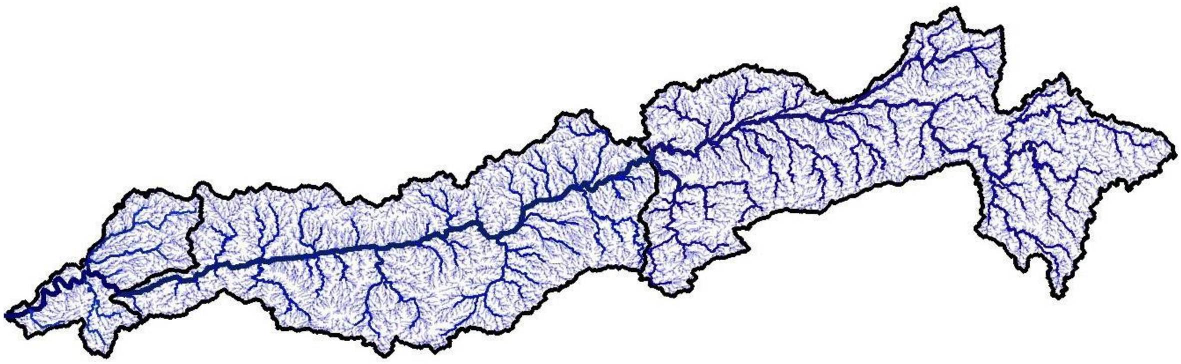
National River Conservation Directorate
Ministry of Jal Shakti, Department of Water Resources,
River Development & Ganga Rejuvenation
Government of India

Narmada River Basin: Assessment of Gross Agricultural Structure



December 2025

Narmada River Basin: Assessment of Gross Agricultural Structure

National River Conservation Directorate (NRCD)

The National River Conservation Directorate, functioning under the Department of Water Resources, River Development & Ganga Rejuvenation, and Ministry of Jal Shakti providing financial assistance to the State Government for conservation of rivers under the Centrally Sponsored Schemes of 'National River Conservation Plan (NRCP)'. National River Conservation Plan to the State Governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the State Governments/ local bodies.
www.nrcd.nic.in

Centres for Narmada River Basin Management Studies (cNarmada)

The Centres for Narmada River Basin Management Studies (cNarmada) is a Brain Trust dedicated to River Science and River Basin Management. Established in 2024 by IIT Gandhinagar and IIT Indore, under the supervision of cGanga at IIT Kanpur, the center serves as a knowledge wing of the National River Conservation Directorate (NRCD). cNarmada is committed to restoring and conserving the Narmada River and its resources through the collation of information and knowledge, research and development, planning, monitoring, education, advocacy, and stakeholder engagement.
www.cnarmada.org

Centre for Ganga River Basin Management and Studies (cGanga)

cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this, it is also responsible for introducing new technologies, innovations, and solutions into India.
www.cganga.org

Acknowledgment

This report is a comprehensive outcome of the project jointly executed by IIT Gandhinagar (Lead Institute) and IIT Indore (Fellow Institute) under the supervision of cGanga at IIT Kanpur. It was submitted to the National River Conservation Directorate (NRCD) in 2024. We gratefully acknowledge the individuals who provided information and photographs for this report.

Disclaimer

This report is a preliminary version prepared as part of the ongoing Condition Assessment and Management Plan (CAMP) project. The analyses, interpretations and data presented in the report are subject to further validation and revision. Certain datasets or assessments may contain provisional or incomplete information, which will be updated and refined in the final version of the report after comprehensive review and verification.

Team

Prof. Pritee Sharma	cNarmada, IIT Indore
Prof. Priyank J Sharma	cNarmada, IIT Indore
Dr. Divyanshu Kumar Dixit	cNarmada, IIT Indore
Mr. Anish Chandra	cNarmada IIT Indore
Dr. Vinod Tare	cGanga, IIT Kanpur

PREFACE

The Narmada River, often referred to as the "Lifeline of Central India," serves as a vital ecological, economic, and cultural artery for millions of people across the states of Madhya Pradesh, Gujarat, Maharashtra, and Chhattisgarh. Recognizing the central role of agriculture in the basin's health, this report, titled *"Narmada River Basin: Assessment of Gross Agricultural Structure of the Basin,"* offers a comprehensive evaluation of the regional agricultural framework as of December 2025.

This assessment is a pivotal outcome of the National River Conservation Plan (NRCP) under the Ministry of Jal Shakti. The project was executed through the collective expertise of IIT Gandhinagar and IIT Indore, acting as the knowledge wing known as cNarmada (Center for Narmada River Basin Management and Studies), under the supervision of cGanga at IIT Kanpur.

The concept of Gross Agricultural Structure, as defined in this report, refers to the holistic organizational and operational framework of the agricultural system within the Narmada hydrological boundaries. This includes the integration of physical resources, land use patterns, cropping compositions, irrigation infrastructure, and input use. By capturing how agricultural land is managed in its totality, the report provides a baseline for understanding the pressures placed on the river's water resources and ecosystem.

The agricultural potential of the Narmada Basin is fundamentally dictated by its diverse physiography and agro-climatic context. The basin exhibits five broad physiographic zones, ranging from the high-relief upland districts in the east to the low-relief coastal plains in the west. This "Rainfall Divide"—transitioning from humid conditions in the upper reaches (over 1,400 mm) to semi-arid conditions in the western plains (below 650 mm)—creates a sophisticated agricultural gradient. While the eastern highlands like Mandla and Dindori remain characterized by hilly terrain and rainfed rice cultivation, the central alluvial corridor of Hoshangabad and Narsinghpur has emerged as a high-intensity agricultural "engine".

To ensure spatial and temporal accuracy, the report utilizes a dual methodological approach. Long-term trends from 1970 to 2017 are analyzed using consistent datasets from ICRISAT, allowing for an assessment of how the basin has transformed over nearly five decades. To address the limitations of administrative district-level data, which may overrepresent agricultural production, the report incorporates high-resolution ESRI Land Use and Land

Cover (LULC) data derived from Sentinel-10 imagery. This geospatial approach quantifies agricultural land strictly within the hydrological boundary of the basin, revealing that in certain western districts like Jhabua and Vadodara, agricultural density reaches as high as 89.7% and 86.7%, respectively.

The findings detailed in the subsequent sections highlight a massive agricultural intensification. Between 1970 and 2017, the basin witnessed a transition toward a high-output wheat-centric system in the central plains and specialized rice cultivation in the upper reaches. This growth has been underpinned by an explosive increase in chemical fertilizer consumption, particularly Nitrogen, which skyrocketed in districts like Hoshangabad from 557 tons to over 87,000 tons. Furthermore, the report explores the irrigation structure, identifying a heavy reliance on groundwater and tubewell technology in the central plains, while public canal systems remain critical in the Gujarat plains and specific upper basin corridors.

In conclusion, this report serves as more than a statistical compendium; it is a strategic document intended to guide policy implications and resource allocation. As the Narmada River Basin faces emerging challenges related to water table depletion and moisture stress, understanding its gross agricultural structure is essential for ensuring the sustainability of its resources. By bridging the gap between traditional administrative data and modern geospatial science, cNarmada provides the National River Conservation Directorate with the insights necessary for the dynamic evolution of basin management plans.

Centres for Narmada River Basin Management and Studies (cNarmada)

IIT Gandhinagar, IIT Indore

TABLE OF CONTENTS

LIST OF TABLES

Appendix

LIST OF FIGURES

1 Introduction

1.1 Overview of the Narmada River Basin

Narmada river is one of the major rivers in India and its basin is expanded over 98,796 square kilometres. Narmada Basin is lifeline to states like Madhya Pradesh, Gujrat, Maharashtra and serves millions of the people in ecological, economic, cultural aspects. In terms of administrative expansion, the Narmada River Basin spans four Indian states—Chhattisgarh, Madhya Pradesh, Gujarat, and Maharashtra—covering vast parts of central and western India. Originating from Amarkantak, the 1,312 km long Narmada River flows westward, with 1,077 km in Madhya Pradesh, 74 km in Maharashtra, and 161 km in Gujarat, before emptying into the Gulf of Khambhat. The basin supports over 20.8 million people across 33 districts, including 27 in Madhya Pradesh and 2 each in Chhattisgarh, Gujarat, and Maharashtra. It plays a crucial role in the region's ecology, economy, and society by providing water for drinking, agriculture, and hydropower. The districts within the basin display wide variation in population density, economic structure, and terrain—from fertile plains to hilly regions—shaping diverse development patterns and environmental challenges.

1.2 Gross Agricultural Structure

Narmada River basin is rich in and diversified in agriculture activities and a significant of population earn its livelihood from agriculture or agriculture-based activities across the districts of the Narmada Basin. Thus, agriculture plays a crucial role for the entirety of the Narmada Basin. However, the role of agriculture as shaped by the agricultural structure of a particular area, in case of this report, Narmada Basin. Gross Agricultural Structure refers to the comprehensive organizational and operational framework of an agricultural system within a defined geographical unit (such as the Narmada River Basin). It is a holistic measure that integrates the physical resources, land use, cropping, irrigation, inputs, and production patterns during a specified agricultural year or period. It captures how agricultural land is utilized and managed in totality. Gross agricultural structure can be understood through following key dimensions:

a) **Net and Gross Sown Area:** The total physical area used for crops vs. the total area including multiple cropping (Cropping Intensity).

b) **Irrigation Infrastructure:** The source and type of irrigation (canals, wells, lift irrigation), which is particularly relevant in the Narmada Basin due to large-scale projects like the Sardar Sarovar.

c) **Cropping Pattern:** The patterns of food grains (wheat, rice) and commercial crops (soybean, cotton, sugarcane).

1.3 Methodology and data

This report primarily relies on data sourced from ICRISAT to ensure consistency and comparability across districts within the Narmada River Basin. Although the Directorate of Economics and Statistics provides a wide range of agricultural statistics, these datasets often lack uniformity across spatial and temporal scales and are therefore used selectively. For analyses involving long-term trends, data covering the period 1970 to 2017 have been used. As this period spans several decades, significant changes in administrative boundaries have occurred, including the creation of new districts and reorganization of existing ones. To maintain temporal consistency in trend analysis, historical district boundaries have been adopted. Consequently, in a few cases, small portions of districts that currently lie outside the basin, such as Durg, Bilaspur, Jalgaon, Damoh, and Panchmahal, are included in the analysis.

This methodological approach ensures continuity in long-term assessment while acknowledging the limitations associated with the use of administratively defined boundaries in basin-scale studies.

Further, as most agricultural data generated by government agencies are compiled at the administrative level, primarily at the district scale, this assessment incorporates entire district-level statistics even in cases where only a portion of a district falls within the Narmada River Basin. This represents a key limitation in achieving an exact delineation of the basin's gross agricultural structure, as district-level aggregates may overrepresent agricultural area and production attributable to the basin. To address this limitation and improve spatial accuracy, basin-specific agricultural area estimation has been undertaken using satellite-based land use and land cover data. High-resolution ESRI Land Use and Land Cover datasets derived from Landsat and Sentinel-10 imagery have been employed to identify and quantify agricultural land strictly within the hydrological boundary of the basin. This geospatial approach enables a more precise estimation of agricultural extent at the basin scale, particularly in districts that are only partially located within the basin, thereby strengthening the reliability of the gross agricultural structure assessment.

2 Physiographic and Agroclimatic Context of the Basin

This section examines the physiography of the Narmada River Basin at the district scale, with particular emphasis on elevation and slope characteristics, rainfall distribution, and dominant soil types, highlighting the contrasting physiographic attributes across the basin. It also identifies the districts representing extreme conditions (highest and lowest values) for key physiographic variables.

The Narmada River Basin extends approximately between longitudes 72°38′E and 81°43′E and latitudes 21°27′N and 23°37′N, covering an area of about 98,796 km². The basin spans four states: Madhya Pradesh, which accounts for nearly 82% of the basin area, followed by Gujarat (12%), Maharashtra (4%), and a small portion of Chhattisgarh (2%). The Narmada River originates in the Amarkantak Plateau in Anuppur district, at an elevation of approximately 1,048 m above mean sea level and flows westward through a well-defined rift valley before draining into the Gulf of Khambhat.

2.1 Elevation and relief (DEM-based)

SRTM-based basin analysis reveals that Dhupgarh (in the Pachmarhi area of the Satpura range) is the highest topographic point in the general basin region (1,333 m), with the largest share of the basin area located between 300 and 500 m.

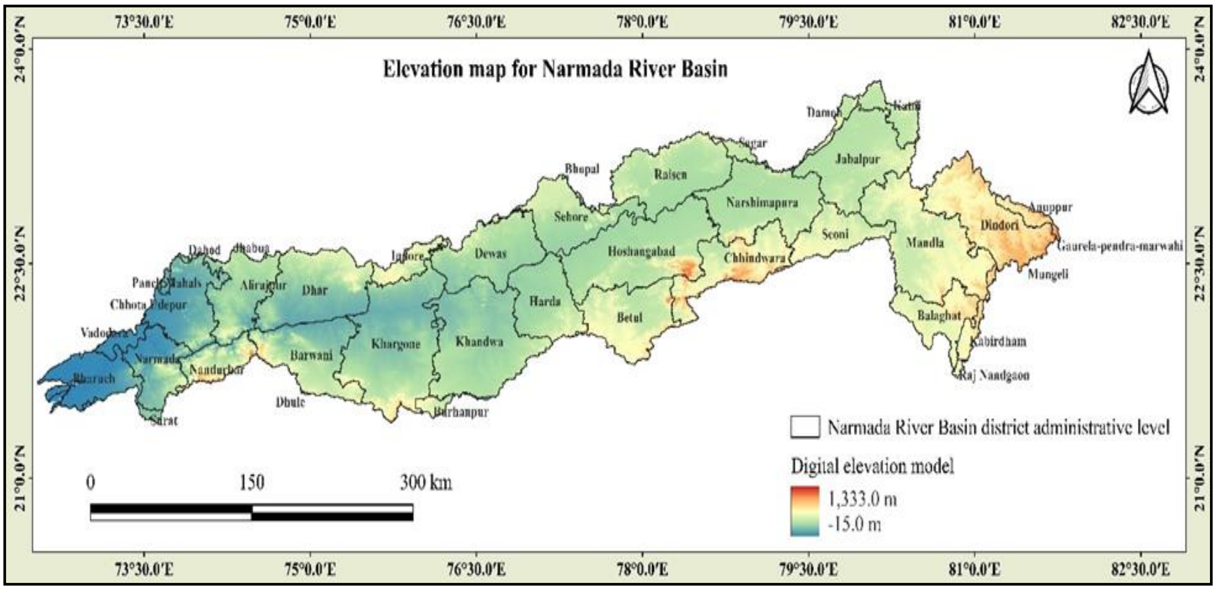


Fig. 1. Physiography of Narmada River Basin

The basin (98,796 km²) is bounded by the Vindhya and Satpura ranges and exhibits five broad physiographic zones (upper hilly, upper plains, middle plains, lower hilly, lower plains). High-relief upland districts in the eastern/central basin contrast with low-relief coastal and lower plain districts in Gujarat.

