32,683 hectares non-agricultural, current fallow at 20,603 hectares, and

NSA at 41,700 hectares; Bhagalpur's 254,300 hectares have minimal forests at 78 hectares, high non-agricultural at 69,055 hectares and current fallow at 40,304 hectares, with NSA at 106,259 hectares; finally, Banka spans 305,621 hectares with 46,310 hectares forests, notable barren at 42,961 hectares, non-agricultural at 42,879 hectares, and NSA at 113,041 hectares amid diverse fallows and groves, collectively reflecting a region where NSA totals 2,041,117 hectares across 4,111,355 hectares, overshadowed by forests at 526,682 hectares and non-agricultural uses at 681,524 hectares, with variations driven by topography, urbanization, and agricultural intensity.

TABLE NO. 2:

SOUTH BIHAR PLAIN: DISTRIBUTION OF NET IRRIGATED AREA -2022-23 (Area in Hectare)

DISTRICTS	TOTAL GEOGRAPHICAL AREA	NET AREA SOWN	NET IRRIGATED AREA	PERCENTAGE OF NET IRRIGATED AREA
KAIMUR	342447	168991	134780	79.76
AURANGABAD	330011	206540	184530	89.34
BUXAR	166999	139229	91260	65.56
ROHTAS	390722	248841	226890	91.17
BHOJPUR	237339	194138	119010	61.30
PATNA	317236	162711	80130	49.24
NALANDA	232732	166885	112560	67.45
JEHANABAD	94043	34070	30220	88.70
GAYA	493774	170670	90320	52.92
ARWAL	62631	25854	17590	68.04
NAWADA	248732	118199	71110	60.16
SHEIKHPURA	62084	45511	25310	55.61
LAKHISARAI	128602	60119	31270	52.01
JAMUI	305289	38359	16720	43.59
MUNGER	139793	41700	24490	58.73
BHAGALPUR	254300	106259	48670	45.80
BANKA	305621	113041	55060	48.71
TOTAL	4111355	2041117	1359920	66.63

Source: Directorate of Economics and Statistics, Government of Bihar- 2022-2023

Table number two shows the distribution of the Net irrigated area in the districts of south Bihar plain. In the Kaimur, with a geographical area of 342,447 hectares and net sown area (NSA) of 168,991 hectares, has a net irrigated area (NIA) of 134,780 hectares, achieving a high irrigation coverage of 79.76%; Aurangabad, spanning 330,011 hectares with an NSA of 206,540 hectares, boasts a robust NIA of 184,530 hectares, reflecting an impressive 89.34% irrigation rate; Buxar, covering 166,999 hectares with an NSA of 139,229 hectares, has an NIA of 91,260 hectares, resulting in a moderate 65.56% coverage; Rohtas, the largest district at 390,722 hectares with an NSA of 248,841 hectares, excels with an NIA of 226,890 hectares, achieving a leading 91.17% irrigation rate; Bhojpur, with 237,339 hectares and an NSA of 194,138 hectares, has an NIA of 119,010 hectares, covering 61.30%; Patna, at 317,236 hectares with an NSA of 162,711 hectares, has a lower NIA of 80,130 hectares, resulting in 49.24% coverage, likely due to urban influences; Nalanda, covering 232,732 hectares with an NSA of 166,885 hectares, has an NIA of 112,560 hectares, achieving 67.45%; Jehanabad, with a compact 94,043 hectares and a small NSA of 34,070 hectares, has an NIA of 30,220 hectares, yielding a high 88.70% irrigation rate; Gaya, spanning 493,774 hectares with an NSA of 170,670 hectares, has an NIA of 90,320 hectares, covering 52.92%; Arwal, at 62,631 hectares with an NSA of 25,854 hectares, has an NIA of 17,590 hectares, achieving 68.04%; Nawada, covering 248,732 hectares with an NSA of 118,199 hectares, has an NIA of 71,110 hectares, resulting in 60.16% coverage; Sheikhpura, with 62,084 hectares and an NSA of 45,511 hectares, has an NIA of 25,310 hectares, covering 55.61%; Lakhisarai, spanning 128,602 hectares with an NSA of 60,119 hectares, has an NIA of 31,270 hectares, achieving 52.01%; Jamui, with 305,289 hectares and a low NSA of 38,359 hectares, has the lowest NIA at 16,720 hectares, resulting in 43.59% coverage, likely due to rugged terrain; Munger, covering 139,793 hectares with an NSA of 41,700 hectares, has an NIA of 24,490 hectares, achieving 58.73%; Bhagalpur, with 254,300 hectares and an NSA of 106,259 hectares, has an NIA of 48,670 hectares, covering 45.80%; and Banka, spanning

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305,621 hectares with an NSA of 113,041 hectares, has an NIA of 55,060 hectares, resulting in 48.71% coverage; collectively, the region's 4,111,355 hectares with a total NSA of 2,041,117 hectares supports a total NIA of 1,359,920 hectares, averaging a 66.63% irrigation rate, highlighting significant variations driven by topography, infrastructure, and agricultural intensity across districts.