This gradient explains not just where water flows, but how fast and with what force. At the district scale, upper-elevation districts include the top-most upper elevation/relief districts (qualitative, basin portion only):

- Anuppur–Amarkantak area (including and around the headwaters, characterized by very high relief within the basin).
- Dindori and Mandla (hilly, forested uplands within the upper Narmada basin).
- Balaghat–Seoni sector (Satpura foothills that contribute steep sub-basins).
- Shahdol area (upper hilly zone with a dissected plateau and high local relief).

and top-most lower elevation/relief districts are:

- Narmada (Gujarat) and Bharuch districts at the lower plains/estuarine reach; very low elevations and a wide valley floor.
- Parts of Barwani and Khargone west (lower plains immediately upstream of Sardar Sarovar backwater zone).
- Kheda/Anand fringe, where the basin merges with coastal alluvial plains (very low gradient alluvium).

2.2 Slope characteristics

Multi-class slope mapping for the Narmada basin (using SRTM DEM) shows that nearly level to gently sloping lands dominate the middle basin, while very steep slopes occupy a small fraction (0.5%) of the area in the upper and lower hilly belts. As shown in the Fig. 2, this is steep terrain. The land rises sharply, with slopes often exceeding 25 degrees. This topography, visible in the dense contour lines of the DEM and the deep reds of the slope map, creates rapid runoff but also spectacular waterfalls and deep pools along the young Narmada. The steepest slopes occur near the headwaters around Amarkantak and in the gorge section upstream of Sardar Sarovar, whereas broad low-gradient surfaces characterize the central alluvial corridor. By analyzing the land's steepness, we can understand the potential for erosion, infrastructure challenges, and agricultural suitability. The steep reds and oranges of the eastern districts contrast sharply with the gentle greens and blues of the central valley and western plains.

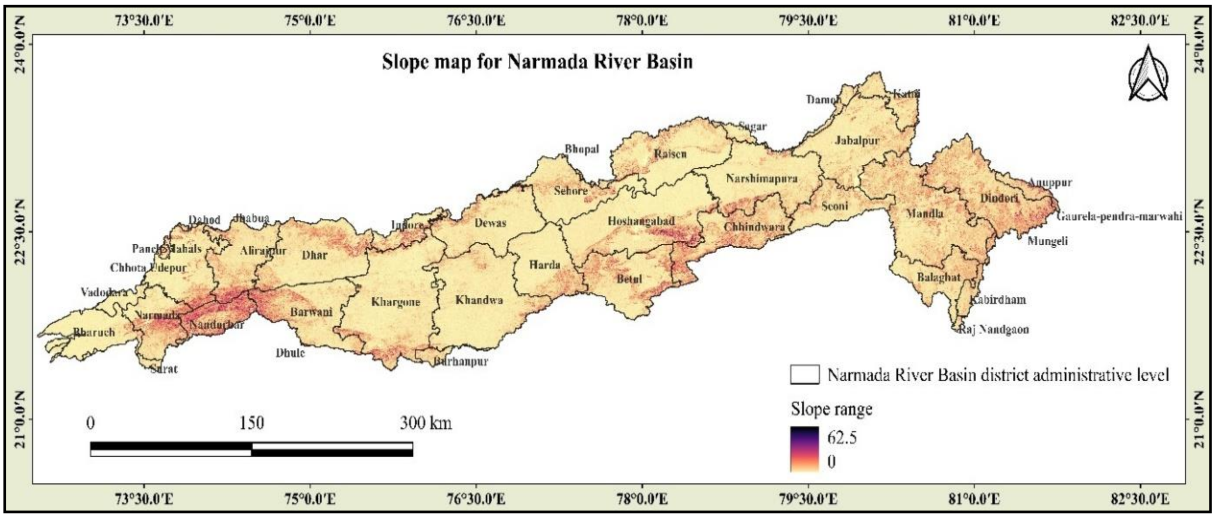


Fig. 2. Slope of Narmada River Basin

The top-most districts with upper extreme slope conditions (high share of steep/very steep slopes in the basin part) are:

- Anuppur / headwater sector (near Amarkantak, very steep slopes >35° on short hill slopes and escarpments).
- Dindori and Mandla (deeply dissected uplands with moderately steep to steep slopes, especially along major tributaries like Banjar and Hiran).
- Balaghat (Satpura hill front with strong local relief and steep valley sides).
- Lower gorge zone straddling Barwani–Alirajpur (steep escarpments and incised valley near Sardar Sarovar reservoir).

The top-most districts with lower extreme slope conditions (dominantly level to gently sloping in the basin part) are:

- Hoshangabad–Narmadapuram and Narsinghpur (middle plains with nearly level to very gently sloping alluvial surfaces extensively under agriculture).
- Jabalpur and Damoh (upper plains with long, gentle slopes and wide valley floors despite local scarps).
- Khargone and Khandwa upstream plains (broad, low-gradient lower middle reach with canal-irrigated command areas).
- Narmada and Bharuch (lower plains and deltaic/estuarine zone, extremely low regional slope towards the Gulf of Khambhat).

2.3 Rainfall regime and spatial gradients

Climatologically, the Narmada River Basin displays a humid to sub-humid monsoonal regime in the eastern and upper reaches, gradually transitioning to semi-arid conditions in the western lower plains. Localized per-humid conditions occur around elevated massifs, most notably the Pachmarhi highlands. Rainfall distribution across the basin is highly uneven and plays a central role in shaping natural vegetation patterns, irrigation dependence, and drought susceptibility.

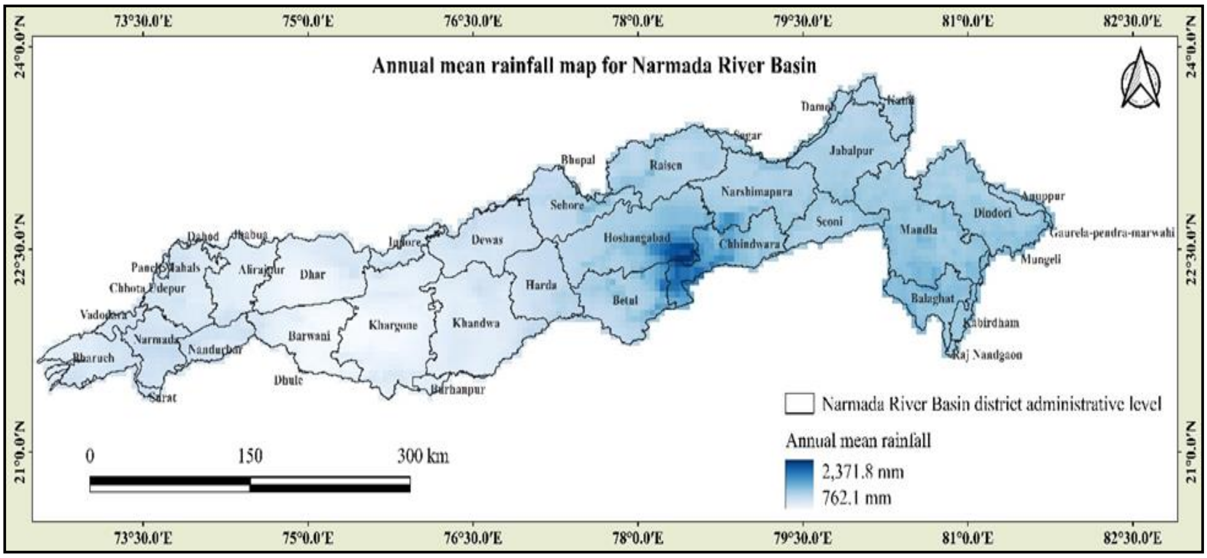


Fig. 3. Annual Mean Rainfall of Narmada River Basin

Nearly 85 to 95 percent of the annual rainfall is received during the southwest monsoon season, with winter and pre-monsoon rainfall contributing only marginal amounts. Annual rainfall generally exceeds 1,400 mm in the eastern and southern upper basin, reaching 1,650 to 1,800 mm in pockets influenced by the Pachmarhi and southern Satpura highlands. The southern upper basin is also characterized by high-intensity rainfall events, with 24-hour maximum of up to 360 mm, as reported in CWC records.

Rainfall declines progressively westward from about 1,400 mm in the Jabalpur region to below 1,000 mm around the Punasa and Indira Sagar sector. It further decreases to less than 650 mm in Barwani, forming the most arid core of the basin. A modest increase in rainfall is observed toward the southwestern and coastal parts of the basin, although strong seasonality and high evaporative demand limit effective moisture availability outside the monsoon months.

At the district level, the highest rainfall zones within the basin include Pachmarhi-influenced parts of Narmadapuram and Chhindwara, where rainfall exceeds 1,800 mm in localized areas, followed by Mandla and Dindori, which typically receive more than 1,400 mm due to their hilly and forested terrain. Parts of the eastern upper basin adjoining the Maikala and Satpura ranges, including sections of the Anuppur and Shahdol region, also fall within this high rainfall category.

In contrast, the lowest rainfall zones are concentrated in Barwani district, which receives less than 650 mm annually and represents the most moisture-stressed part of the basin. Western Khargone and Khandwa experience sub-humid to semi-arid conditions with strong monsoon concentration, while the Narmada and Bharuch coastal plains receive moderate rainfall but remain vulnerable to moisture stress due to pronounced seasonality and high evapotranspiration during non-monsoon periods.

2.4 Agro-climatic Zones of the Basin

The Narmada Basin is divided into four major agro-climatic zones, defined by unique soil, terrain, and climate profiles. The Central Plateau and Hills Region are the most prominent, covering 53% of the basin area. This region features fertile black soils and consistent rainfall, supporting a diverse output of soybean, wheat, pulses, and maize. High productivity is concentrated in districts such as Narmadapuram, Jabalpur, Narsinghpur, and Chhindwara (Fig. 4).

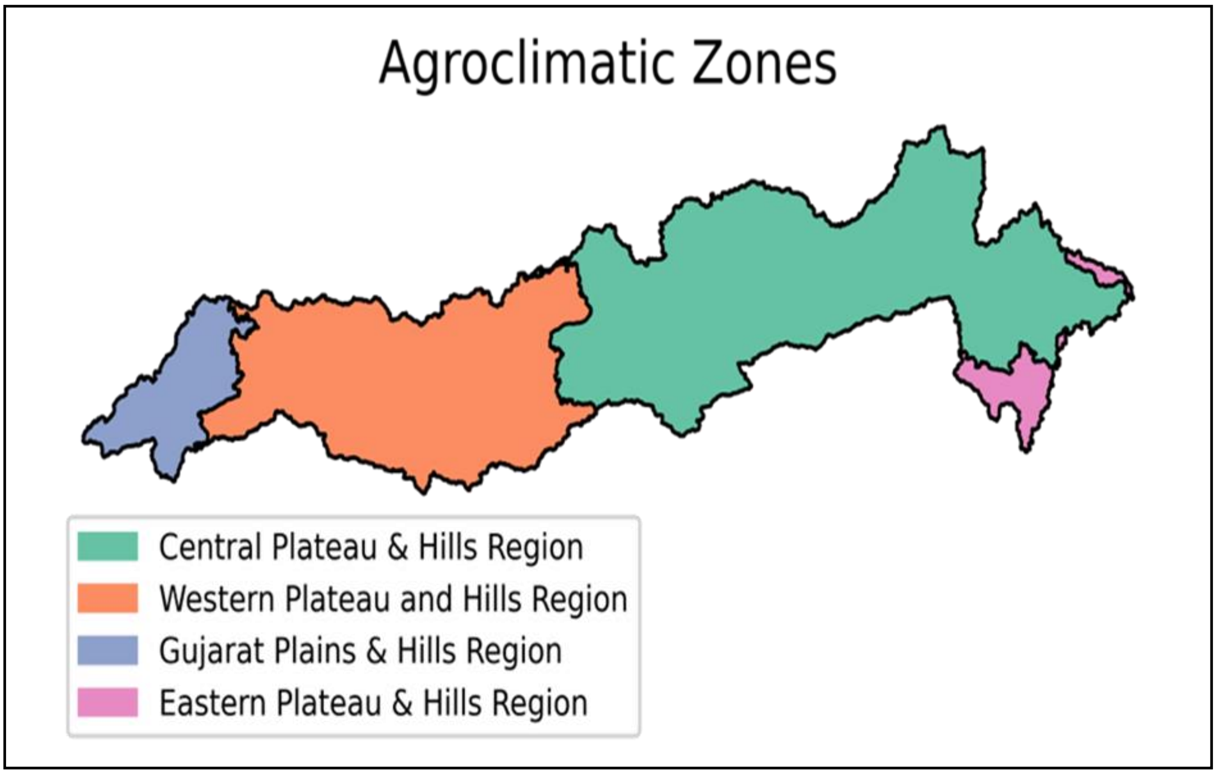


Fig. 4. Agro-climatic Zones of Narmada Basin

The Western Plateau and Hills Region accounts for 34.9% of the basin. This area features undulating terrain and shallower soils, primarily supporting oilseeds like soybean and groundnut alongside coarse cereals and pulses. Districts such as Dewas, Betul, and Raisen are representative of this zone (Fig. 5).

The Gujarat Plains and Hills Region cover 8.5% of the basin but remains highly productive. Fertile alluvial soils and extensive irrigation in districts like Vadodara and Bharuch allow for high cropping intensities of cotton, groundnut, and tobacco.

Fig. 5 shows that the Eastern Plateau and Hills Region are the smallest zone at 3.6%. Characterized by steep slopes and shallow soils, it focuses on rainfed millets and forest-based agriculture in parts of Shahdol and Bilaspur. Understanding these distinct zones is essential for targeted agricultural planning and resource allocation.

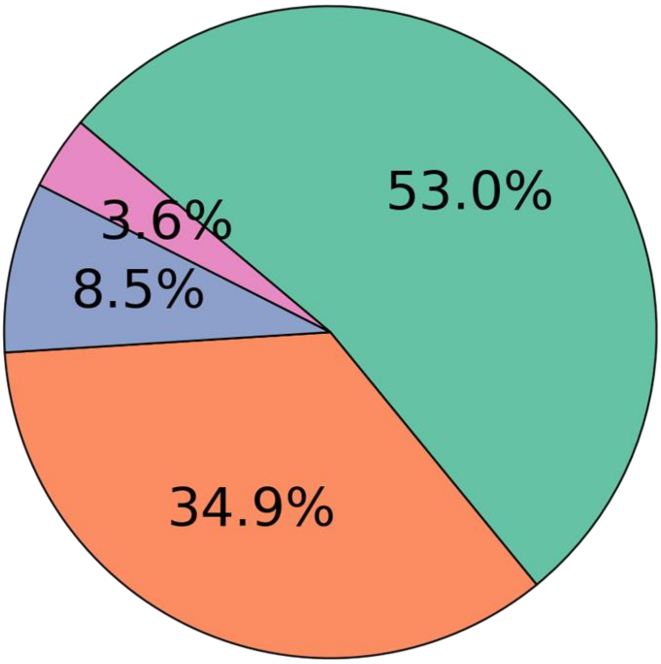


Fig. 5. Area percentage (%) of agro-climatic regions in Narmada basin

2.5 Physiography and Agriculture Interplay

The agricultural structure of the Narmada River Basin is fundamentally shaped by the interaction of topography, slope, rainfall regime, and soil characteristics, which together determine crop choice, irrigation dependence, cropping intensity, and overall agricultural productivity across districts. However, to some extent, modern agriculture practices, overshadow the physiographic influence on agricultural practices and patterns. Still, the role of physiography cannot be negated while assessing gross agricultural structures of the basin as elevation and relief exert a primary control on agricultural potential. High-relief districts in the upper basin such as Anuppur, Dindori, Mandla, Balaghat, and Shahdol are characterized by steep slopes, dissected terrain, and shallow soils. These conditions restrict large-scale mechanization, limit field size, and increase runoff and soil erosion. As a result, agriculture in these districts depends on irrigation related technologies or availability of canal system. Also crops tolerant to slope and moisture variability, including millets, pulses, and coarse cereals shape the agricultural practices. Plantation agriculture and intensive irrigated cropping are structurally constrained in these upland zones.

On the other hand, the middle basin plains, particularly in districts such as Narmadapuram, Narsinghpur, Jabalpur, Damoh, and parts of Khandwa and Khargone, exhibit moderate elevations, gentle slopes, and broad valley floors. These physiographic conditions favour easer canal development, groundwater abstraction, and mechanized farming, enabling higher cropping intensity and diversification. The dominance favorable soils combined with relatively reliable monsoon rainfall supports wheat, soybean, pulses, maize, and irrigated rabi crops, forming the core of the basin's agricultural output.

The lower plains and coastal districts such as Bharuch, Narmada district in Gujarat, and parts of western Khargone and Barwani are characterized by very low relief and minimal slope gradients. While these conditions are favorable for irrigation infrastructure and high cropping intensity, low and highly seasonal rainfall, tied with high evapotranspiration, creates structural dependence on canal irrigation, reservoirs, and regulated flows from upstream dams. Cotton, groundnut, tobacco, and irrigated cereals dominate these zones, but agriculture remains vulnerable to water allocation variability and dry-season moisture stress.

Slope characteristics further refine agricultural suitability. Steep and very steep slopes in the upper hilly districts accelerate runoff, reduce soil moisture retention, and increase erosion risk, discouraging water-intensive or long-duration crops. Contrarywise, nearly level to gently sloping lands in the middle and lower plains facilitate water retention, uniform irrigation application, and the adoption of high-yielding varieties. These slope-controlled differences explain the spatial concentration of irrigated agriculture in the central corridor and lower basin.

Rainfall gradients reinforce these structural patterns. High rainfall in the eastern and upper basin sustains dense natural vegetation and supports rainfed agriculture but also increases runoff losses due to slope. Declining rainfall westward reduces crop choice flexibility and increases irrigation demand.

The agro-climatic zones integrate these physiographic and climatic controls into distinct agricultural regimes. The Central Plateau and Hills region support diversified and relatively stable agriculture due to favourable soil moisture and terrain. The Western Plateau and Hills region remains more constrained by soil depth and rainfall variability, while the Gujarat Plains and Hills region achieves high productivity primarily through irrigation-intensive systems. The Eastern Plateau and Hills region remains predominantly rainfed, with limited scope for intensification due to terrain and soil constraints.

3 Irrigation Structure of Narmada Basin

Irrigation constitutes a central component of agricultural production in the Narmada River Basin and strongly influences cropping intensity, crop selection, and spatial patterns of agricultural productivity. Owing to pronounced variations in physiography, rainfall, and soil conditions across the basin, the development and use of irrigation infrastructure vary substantially between districts. An assessment of the irrigation structure is essential for understanding patterns of gross irrigated area, source-wise dependence on surface and groundwater, seasonal availability of water, and district-level exposure to rainfall variability, all of which have direct implications for agricultural sustainability and basin-level water management.

This section presents an assessment of irrigation structures across districts associated with the Narmada River Basin. Owing to the absence of irrigation statistics compiled strictly along hydrological basin boundaries, the analysis relies on district-level data based on administrative jurisdictions. Accordingly, for districts that are only partially located within the basin, entire district-level figures have been considered for the purpose of assessment. This approach has been adopted to ensure data consistency and comparability across districts, while acknowledging the inherent limitations of administratively defined datasets in basin-scale analysis. Also, districts like Nandurbar, Dhule of Maharashtra and, Kabirdham and Rajnandgaon of Chhattisgarh has not been included in the analysis due to their small area proportion to the basin.

3.1 Pattern of Irrigation Sources

3.1.1 Net Irrigated Area

Fig. 6 shows dominance of **groundwater resources** in terms of net irrigated area across the districts of the basin. Groundwater, accessed through tubewells and other wells, is the most prevalent source of irrigation in many districts. In districts like Indore, tubewells account for an overwhelming 92.7% of the net irrigated area. Similarly, Narsinghpur (86.5%), Burhanpur (81.6%), and Dewas (58.4%) show a heavy reliance on tubewell technology. When combined with "Other Wells," groundwater emerges as the main source for the Western Plateau and Hills region, providing the necessary moisture for the intensive cultivation of crops like soybean and wheat.

Canal irrigation plays a pivotal role in districts that benefit from major river projects and level topography. Anuppur stands out with 80.8% of its irrigation coming from canals. Significant canal dependency is also observed in Surat (68.2%), Narmada (54.9%), and Dindori (50.4%). In the middle basin plains, districts like Harda (43.4%), Hoshangabad (43%), and Seoni (46.3%) utilize canal networks to support their robust agricultural productivity. This surface water infrastructure is essential for mitigating the moisture deficits identified in the western and central parts of the basin (Fig. 6).

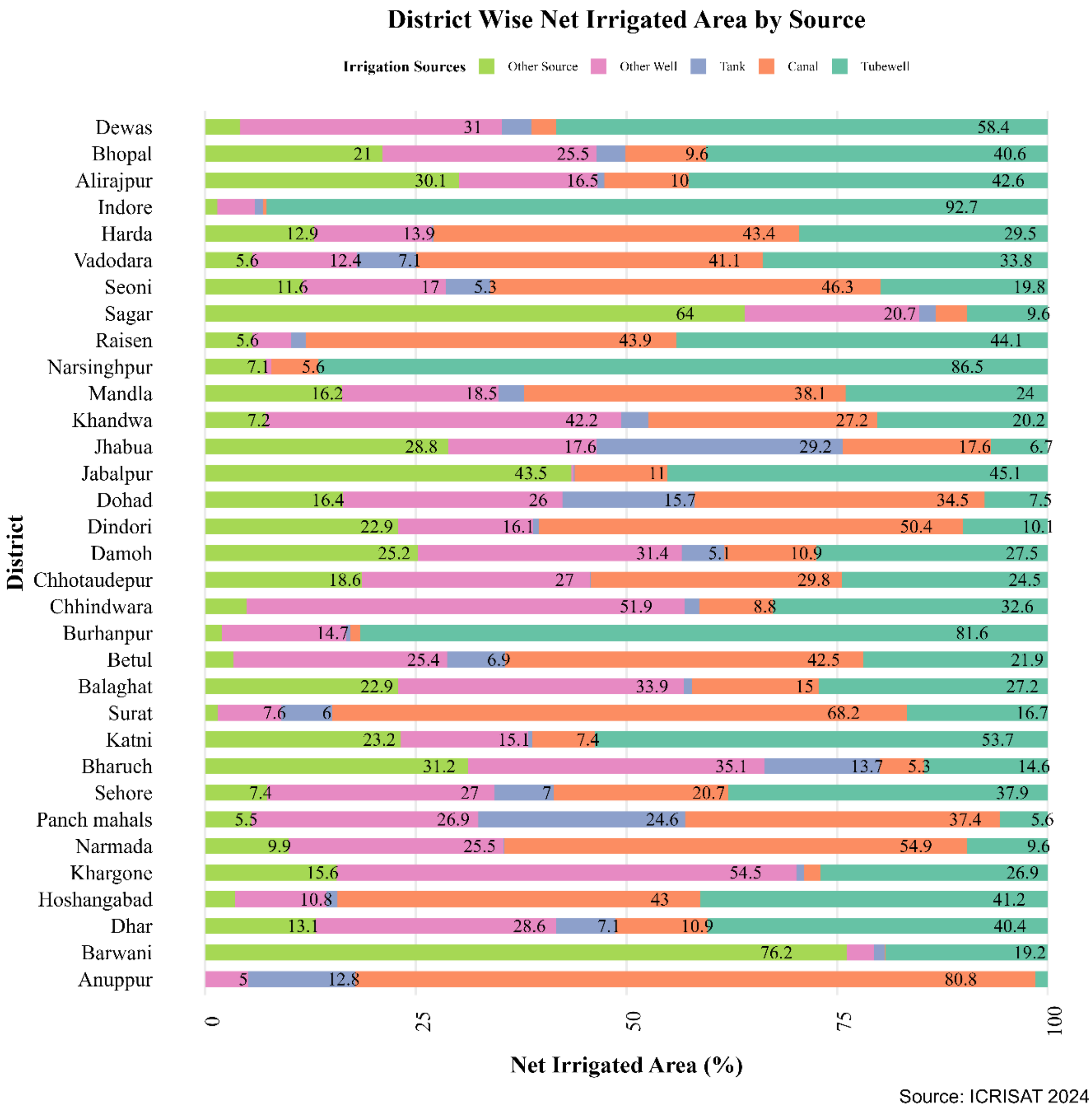


Fig. 6. District-wise Net Irrigated Area Sources

Tank irrigation contributes a relatively small share across most districts, remaining significant only in a few locations such as Jhabua, Panchmahals, Dohad, and Bharuch. This reflects the localized importance of traditional water harvesting structures, especially in tribal and undulating regions where canal and groundwater development is limited (Fig. 6. District-wise Net Irrigated Area Sources).

Thus Narmada Basin shows variation in irrigation strategies:

- **Diversified Districts:** Some districts maintain a more balanced portfolio of water sources. For instance, Vadodara utilizes a mix of canals (41.1%), tubewells (33.8%), and other wells (12.4%).

Table 1. Narmada Basin: District wise Net Irrigated area

	Net Irrigated Area (ha.)				
District	**Canal**	**Tank**	**Tubewell**	**Other Well**	**Other Source**
Alirajpur	3518	9054	9668	23226	20648
Anuppur	1316	103	5585	2160	3950
Balaghat	206879	32701	3606	12899	107
Barwani	31960	2208	58026	72319	48810
Betul	242	2648	40557	6815	160859
Bharuch	52855	8595	27225	31568	4148
Bhopal	14103	4999	59856	37552	31005
Burhanpur	1019	440	70120	12650	1710
Chhindwara	30262	6090	112270	178916	16967
Chhotaudepur	19179	72	15749	17388	11998
Damoh	32165	14944	81043	92494	74362
Dewas	12022	14193	237730	126412	16884
Dhar	48874	31663	181022	127960	58670
Dindori	8198	98	1635	2617	3722
Dohad	32382	14706	7016	24460	15368
Harda	83657	435	56761	26838	24877
Hoshangabad	126348	4005	121118	31756	10368
Indore	1023	2213	211257	10110	3270
Jabalpur	21992	347	90389	441	87009
Jhabua	21020	34855	8022	21000	34406
Katni	16089	1133	116341	32629	50302
Khandwa	80778	9667	60120	125470	21250
Khargone	6580	2940	88779	179740	51446
Mandla	21790	1778	13703	10593	9290
Narmada	16680	31	2915	7753	3002
Narsinghpur	16367	10	251787	2045	20743
Panch mahals	17141	11250	2582	12348	2507
Raisen	177563	7105	178182	18408	22800
Sagar	19827	10431	50800	110160	340338
Sehore	77002	25863	140934	100231	27414
Seoni	138235	15728	59112	50769	34514
Surat	90357	8018	22146	10062	1941
Vadodara	110849	19068	90986	33439	15054

Source: ICRISAT, 2023-24

- **Tank Irrigation:** While less common basin-wide, tank irrigation is significant in specific areas like Jhabua (29.2%) and Panch Mahals (24.6%), where the undulating terrain likely favors traditional harvesting structures.

Other Source Dependency: Barwani shows a unique profile where 76.2% of its irrigation comes from "Other Sources," which could include lift irrigation from the Narmada main stem or small-scale river diversions. This is particularly critical given its status as the most arid part of the basin.

3.1.2 Gross Irrigated Area

Since net irrigated areas capture the land that has access to irrigation at least once a year, it does not present which irrigation sources an area relies most. On the other hand, gross irrigated areas show total irrigated area under all the crops across all the seasons of a year. Thus, sources of gross irrigation and their share to the total sources of gross irrigation reflect true picture of water uses.

The sources of gross irrigated area (GIA) of the Narmada Basin reveals a structural reliance on groundwater, specifically through tubewell technology, to sustain multi-seasonal cropping cycles (Fig. 7). In high-productivity districts such as Narsinghpur, tubewells account for a dominant 96.2% of the gross irrigated area, while Indore and Jabalpur show similarly high figures at 94.1% and 87.9% respectively. These statistics indicate that groundwater is the primary driver for agricultural intensity, providing the year-round water security necessary for growing multiple crops on the same piece of land. Traditional "Other Wells" also play a significant role in the western parts of the basin, contributing to over 50% of the GIA in districts like Khargone, Khandwa, and Chhindwara. This underscores a decentralized irrigation model where individual farm-level investments in well infrastructure dictate the basin's total agricultural output.

In contrast, surface water systems through canal networks provide a critical secondary pillar, particularly in districts integrated into large-scale irrigation projects. Surat and Anuppur show a strong preference for surface water, with canals accounting for 66.6% and 64.9% of their gross irrigated area.