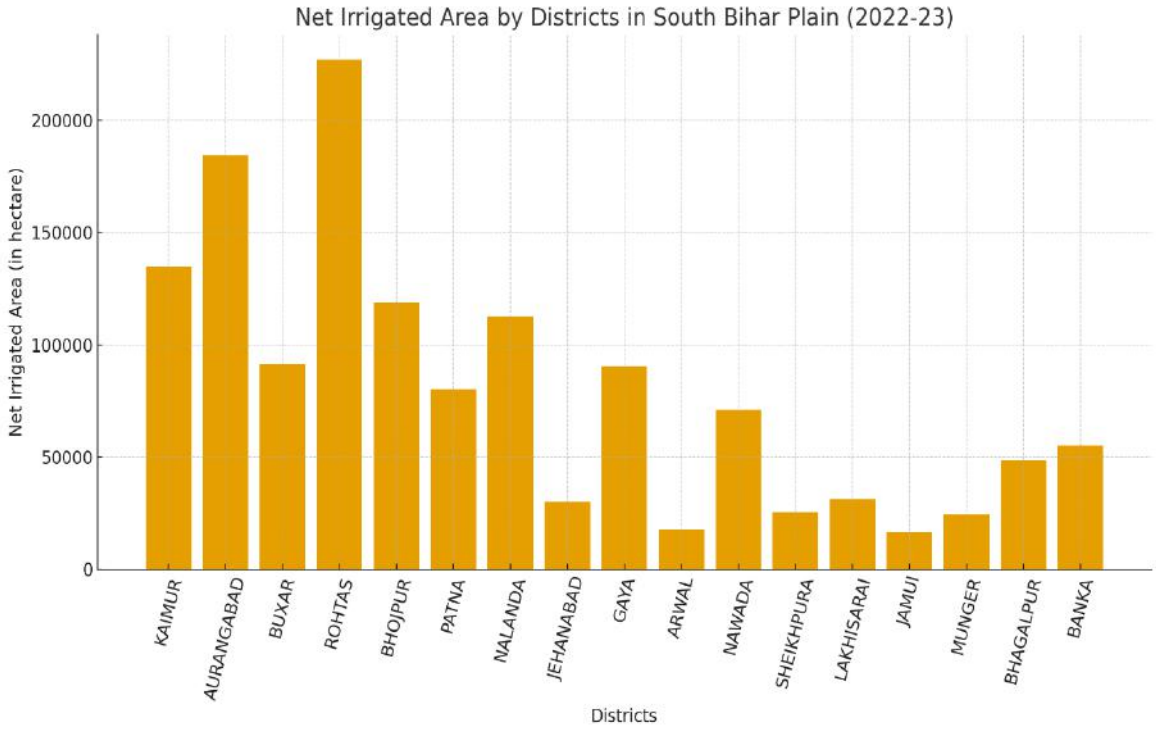

TABLE NO. 3
COVERAGE AND PRODUCTION OF CERELES, PULSES AND OILSEEDS IN SOUTH BIHAR PLAIN - 2022-23

DISTRICTS	CERELES		PULSES		OILSEEDS	
	AREA (in hectare)	PRODUCTION (in metric ton)	AREA (in hectare)	PRODUCTION (in metric ton)	AREA (in hectare)	PRODUCTION (in metric ton)
KAIMUR	251529	888956	4608	3951	2175	1647
AURANGABAD	246671	800114	39010	26678	5084	4293
BUXAR	183111	675195	6122	5578	1734	1348
ROHTAS	398794	1616843	2979	3047	4642	6298
BHOJPUR	218758	779539	8011	7859	1583	2251
PATNA	150879	520497	49423	47811	4336	4540
NALANDA	210448	718341	20664	21268	3013	4383
JEHANABAD	82792	285746	13686	13209	2039	1933
GAYA	162392	475131	16899	14846	3927	4489
ARWAL	28009	101853	3615	3415	259	232
NAWADA	120683	376737	19287	7826	1318	1198
SHEIKHPURA	47825	156081	4692	5416	1133	939
LAKHISARAI	65820	253077	18145	12989	2809	5530
JAMUI	63247	198614	6497	4289	1192	824
MUNGER	42952	157137	1879	1628	441	483
BHAGALPUR	125730	399114	7307	5196	1860	2154
BANKA	122129	405712	6064	4226	552	471
TOTAL	2521769	8808687	228888	189232	38097	43013