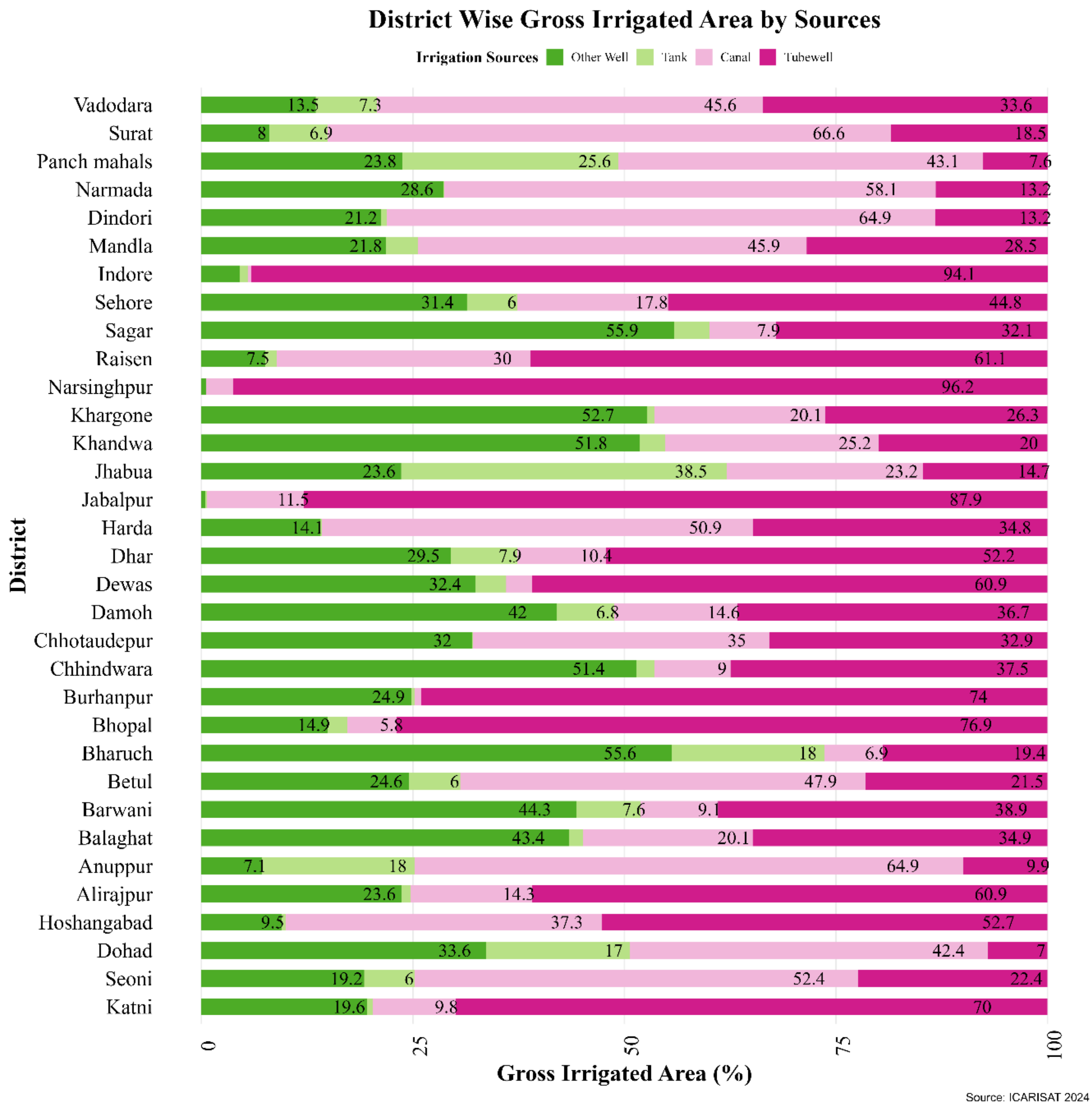


Fig. 7. District-wise Net Irrigated Area Sources

In Dindori and Seoni, canals contribute over 50% of the total irrigated crop area, illustrating how public infrastructure stabilizes production in these specific corridors. While tank irrigation remains a minor contributor basin-wide, it is essential in Jhabua and Panch Mahals, where it supports 38.5% and 25.6% of the gross irrigated area. Collectively, the data suggests that while the GIA is a composite of various sources, the expansion of the basin's agricultural structure is heavily tethered to the reliability of tubewells and the strategic reach of canal systems.

Table 2. Narmada Basin: District wise Gross Irrigated area

	Gross Irrigated Area (ha.)			
District	**Canal**	**Tank**	**Tubewell**	**Other Well**
Alirajpur	3518	9154	9868	28226
Anuppur	1316	103	5590	2170
Balaghat	254952	70883	39079	27992
Barwani	36754	3005	63832	79559
Betul	17080	14261	72804	82864
Bharuch	88133	11123	39632	45220
Bhopal	14757	5978	193894	37552
Burhanpur	1019	440	96316	32328
Chhindwara	32262	7517	134255	184287
Chhotaudepur	33165	72	31076	30299
Damoh	32165	14944	81043	92794
Dewas	12022	14193	237730	126412
Dhar	48874	36783	243994	137890
Dindori	9141	98	1865	2987
Dohad	71028	28415	11723	56340
Harda	153114	496	104734	42357
Hoshangabad	318252	4285	448918	80796
Indore	1023	2213	224652	10777
Jabalpur	41208	815	315898	1563
Jhabua	21020	34855	13276	21360
Katni	31076	2208	222429	62232
Khandwa	80778	9667	63870	165571
Khargone	110712	4852	144619	289740
Mandla	35827	2955	22218	17042
Narmada	20985	31	4773	10349
Narsinghpur	16367	10	484626	2645
Panch mahals	52133	30908	9206	28744
Raisen	177563	8226	362101	44488
Sagar	19926	10521	81400	141666
Sehore	85969	28866	216422	151389
Seoni	197479	22469	84446	72527
Surat	144782	14980	40303	17466
Vadodara	154932	24692	114312	45917

Source: ICRISAT, 2023-24

3.2 Trend of Ground Water Uses in Agriculture

As the above two sub-sections, 3.1.1 and 3.1.2 clearly show that overall groundwater is prominent source of irrigation, it is also important to look into its trend over the period. Fig. 8 illustrates irrigation area by tubewells and wells from 1970 to 2017. It is clearly visible that over the decades, groundwater irrigated areas have significantly increased across the basin especially in Narshinghpur, Hoshangabad, Raisen, Dhar, Dewas, Jabalpur, Khargone, and Vadodara districts.

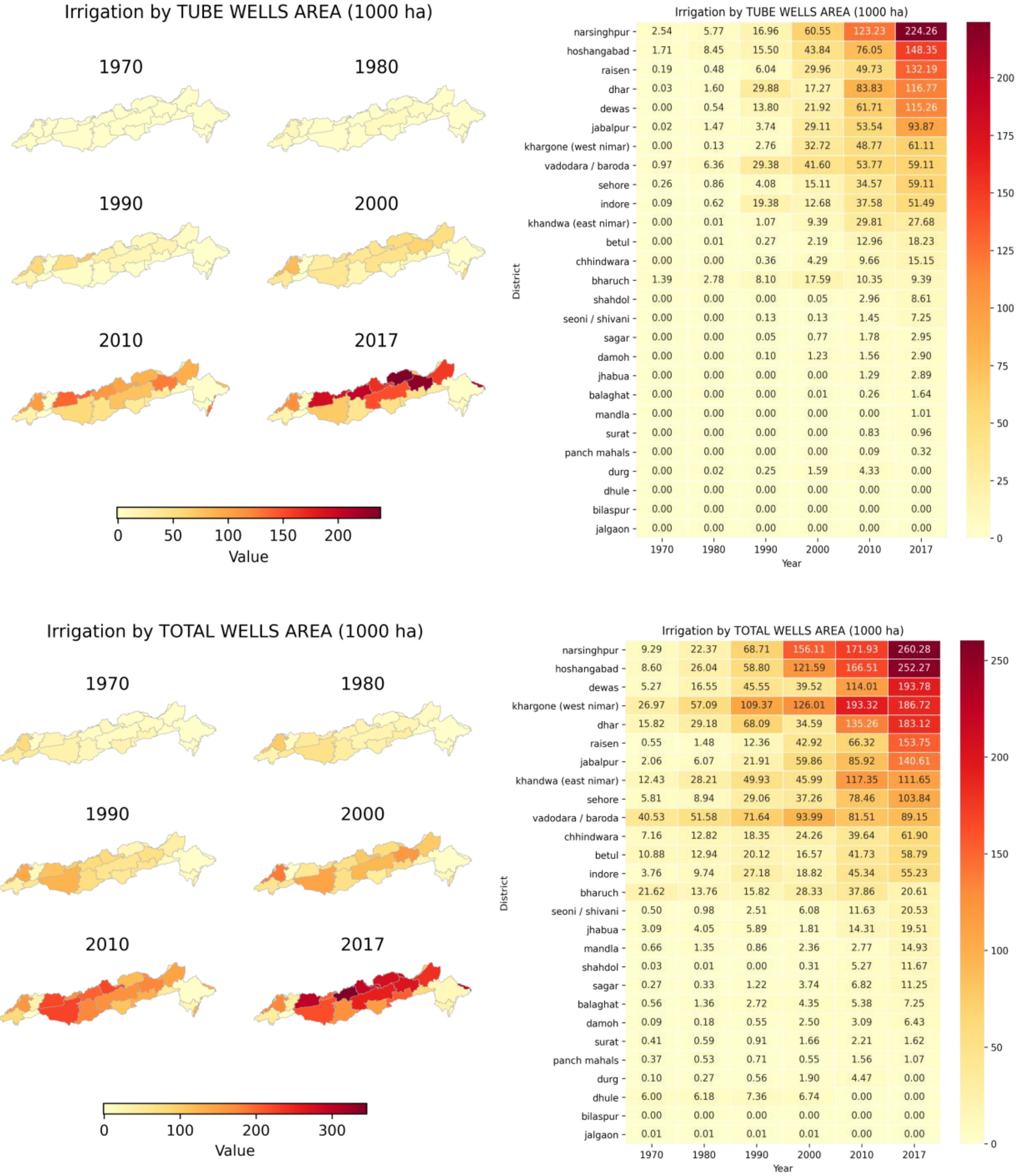


Fig. 8. Trend of Groundwater (tubewell and tank) in Narmada Basin

On the other, despite multiple ongoing irrigation projects across the basin, irrigated area by canal, in the same period, have significantly increased in few districts such as Hoshangabad, Khargone and Risen. It is also important to note that increase in canal irrigated area is more prominent after 2010 (Fig. 9).

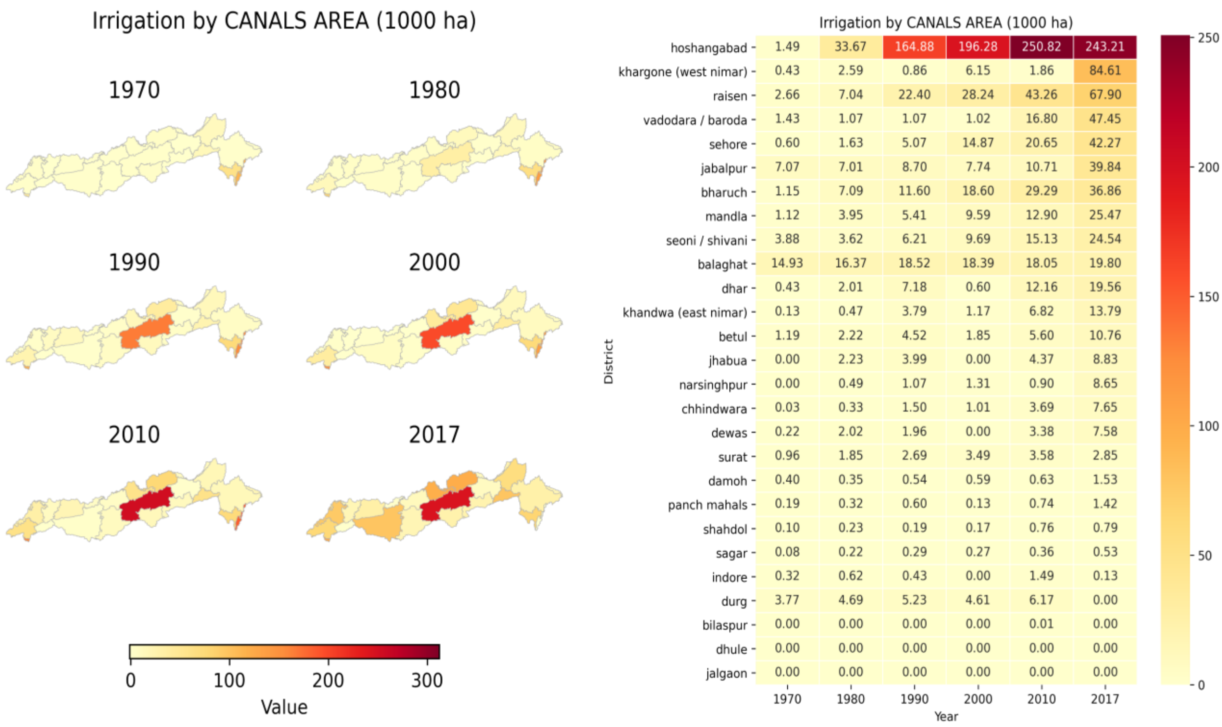


Fig. 9. Narmada River Basin: Irrigated area by Canal

4 Agricultural Land

The district-wise land use and land cover composition highlights agricultural land as the dominant land use class across much of the Narmada River Basin, though with strong inter-district variation that reflects differences in physiography, irrigation access, and ecological constraints. Fig. 10 presents detailed picture of agricultural land withing the basin boundaries based on Sentinel -10 ESRI, 2023 release.

4.1 Districts with Very High Agricultural Land Share

Several districts demonstrate a very high proportion of agricultural land, indicating intensive land conversion for cultivation and strong dependence on agriculture. Vadodara records the highest agricultural share at 86.7 percent, followed by Jhabua at 89.7 percent, West Nimar at 74.8 percent, Dhar at 76.9 percent, Bharuch at 76.5 percent, and Surat at 71.2 percent. In these districts, agriculture clearly dominates land use. This pattern is typical of lower basin and Gujarat plains districts, where flat terrain, alluvial soils, and canal irrigation systems support extensive cultivation and high cropping intensity (Fig. 10).

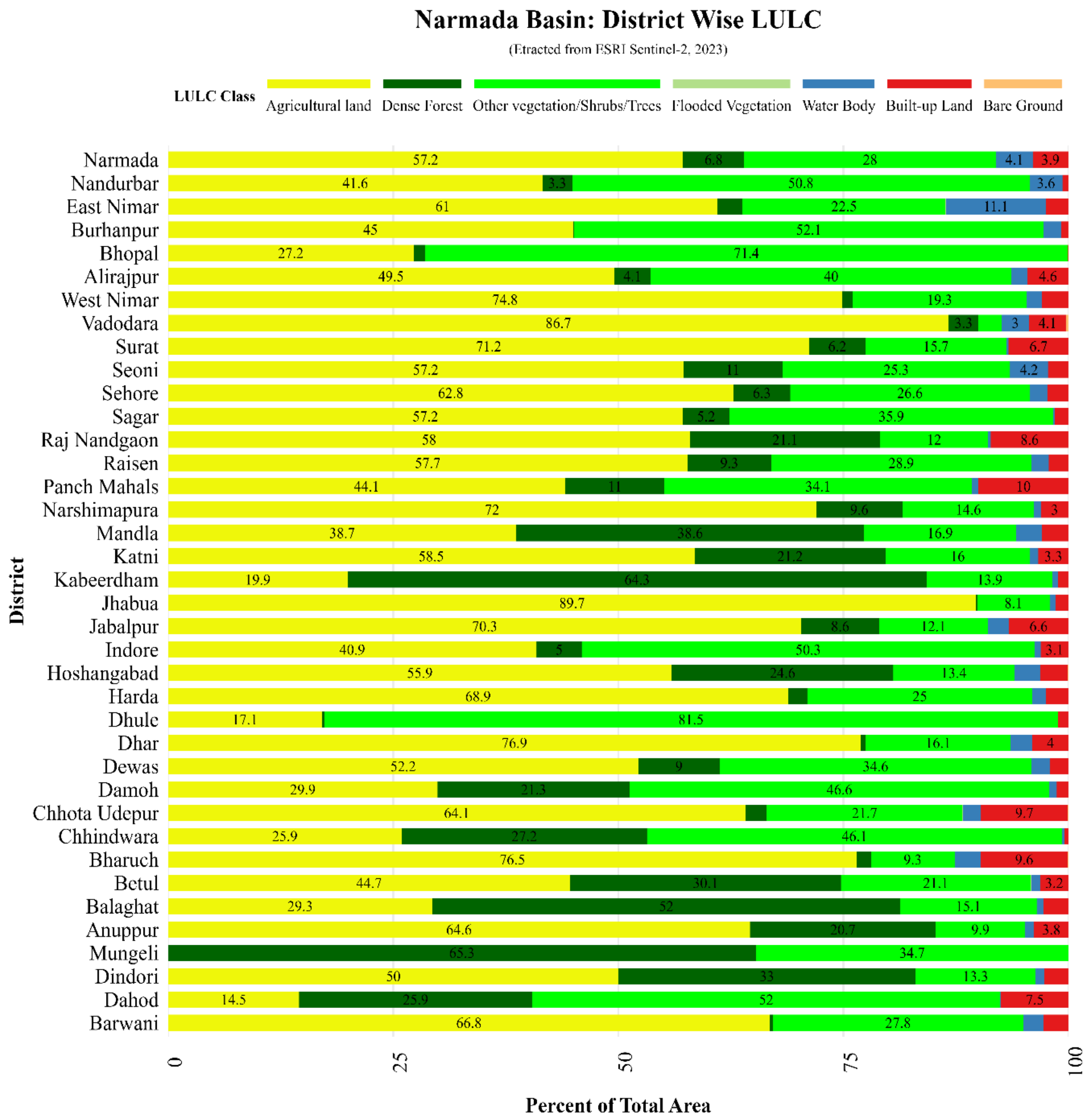


Fig. 10. Narmada Basin: District-wise LULC, (ESRI 2023)

4.2 Core Agricultural Districts of the Middle Basin

The middle basin districts form the structural backbone of agriculture in the basin, combining large spatial extent with high agricultural dominance. Districts such as Sehore (62.8 percent), Raisen (57.7 percent), Sagar (57.2 percent), Hoshangabad (55.9 percent), Dewas (52.2 percent), Jabalpur (70.3 percent), and Narsinghpur (72 percent) show agricultural land occupying more than half of their basin area. These districts are characterized by gentle slopes, deep black soils, and widespread groundwater and canal irrigation, allowing for stable and intensive agricultural systems. Their consistently high agricultural shares explain their central role in basin-level gross cropped area and foodgrain production.

4.3 Moderate Agricultural Share with Ecological Constraints

Several districts show moderate agricultural dominance, where cultivated land coexists with substantial forest or tree cover. Mandla (38.7 percent), Chhindwara (25.9 percent), Betul (44.7 percent), Balaghat (29.3 percent), and Dindori (50 percent) fall into this category. In these districts, agriculture is constrained by hilly terrain, forest cover, and protected landscapes, particularly in the Satpura and Maikala ranges. Although agriculture remains important, its expansion is structurally limited, and cropping systems tend to be rainfed with lower intensity (Fig. 10).

4.4 Districts with Low Agricultural Land Share

A small set of districts exhibits low agricultural land share, indicating that cultivation plays a secondary role within the basin portion of these districts. Kabirdham shows only 19.9 percent agricultural land, Dahod 14.5 percent, Bhopal 27.2 percent, and Dhule 17.1 percent (Fig. 10). In these cases, the basin area is dominated by dense forest, other vegetation, or urban land, or the basin occupies only a limited fraction of the district. As a result, these districts contribute minimally to the basin's overall agricultural structure, despite local dependence on farming.

4.5 Lower Basin and Tribal Belt

Districts such as Alirajpur (49.5 percent), Chhota Udepur (64.1 percent), and Nandurbar (41.6 percent) illustrate a mixed pattern. While agricultural forms a substantial share, it is interspersed with other vegetation and forest cover. These areas are characterized by tribal-dominated landscapes, fragmented landholdings, and variable irrigation access, resulting in lower cropping intensity compared to the central plains.

Thus, the uneven distribution demonstrates that the basin's gross agricultural structure is geographically concentrated rather than evenly spread, with a limited number of districts accounting for the majority of cultivated land. Consequently, changes in land use, irrigation availability, or agricultural policy in these high-share districts will have a disproportionately large impact on basin-wide agricultural outcomes.

5 Cropping Intensity

Crop intensity is a critical metric that measures how many times a single piece of land is cropped in a year. A value of 100% indicates single cropping, while values exceeding 200% signify that the agricultural structure has successfully transitioned to triple-cropping or intensive double-cropping systems (Appendix 1).

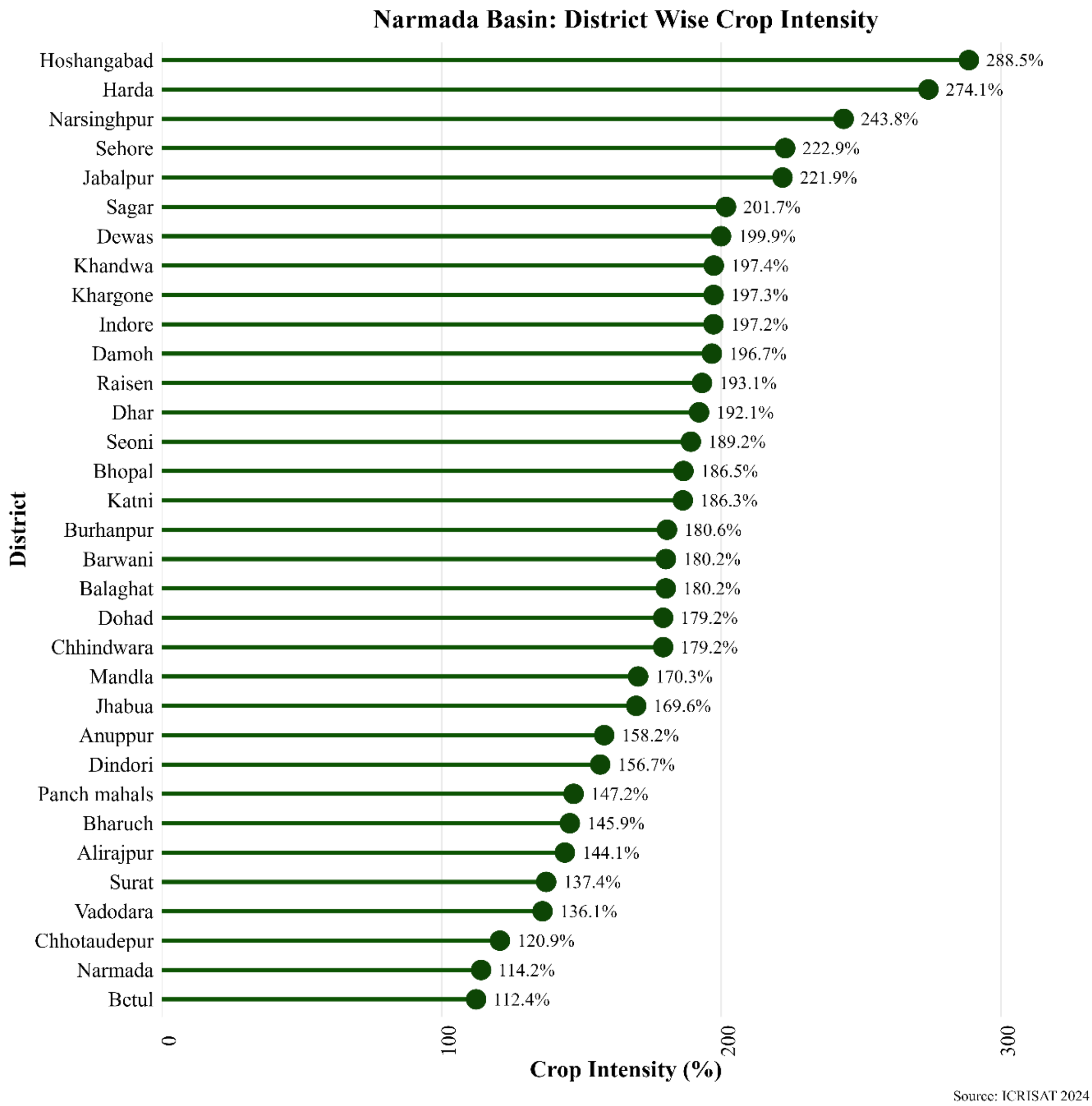


Fig. 11. Narmada Basin: District-wise Cropping Intensity

In the Narmada Basin, this intensity is largely a function of the reliable water supply provided by either extensive canal networks or high-density tubewell clusters resulting in noticeable inter-district and regional variation, ranging from below 115 percent to nearly 290 percent (Fig. 11). Which reflects differences in irrigation availability, physiography, and agricultural infrastructure. The spatial pattern reveals a strong middle-basin dominance, followed by moderate intensity in the upper basin and relatively lower intensity in parts of the lower basin.

5.1 High Cropping Intensity Regions

The highest cropping intensities are concentrated in the middle basin districts, where irrigation infrastructure is most developed and physiographic conditions are highly favourable for multiple cropping.

Hoshangabad records the highest cropping intensity at 288.5 percent, followed by Harda (274.1 percent) and Narsinghpur (243.8 percent). These values indicate nearly three crops per year in parts of these districts. Other middle basin districts such as Sehore (222.9 percent), Jabalpur (221.9 percent), Sagar (201.7 percent), and Dewas (199.9 percent) also exceed or approach 200 percent, reflecting widespread double cropping with localized triple cropping. It is important to note that most of these high cropping intensity districts also presents role of tubewells in irrigation for example in Narsinghpur, share of tubewells to the total irrigated area is 96.2 percent. The precision and year-round availability of groundwater in these districts allow farmers to squeeze nearly three crop cycles into a single year, often rotating Soybean (*Kharif*) with Wheat (*Rabi*) and a short-duration pulse or vegetable crop (*Zaid*).

This exceptionally high intensity is closely linked to:

- Extensive canal irrigation from major reservoirs and command areas
- High groundwater uses through tubewells
- Gentle slopes and deep black soils
- Dominance of irrigated rabi crops such as wheat and pulses

5.2 Moderate Intensity Regions

The eastern highlands and parts of the middle basin show moderate crop intensity, typically ranging between 150% and 190%. This group includes Khandwa (197.4 percent), Khargone (197.3 percent), Indore (197.2 percent), Damoh (196.7 percent), Raisen (193.1 percent), Dhar (192.1 percent), and Seoni (189.2 percent). These districts lie largely in the middle to lower-middle basin, where canal irrigation is supplemented by groundwater, but spatial coverage is more uneven compared to the core middle basin districts (Fig. 11). Here, cropping intensity remains high but shows greater dependence on monsoon reliability and localized irrigation access, particularly in upland and tribal pockets.

5.3 Moderate Cropping Intensity Regions

The lowest crop intensities are found in the lower basin reaches and specific hilly districts where topographic or structural constraints limit multi-seasonal farming. Districts like Surat

(137.4%), Vadodara (136.1%), and Bharuch (145.9%) show lower intensity despite having advanced canal systems. This is likely because these regions specialize in long-duration commercial crops such as Sugarcane, which occupies the field for most of the year, preventing multiple crop rotations. Chhota Udepur (120.9%), Narmada (114.2%), and Betul (112.4%) report the lowest intensities among all districts (Fig. 11). In Narmada, for instance, although canals provide 58.1% of gross irrigation, the rugged terrain often restricts the physical area that can be double cropped.

This pattern reflects:

- Strong seasonality of irrigation, particularly dependence on canal releases
- Single-crop dominance in kharif in several tribal and coastal districts
- High evapotranspiration and moisture stress outside the monsoon season

In Gujarat districts such as Bharuch, Surat, and Vadodara, high-value crops like cotton and sugarcane occupy land for longer durations, which raises gross production value but lowers cropping frequency, thereby moderating cropping intensity.

5.4 Irrigated Area by Groundwater Resource and Cropping Intensity

During data exploration and analysis, a clear pattern is evident: districts with a higher share of irrigated area served by tubewells also exhibit higher cropping intensity. The bivariate analysis map (Fig. 12) of the Narmada Basin illustrates a strong spatial correlation between the density of tubewell irrigation and the resulting cropping intensity. By examining these two variables simultaneously, the map categorizes districts into distinct agricultural profiles based on their technical inputs and land-use efficiency.

5.4.1 High-Input, High-Intensity Hubs (Dark Purple/Blue)

The districts in the central portion of the basin represent the most advanced agricultural systems, where a high percentage of tubewell irrigation directly facilitates maximum cropping intensity.

Core Performance: Districts such as Hoshangabad (indicated with a 289% intensity and 53% tubewell coverage) and Narsinghpur (244% intensity and 96% tubewell coverage) are the primary examples of this category.

Strategic Advantage: The reliability of groundwater through tubewells in these regions allows for nearly three full cropping cycles per year, supporting the high-yield wheat and soybean belt identified in earlier data.

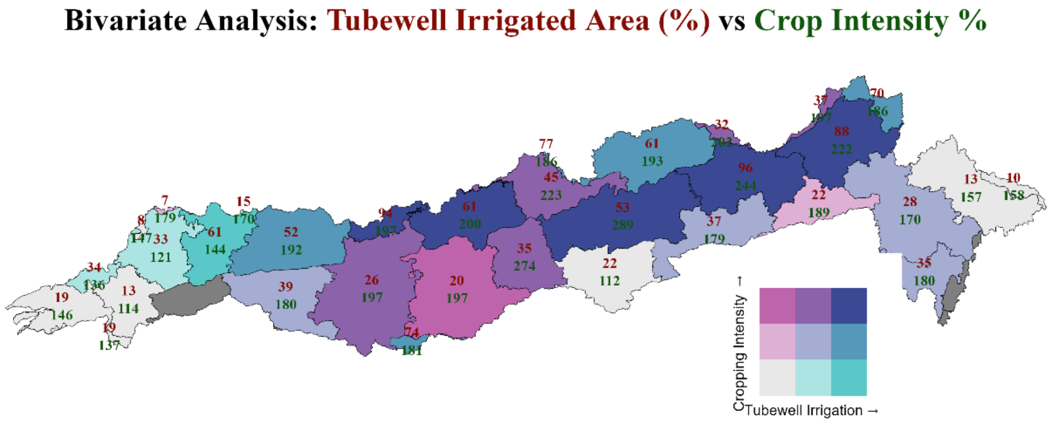


Fig. 12. Groundwater Resource vs Crop Intensity

5.4.2 High-Efficiency Zones (Light Purple)

Several districts show remarkably high cropping intensity even with moderate tubewell coverage, suggesting a highly efficient use of available water resources.

- **Intensive Rotation:** Harda stands out with a 274% cropping intensity despite having only 35% tubewell irrigation. This suggests that other sources, likely canals (which account for 50.9% of its gross irrigation), are being utilized with extreme efficiency to sustain multiple harvests.
- **Moderate Tubewell Users:** Sehore (223% intensity) and Raisen (193% intensity) also fall into this high-efficiency bracket, maintaining double and triple cropping cycles through integrated water management.

5.4.3 Surface Water Dominant or Traditional Zones (Light Blue/Cyan)

The western and coastal districts exhibit a different agricultural structure where lower cropping intensity often coincides with either a reliance on canal systems or a shift toward long-duration commercial crops.