Source: Directorate of Economics and Statistics, Government of Bihar- 2022-2023

Table number three shows the coverage and production of cereals, pulses and oilseeds in the districts of south Bihar plain. In the South Bihar Plain for 2022-23, Kaimur, with 251,529 hectares under cereals producing 888,956 metric tons, has 4,608 hectares for pulses yielding 3,951 metric tons and 2,175 hectares for oilseeds producing 1,647 metric tons; Aurangabad cultivates 246,671 hectares of cereals yielding 800,114 metric tons, 39,010 hectares of pulses producing 26,678 metric tons, and 5,084 hectares of oilseeds yielding 4,293 metric tons; Buxar covers 183,111 hectares of cereals producing 675,195 metric tons, 6,122 hectares of pulses yielding 5,578 metric tons, and 1,734 hectares of oilseeds producing 1,348 metric tons; Rohtas, the largest cereal producer, cultivates 398,794 hectares yielding 1,616,843 metric tons, with 2,979 hectares of pulses producing 3,047 metric tons and 4,642 hectares of oilseeds yielding 6,298 metric tons; Bhojpur grows 218,758 hectares of cereals producing 779,539 metric tons, 8,011 hectares of pulses yielding 7,859 metric tons, and 1,583 hectares of oilseeds producing 2,251 metric tons; Patna cultivates 150,879 hectares of cereals yielding 520,497 metric tons, a significant 49,423 hectares of pulses producing 47,811 metric tons, and 4,336 hectares of oilseeds yielding 4,540 metric tons; Nalanda covers 210,448 hectares of cereals producing 718,341 metric tons, 20,664 hectares of pulses yielding 21,268 metric tons, and 3,013 hectares of oilseeds producing 4,383 metric tons; Jehanabad grows 82,792 hectares of cereals yielding 285,746 metric tons, 13,686 hectares of pulses producing 13,209 metric tons, and 2,039 hectares of oilseeds yielding 1,933 metric tons; Gaya cultivates 162,392 hectares of cereals producing 475,131 metric tons, 16,899 hectares of pulses yielding 14,846 metric tons, and 3,927 hectares of oilseeds producing 4,489 metric tons; Arwal, with a smaller 28,009 hectares of cereals yielding 101,853 metric tons, has 3,615 hectares of pulses producing 3,415 metric tons and 259 hectares of oilseeds yielding 232 metric tons; Nawada grows 120,683 hectares of cereals producing 376,737 metric tons, 19,287 hectares of pulses yielding 7,826 metric tons, and 1,318 hectares of oilseeds producing 1,198 metric tons; Sheikhpura cultivates 47,825 hectares of cereals yielding 156,081 metric tons, 4,692 hectares of pulses producing 5,416 metric tons, and 1,133 hectares of oilseeds yielding 939 metric tons; Lakhisarai covers 65,820 hectares of cereals producing 253,077 metric tons, 18,145 hectares of pulses yielding 12,989 metric tons, and 2,809 hectares of oilseeds producing a notable 5,530 metric tons; Jamui grows 63,247 hectares of cereals yielding 198,614 metric tons, 6,497 hectares of pulses producing 4,289 metric tons, and 1,192 hectares of oilseeds yielding 824 metric tons; Munger cultivates 42,952 hectares of cereals producing 157,137 metric tons, 1,879 hectares of pulses yielding 1,628 metric tons, and 441 hectares of oilseeds producing 483 metric tons; Bhagalpur grows 125,730 hectares of cereals yielding 399,114 metric tons, 7,307 hectares of pulses producing 5,196 metric tons, and 1,860 hectares of oilseeds yielding 2,154 metric tons; Banka cultivates 122,129 hectares of cereals producing 405,712 metric tons, 6,064 hectares of pulses yielding 4,226 metric tons, and 552 hectares of oilseeds yielding 471 metric tons; collectively, the region spans 2,521,769 hectares of cereals producing 8,808,687 metric tons, 228,888 hectares of pulses yielding 189,232 metric tons, and 38,097 hectares of oilseeds producing 43,013 metric tons, reflecting cereals as the dominant crop, with pulses and oilseeds showing varied but smaller contributions across districts, driven by land availability and irrigation patterns.