- **The Lower Basin:** Districts in the Gujarat plains, such as Surat (137% intensity) and Bharuch (146% intensity), show lower intensity despite significant agricultural development. As previously analyzed, this is largely because these regions specialize in sugarcane (occupying field space for 10-12 months) and cotton, which reduces the frequency of land turnover.

- **Infrastructure Transition:** In these zones, tubewell irrigation is secondary to massive canal networks. For instance, Surat relies on canals for 66.6% of its gross irrigation, leading to a cyan-shaded profile on the map that prioritizes commercial stability over rotational frequency.

5.4.4 Low-Intensity/Developmental Zones (Grey/Light Grey)

The eastern highlands and specific rugged terrains in the middle basin show the lowest correlation between these variables.

- **Topographic Constraints:** Districts like Anuppur (158% intensity), Dindori (157% intensity), and Betul (112% intensity) report the lowest intensities.
- **Eastern Structure:** These regions, particularly the eastern plateau, remain dominated by single-season paddy cultivation. Despite having significant canal infrastructure in places like Anuppur (80.8% net irrigation), the lack of tubewell penetration and the hilly terrain prevent the transition to high-intensity multi-cropping.

6 Cropping Pattern and Crop Composition

The cropping pattern of the Narmada Basin represents a sophisticated adaptation to the regional "Rainfall Divide" and the specific irrigation infrastructures previously analyzed. In the eastern highlands and humid upper basin, Rice emerges as the foundational crop, particularly in districts like Balaghat (63.56%), Anuppur (60.3%), and Mandla (50.64%). These regions benefit from high annual precipitation and a reliance on canal systems, which provide the

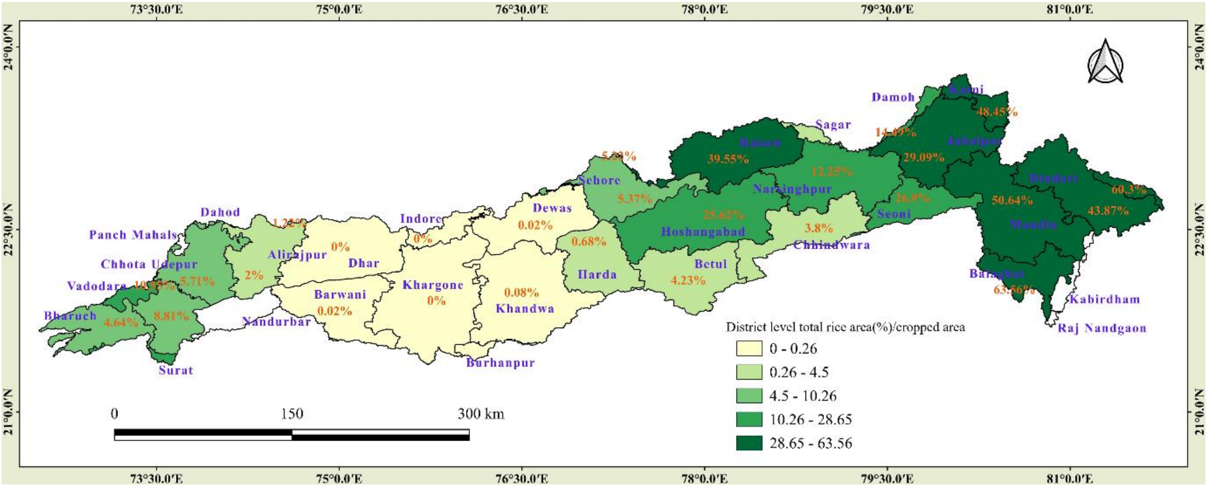


Fig. 13. Proportion of Rice Area to Gross Cropped Area [1]

consistent flooding required for paddy cultivation (Fig. 13). Moving into the central alluvial plains and the Western Plateau, the structure shifts toward a Wheat-dominant system. This is most evident in districts such as Bhopal (50.82%), Indore (46.48%), and Katni (45.49%), where the extensive use of tubewells supports intensive Rabi production (Fig. 14). The high percentage of Wheat in these areas directly correlates with the high gross irrigated area provided by groundwater, allowing these districts to function as the basin's primary grain basket.

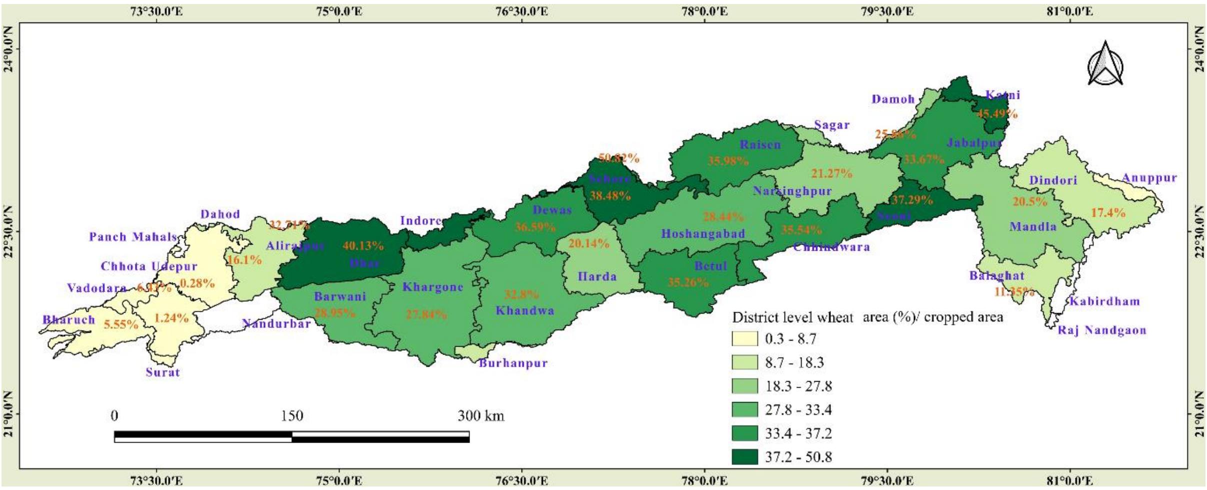


Fig. 14. Proportion of Wheat Area to Gross Cropped Area

Nutritional and economic diversification is achieved through the cultivation of pulses and coarse cereals, which are strategically distributed based on soil depth and water availability. Maize is a critical component in the hilly and undulating terrains of Chhindwara (39.7%),

[1] A value of zero percent indicates that data for the respective district were not recorded, rather than the absence of the variable.

Dahod (34.15%), and Panch Mahals (32.8%), where farmers often contend with shallower soils and a mix of tank or well irrigation (Fig. 15). In the more arid western stretches like Barwani and Khargone, the crop profile includes significant portions of Gram (16.87% in Khargone) and coarse grains, reflecting a shift toward drought-resilient varieties in response to lower rainfall and seasonal moisture deficits (Fig. 16).

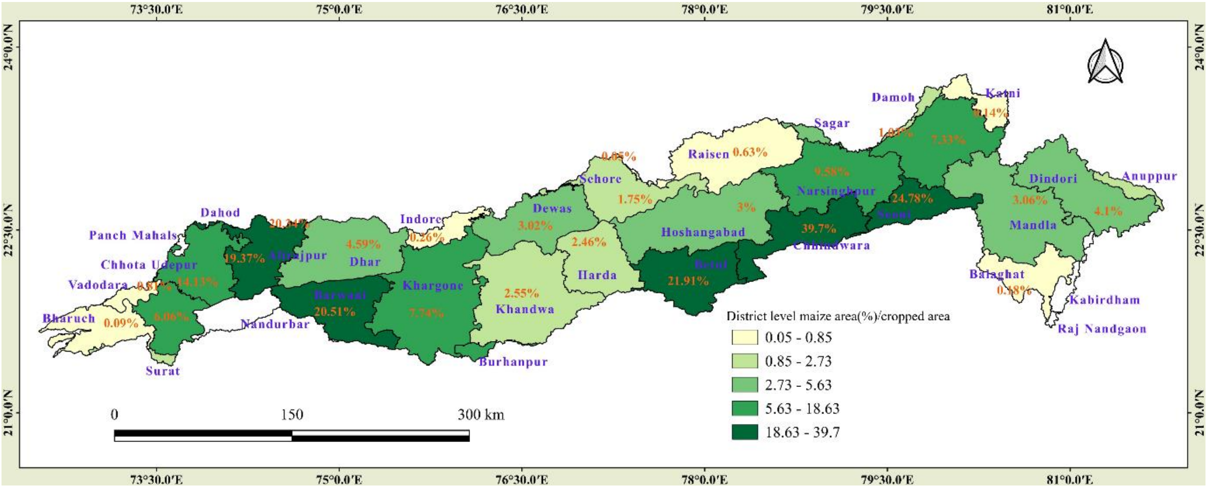


Fig. 15. Proportion of Maize Area to Gross Cropped Area

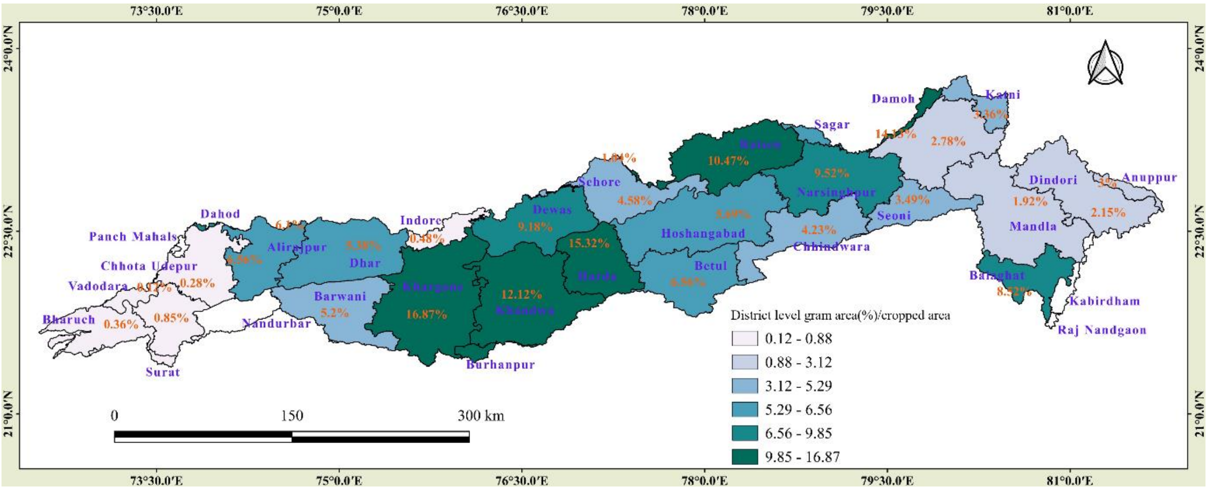


Fig. 16. Proportion of Gram Area to Gross Cropped Area

The Gujarat plains and lower basin reach show a distinct specialization in commercial and high-value pulses. Bharuch (19.1%) and Narmada (13.9%) report substantial Arhar (Pigeon Pea) cultivation, benefiting from the fertile alluvial soils and the stability provided by the canal networks of the lower Narmada projects. Furthermore, the central districts of Hoshangabad (32.36%) and Narsinghpur (30.15%) maintain high percentages of "Other Pulses," which are often integrated into crop rotations with Wheat and Soybean to preserve soil fertility in these highly mechanized zones. This spatial organization confirms that the Gross Agricultural Structure of the Narmada Basin is a highly localized phenomenon, where the choice of crop is a direct function of the district's topographic relief, its specific climatic zone, and its access to either private groundwater or public surface water resources.

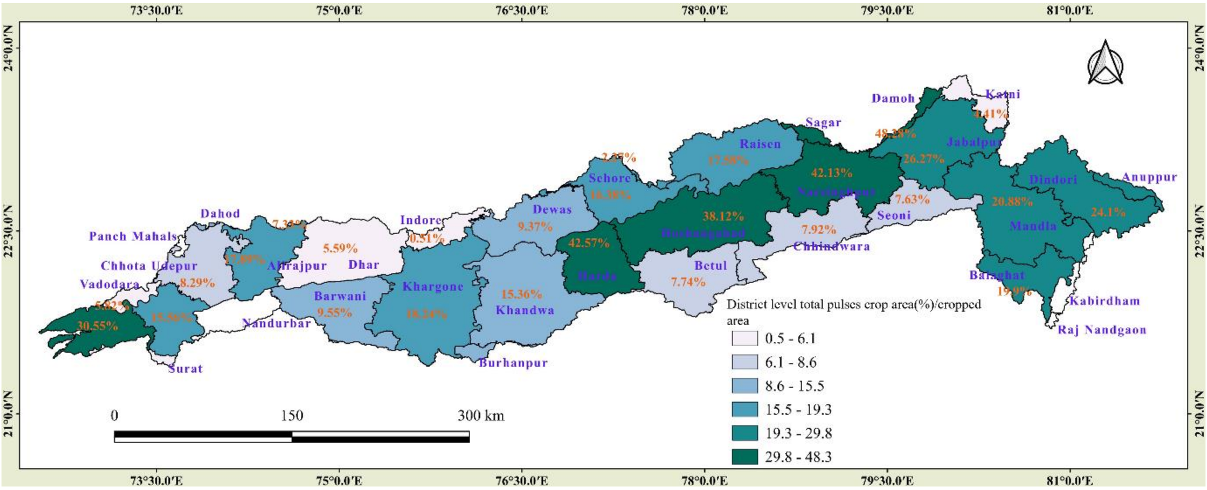


Fig. 17. Proportion of Pulses Area to Gross Cropped Area

It is important to note that Narmada Basin's gross agricultural structure is further defined by a high concentration of food crops, which account for most of the land use across nearly all districts. In the eastern highland districts such as Balaghat, Mandla, and Anuppur, total food crops exceed 93% of the gross cropped area. This extreme specialization is heavily oriented toward rice, which occupies 63.56% of the area in Balaghat and 60.3% in Anuppur. The reliance on rice in these regions is supported by the high annual rainfall and significant canal irrigation infrastructure previously noted, where canals provide over 64% of the gross irrigated area in districts like Anuppur and Dindori (Fig. 18). The integration of high-moisture crops with robust surface water delivery systems creates a stable but highly specialized agricultural framework in the upper basin.

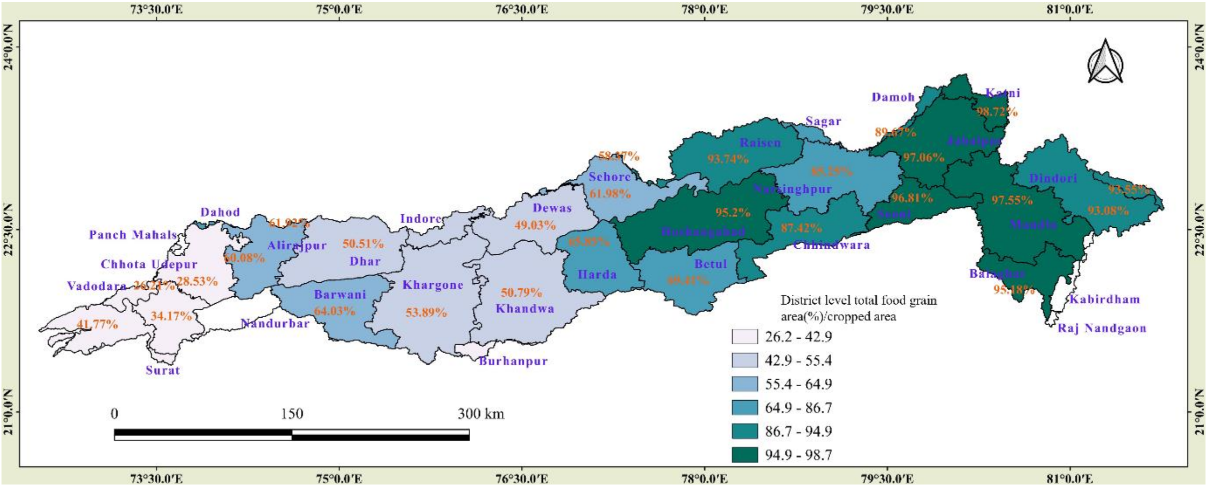


Fig. 18. Proportion of Food Crop Area to Gross Cropped Area

Fig. 18 shows that the central and western plains transition toward a wheat-centric structure that leverages private groundwater investments. In districts like Jabalpur, Hoshangabad, and Narsinghpur (Narshimapura), total food crops remain exceptionally high, often exceeding 92%. Wheat is the primary contributor here, covering 33.67% of the area in Jabalpur and 28.44% in Hoshangabad. The heavy reliance on tubewells for over 87% of gross irrigation in Jabalpur and 96% in Narsinghpur provides the precise water control necessary for such intensive food grain and pulse production.

In the lower basin and Gujarat plains, the agricultural structure becomes more diversified with the inclusion of high-value commercial and horticultural crops. While food grains remain important, districts like Surat and Bharuch allocate significant portions of their land to non-cereal crops. Bharuch, for example, has a lower total food crop share of 67.5%, allowing for a substantial 16.83% of land to be dedicated to sugarcane. Surat demonstrates the most intense diversification in the basin, with 28.37% of its area under sugarcane and nearly 20% dedicated to total vegetables (Fig. 19.) This shift toward high-value, water-intensive crops is made possible by the Gujarat region's advanced canal infrastructure, which provides 66.6% of the gross irrigated area in Surat. Additionally, the western semi-arid districts like Barwani and Khargone maintain their food security through a mix of wheat and maize, supported by a combination of tubewells and "Other Wells" that together account for over 80% of their irrigation needs.

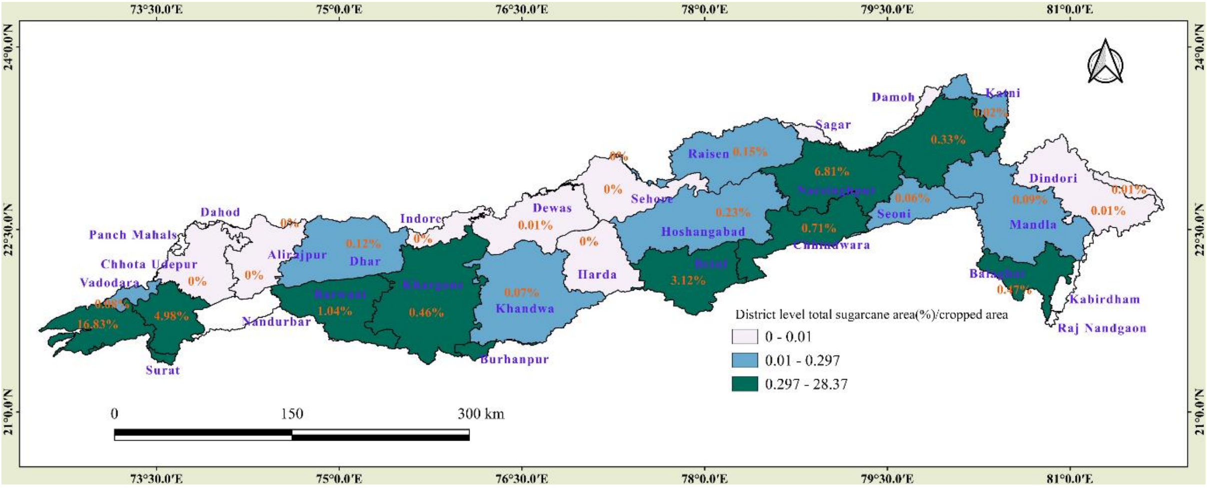


Fig. 19. Proportion of Sugarcane area to Gross Cropped Area

In terms of non-food crop (Fig. 21), Narmada Basin is dominated by fiber crops and oilseeds, which are distributed according to regional irrigation stability and soil suitability (Fig. 20). In the lower basin and Gujarat plains, Cotton emerges as the primary driver of the agricultural economy.

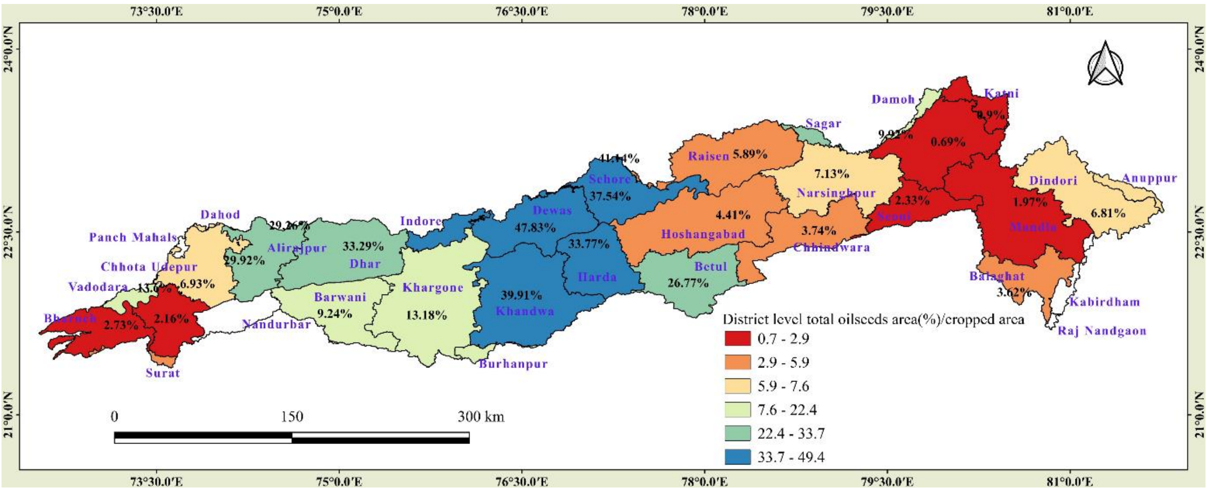


Fig. 20. Proportion of Oilseeds to Gross Cropped Area

Districts such as Chhota Udepur (43.94%), Narmada (42.76%), and Bharuch (28.73%) dedicate massive shares of their gross cropped area to cotton (Fig. 22). This specialization is supported by the fertile alluvial soils and the extensive canal networks previously identified as the primary irrigation sources in these regions. Furthermore, Tobacco cultivation is a distinct commercial feature in Vadodara, where "Drugs, Narcotics, and Plantation Crops" account for 2.61% of the area, representing one of the few zones where such industrial crops are concentrated.

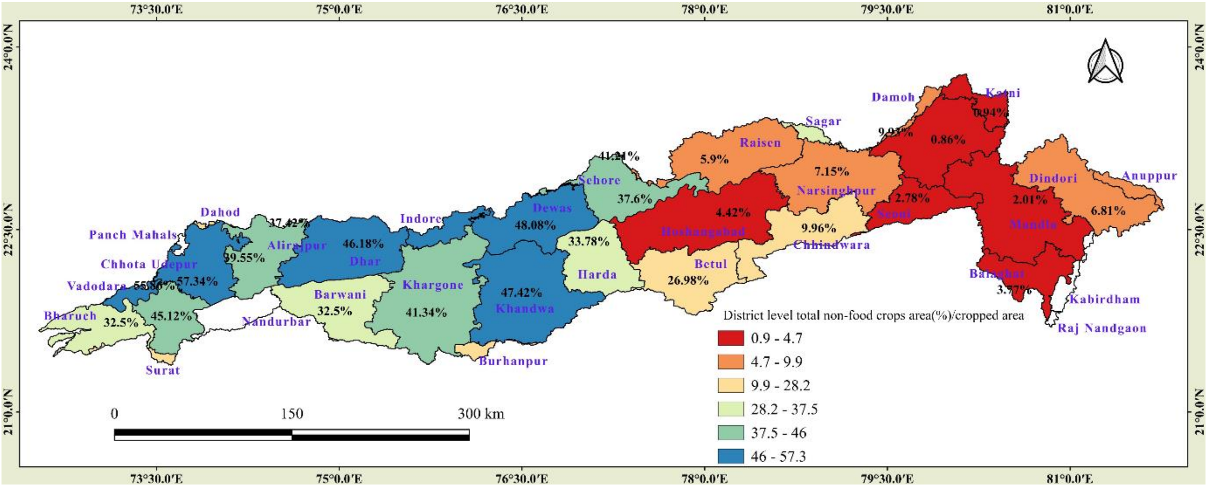


Fig. 21. Proportion of Non-food area to Gross Cropped Area

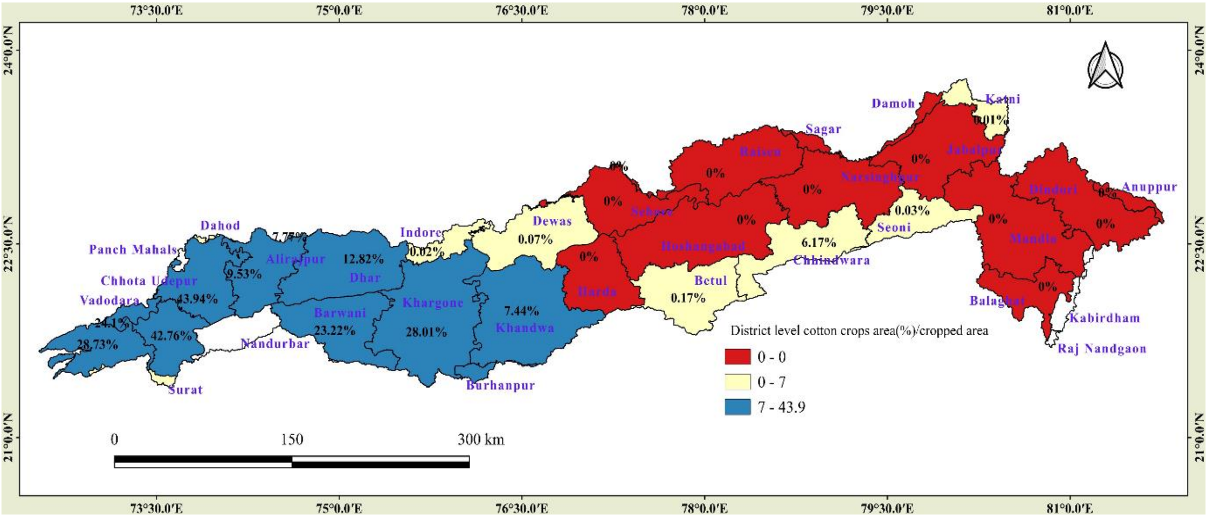


Fig. 22. Proportion of Cotton to Gross Cropped Area

6.1 Major Crops and Their Distribution

7 Crop Yield Patterns

The district-wise crop yield data (from ICRISAT, 2019) reveal pronounced spatial variations across the Narmada River Basin, reflecting the combined influence of irrigation availability, agro-climatic conditions, soil characteristics, and cropping practices. Ignoring missing values, the data highlight clear upstream to downstream contrasts as well as differences between irrigated plains and rainfed uplands.

7.1 Cereal Crops

Rice yields show (Fig. 23) wide inter-district variability. Very high yields are observed in Sehore (4379 kg per hectare), Katni (3007 kg per hectare), and Hoshangabad (2911 kg per hectare), indicating the presence of assured irrigation and favourable soil moisture conditions. In contrast, extremely low rice productivity in Barwani (129 kg per hectare) and Khandwa (422 kg per hectare) reflects arid conditions, limited surface water access, and a marginal role of rice in local cropping systems.

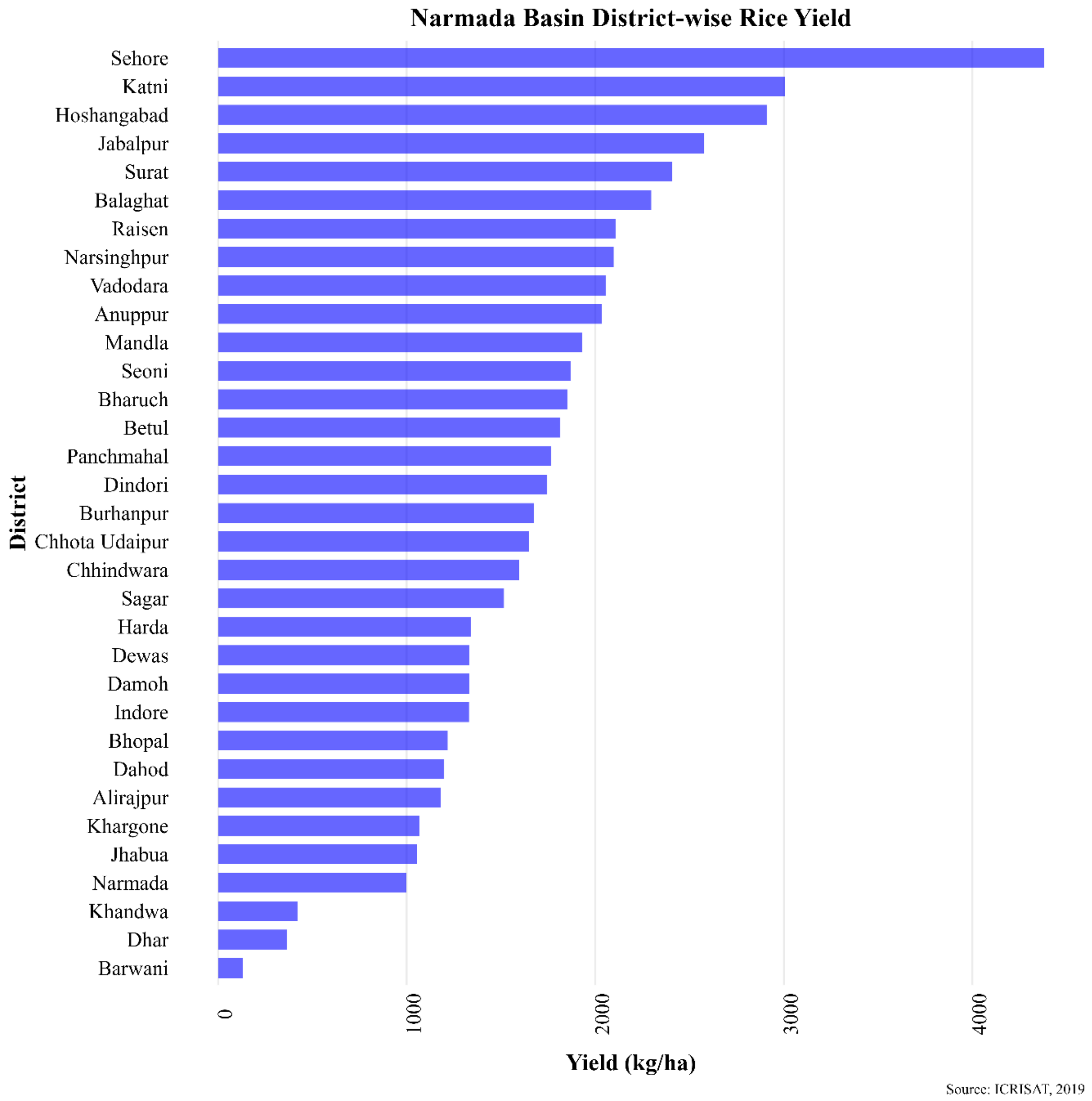


Fig. 23. Narmada Basin: District-wise Rice Yield

Wheat yields are consistently high in the central and middle basin districts. Chhindwara (5454 kg per hectare), Indore (5149 kg per hectare), Narsinghpur (4864 kg per hectare), and Hoshangabad (4720 kg per hectare) represent the wheat productivity core of the basin. These districts benefit from canal and tubewell irrigation, level terrain, and fertile black soils. Lower yields in eastern upland districts such as Dindori (1581 kg per hectare) and Anuppur (1617 kg per hectare) indicate rainfed constraints and shorter rabi growing seasons (Fig. 24).