Pathway to sustainable agricultural development in south Bihar plain

The South Bihar Plain faces multiple agricultural challenges such as erratic monsoon rainfall, over-dependence on groundwater, small and fragmented landholdings, declining soil fertility, and limited adoption of modern techniques. To achieve sustainable agricultural development, an integrated pathway is essential that balances productivity, environmental health, and farmers' livelihoods. The following suggestions may be effective for sustainable agricultural development in south Bihar plain.

Enhancing Irrigation Efficiency and Water Management

The South Bihar Plain has a net irrigated area (NIA) of 1,359,920 hectares, covering 66.63% of the net sown area (NSA) of 2,041,117 hectares (2022-23). Districts like Rohtas (91.17%) and Aurangabad (89.34%) have high irrigation coverage, while Jamui (43.59%) and Bhagalpur (45.80%) lag due to topographic constraints and reliance on diesel-powered tube wells, which are costly and unsustainable. Transition from diesel to solar or electric pumps to reduce costs and emissions. The Bihar government's BIGWIS scheme can be expanded with subsidies for solar pumps. Leverage rivers like Son, Punpun, and Kiul for inter-basin water transfer from water-rich North Bihar to drought-prone southern districts (e.g., Gaya, Jamui). Implement farm ponds and check dams under the Jal Jeevan Hariyali Mission, which has constructed over 64,098 new water bodies and renovated 24,448 ponds and lakes since 2019. Promote System of Rice Intensification (SRI) and zero-tillage farming, which reduce water use by 25-30% and increase yields by 20-30%.

Promoting Soil Health and Nutrient Management

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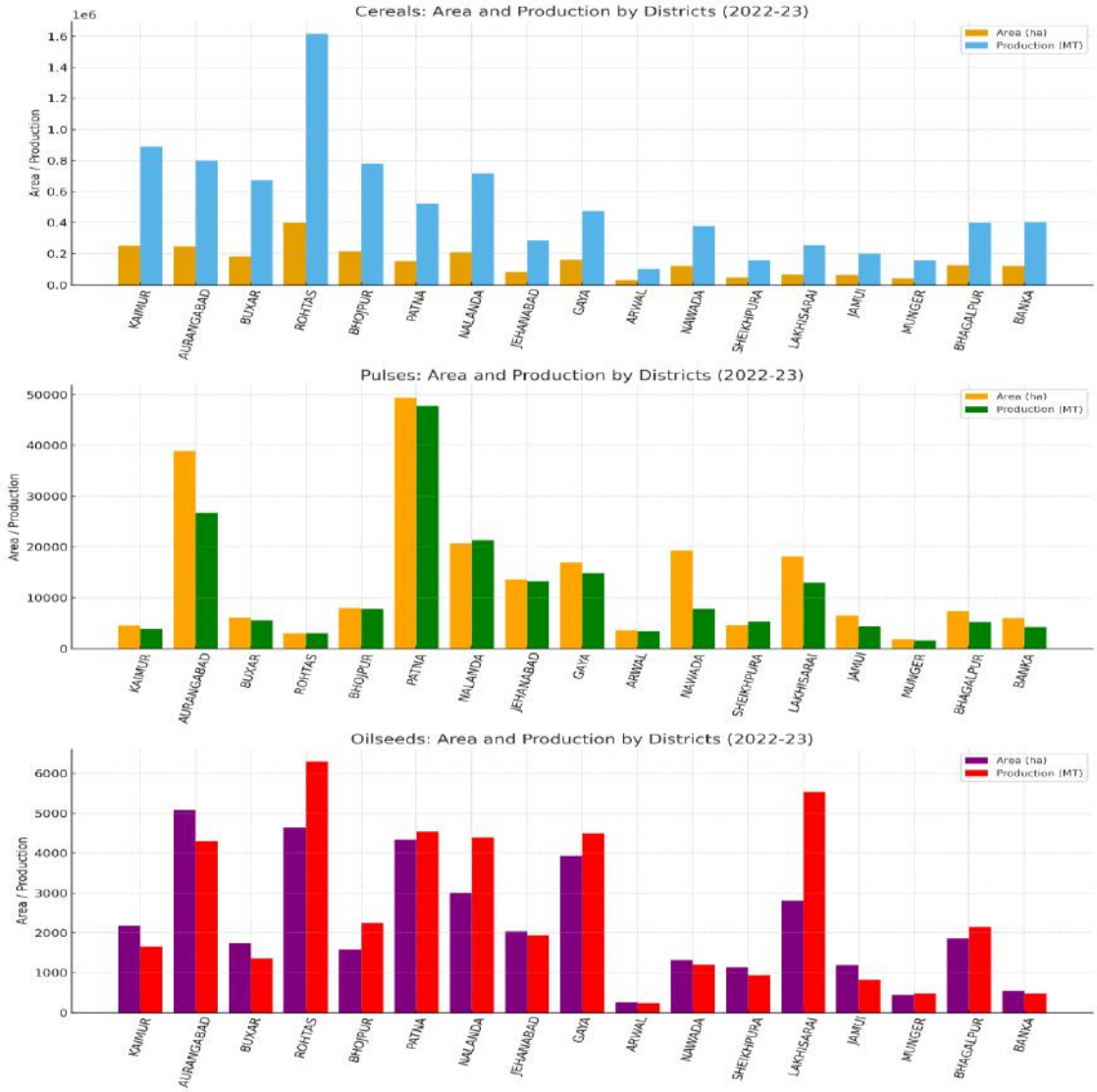
Soil degradation due to intensive rice-wheat systems and overuse of chemical fertilizers reduces fertility. Scale up the Soil Health Card scheme to provide district-specific nutrient recommendations. SHCs can guide balanced fertilizer use, reducing nitrogen overuse by 20%. Promote vermicompost, green manure, and biofertilizers like Rhizobium and Azotobacter, supported by subsidies under the National Mission for Sustainable Agriculture (NMSA). Establish local biofertilizer units in districts of south Bihar plain. Combine organic and chemical inputs to improve nitrogen use efficiency. Use crop residues and cover crops to enhance soil organic carbon. Expected outcomes include improved soil fertility, reduced chemical input costs and increased yields in cereals and pulses, in those districts where fallow lands indicate underutilized potential.



Crop Diversification and High-Value Agriculture

In the cropping pattern of south Bihar plain, Cereals dominate (2.52 million hectares, 8.8 million metric tons), but pulses (228,888 hectares) and oilseeds (38,097 hectares) have lower coverage and yields. High-value crops like lichi, mango, onion, chili, mentha, potato, and winter maize offer untapped potential. Shift 10-15% of rice-wheat areas to winter maize (3.5 tons/ha yield), vegetables, and fruits like lichi and mango, supported by hybrid seeds and training. Combine crops with livestock, fisheries, and poultry to increase incomes by 30-40%. Promote fish-cum-paddy systems in flood-prone districts like Patna, Lakhisarai, Munger, and Bhagalpur. Develop climate-resilient, high-yielding varieties and establish seed banks to ensure quality seed access for smallholders. Expected outcomes include increased farmer incomes by 25-30%, reduced monoculture risks, and enhanced food security through diverse diets, particularly in districts with low pulse or oilseed production like Munger and Jamui.

Adopting Climate-Resilient Technologies

The South Bihar Plain faces flood-drought cycles, with southern districts like Gaya, Nawada and Jamui prone to drought and northern areas like Patna Munger and Bhagalpur vulnerable to floods. Climate change exacerbates erratic rainfall and temperature spikes. Promote flood-tolerant rice and drought-resistant maize and pulses. Expand agroforestry under the Sub-Mission on Agroforestry, planting fruit and timber trees to enhance biodiversity and carbon sequestration. Adopt conservation tillage, mulching, and rainwater harvesting to mitigate drought in Jamui and flooding in Lakhisarai. Use geospatial tools for flood-risk mapping in Bhagalpur. Expected outcomes include reduced crop losses improved resilience to climate variability, and increased biodiversity by integrating 50,000 hectares under agroforestry by 2030.

Strengthening Infrastructure and Market Access

In the south Bihar plain Postharvest losses are high due to limited cold storage and processing units and poor market linkages. Build cold storage and processing units in Bhagalpur (horticulture hub) and Rohtas (cereal hub), targeting a 50% reduction in losses. Expand rural roads under PMGSY for better market access. Strengthen Farmer Producer Organizations (FPOs) post-APMC Act abolition to ensure fair pricing and direct market linkages. Establish e-NAM integration in Patna and Nalanda for transparent trading. Increase paddy and pulse procurement to 5 million tons annually, focusing on districts like Bhojpur and Aurangabad, to stabilize incomes. Expected outcomes include reduced post-harvest losses, increased farmer income.

Scaling Agricultural Research and Extension Services

In the districts of south Bihar plain low adoption of modern practices stems from weak extension services like Krishi Vigyan Kendra and limited mechanization. Expand Kisan Gyan Rath and mobile-based advisories cvdfkto deliver real-time crop management tips in all 17 districts. Subsidize small-scale machinery (e.g., seed drills, harvesters) under the Bihar Agricultural Roadmap, targeting marginal farmers. Promote custom hiring centers for affordability. Leverage Bihar Agricultural University and ICAR to develop region-specific technologies, such as precision agriculture tools and use remote sensing for crop monitoring. Expected outcomes include increased technology adoption, improved yields and enhanced farmer awareness of sustainable practices across all districts.

Enhancing Financial Access and Policy Support

In study area smallholder farmers facing limited credit access and high transition costs for organic farming, with subsidies skewed toward chemical inputs. Expand Kisan Credit Card (KCC) coverage to 80% of farmers, with microfinance support for women-led FPOs. Link credit to sustainable practices like SRI. Increase subsidies for biofertilizers and organic inputs, matching chemical fertilizer subsidies. Implement village-level planning for localized solutions. Strengthen Pradhan Mantri Fasal Bima Yojana to cover 50% of farmers, ensuring timely payouts for flood or drought losses. Expected outcomes include improved credit access for 60% of smallholders, reduced input costs and enhanced financial security for climate-related risks.

Promoting Agroforestry and Biodiversity Conservation

In the districts of south Bihar plain Agroforestry is underutilized despite its potential for soil health and income diversification. Integrate fruit and timber trees on 100,000 hectares by 2030, focusing on Kaimur, Banka, and Nawada, with species like mango, guava, and bamboo to support soil conservation and carbon sinks. Promote crop diversification and intercropping with legumes to enhance agrobiodiversity. Protect native species in forest-adjacent areas like Gaya and Jamui. Involve local communities in agroforestry schemes through training and incentives, ensuring equitable benefits for marginal farmers and tribal groups in Banka and Jamui. Expected outcomes include increased forest cover by 5%, enhanced biodiversity by 15%, and additional income streams for 20% of farmers through agroforestry products.

Digital Agriculture and Technologies

The recent approval of Bihar's Digital Agriculture Directorate (2025) aims to integrate technology, but adoption of digital tools like AI and geospatial mapping is low among smallholders. Use remote sensing and GIS for real-time monitoring of irrigation, crop health, and land use. Conduct annual impact assessments to track yield, income, and environmental metrics. Roll out mobile apps for crop forecasting, weather alerts, and market prices, targeting 50% farmer coverage. Use drones for soil moisture and nutrient monitoring in high-productivity districts like Aurangabad and Buxar. Pilot AI-based yield prediction models in Bhagalpur. Train 5,000 youth annually in digital agriculture skills through partnerships with agricultural universities, focusing on women and marginal farmers. Expected outcomes include improved resource-use efficiency by 20%, reduced input costs by 10%, and enhanced crop planning accuracy, particularly in flood-prone and drought-affected district.

5. CONCLUSION:

The South Bihar Plain, one of the most fertile yet vulnerable agricultural regions of eastern India, plays a crucial role in ensuring food and livelihood security. With over two million hectares under cultivation, cereals dominate the cropping pattern, while pulses and oilseeds occupy limited areas, indicating a need for diversification. Districts such as

Rohtas, Kaimur, and Aurangabad achieve higher productivity due to better irrigation coverage exceeding 85 percent, whereas Jamui, Banka, and Bhagalpur lag behind because of hilly terrain, low vhgirrigation, and larger fallow lands. Patna sustains extensive cultivation despite urban expansion, though its irrigation share has declined to below 50 percent. Agriculture remains highly dependent on monsoons, as traditional systems like Ahar–Pyne and canal networks function sub-optimally, leaving the sector vulnerable to floods, droughts, and climatic variability. Persistent challenges include land fragmentation, soil degradation, low mechanization, and weak market infrastructure. To overcome these constraints, sustainable pathways must emphasize climate-resilient crop varieties, organic and natural farming, efficient water management, agroforestry, and digital precision agriculture. Policy support through farmer producer organizations (FPOs), market integration, and realignment of subsidies is equally vital. A multi-pronged strategy integrating ecological balance, technological innovation, and socio-economic equity is essential for sustainable agricultural transformation in the region.

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