Maize yields are particularly high in Burhanpur (5320 kg per hectare) and Barwani (4466 kg per hectare), suggesting localized irrigation support and commercial maize cultivation. Elevated yields in Chhindwara (3803 kg per hectare) and Seoni (3737 kg per hectare) further reflect favourable rainfall and soil conditions in the upper and middle basin. Lower maize productivity in districts such as Harda (951 kg per hectare) indicates crop stress and limited adoption of improved varieties (Table 3, Fig. 25. Narmada Basin: District-wise Maize Yield).

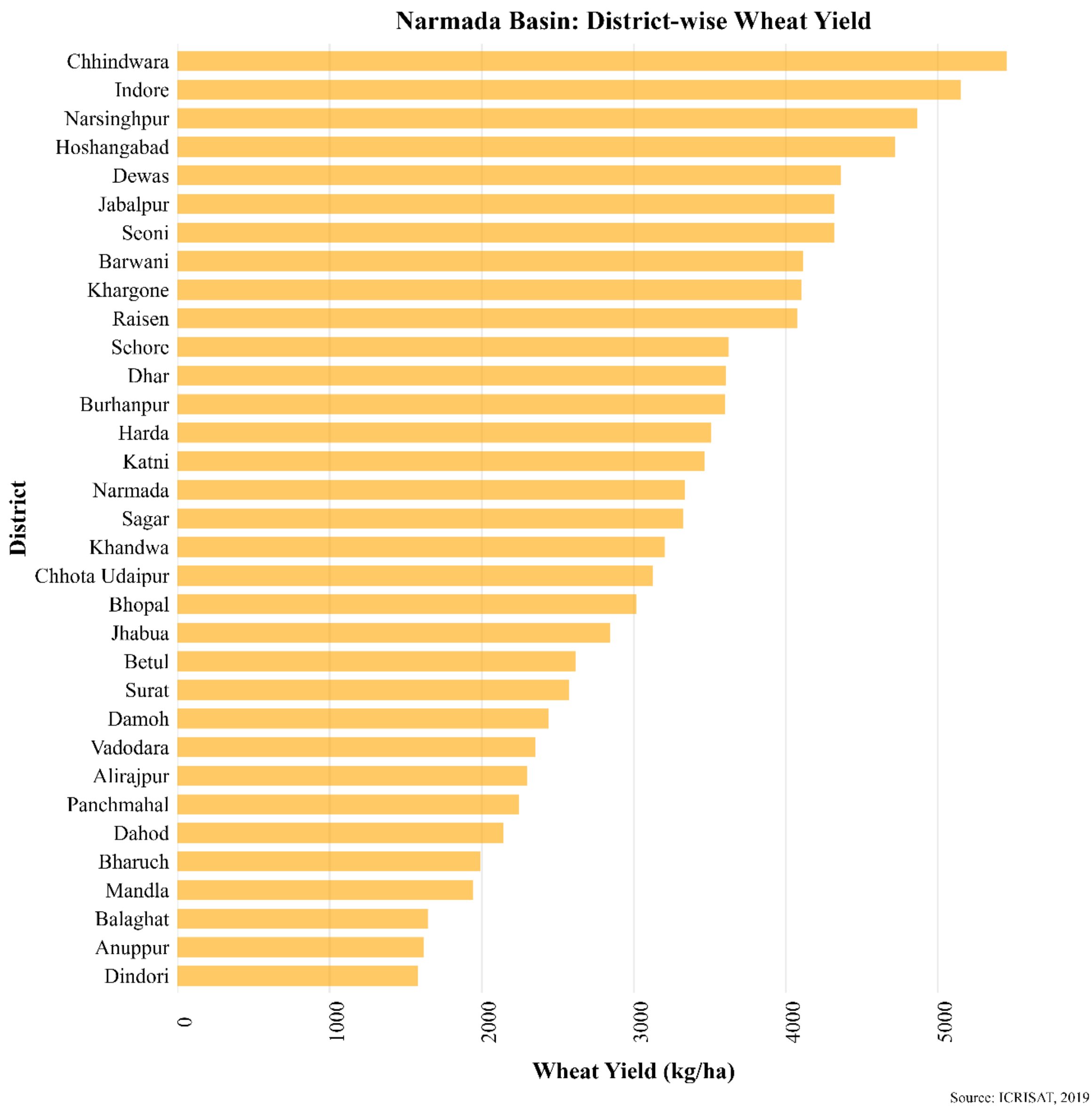


Fig. 24. Narmada Basin: District-wise Wheat Yield

7.2 Coarse Cereals and Millets

Sorghum and pearl millet display higher yields in districts with mixed rainfall and supplemental irrigation. Sorghum yields peak in Burhanpur (2377 kg per hectare) and Sehore (2328 kg per hectare), while pearl millet yields are highest in Chhota Udaipur (2857 kg per hectare), Dahod (2872 kg per hectare), and Indore (2714 kg per hectare). These patterns indicate adaptation of coarse cereals to both semi-arid conditions and tribal-dominated upland regions (Table 3).

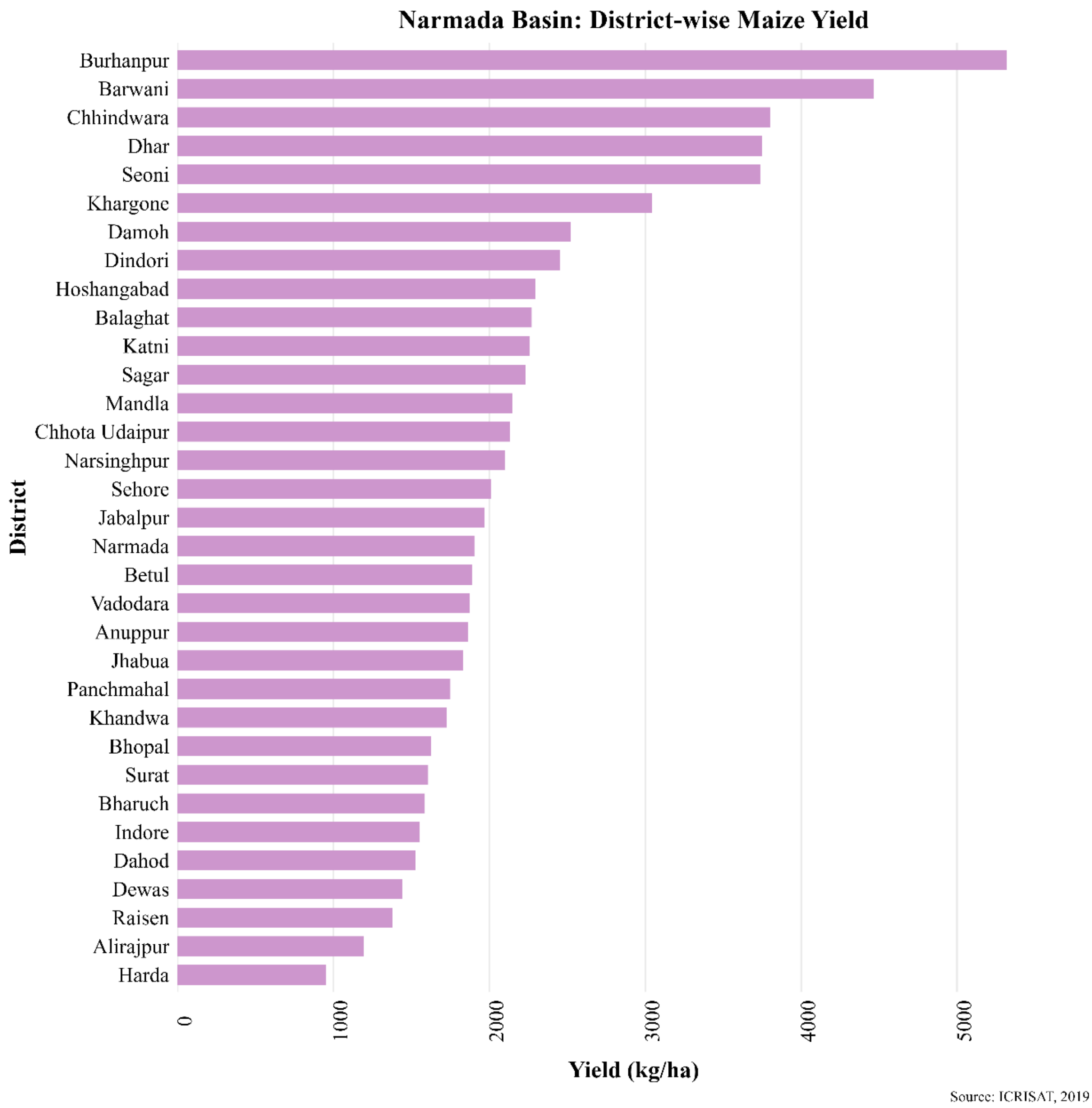


Fig. 25. Narmada Basin: District-wise Maize Yield

7.3 Pulses and Oilseeds

Chickpea yields (Fig. 26) are strongest in Chhindwara (2743 kg per hectare), Katni (2216 kg per hectare), and Harda (2234 kg per hectare), pointing to the importance of rabi pulse cultivation under irrigated or well-managed moisture regimes. Lower yields in upland districts such as Dindori (916 kg per hectare) highlight soil and moisture limitations. Groundnut productivity is notably high in the western and lower basin districts. Surat (2690 kg per hectare), Vadodara (2667 kg per hectare), Bharuch (2667 kg per hectare), and Narmada district (2729 kg per hectare) show strong performance, supported by alluvial soils and canal irrigation. These districts form the oilseed-intensive belt of the basin.

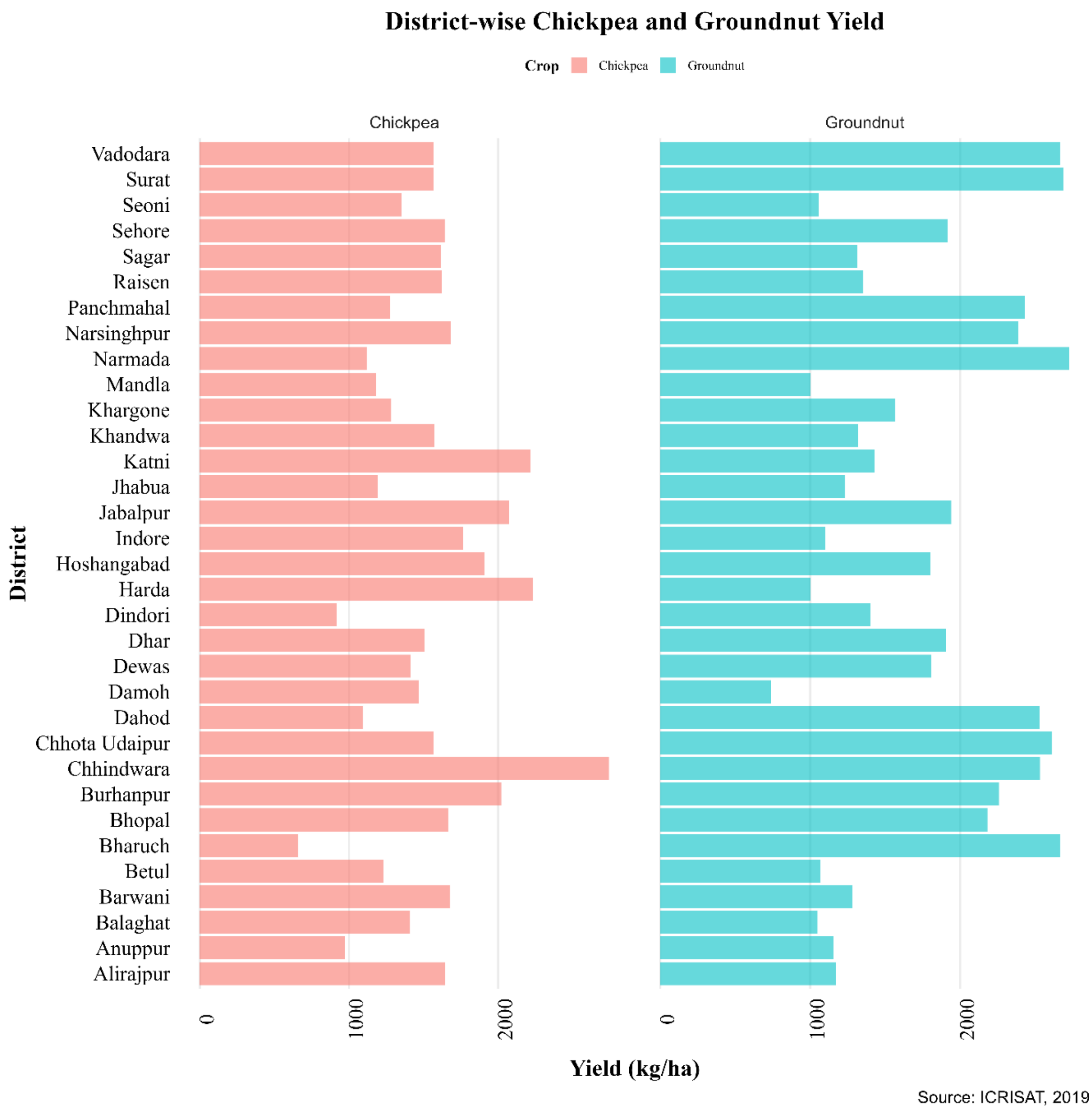


Fig. 26. Narmada Basin: District-wise Chickpea and Groundnut Yield

Rapeseed and mustard yields are relatively high in Khandwa (3400 kg per hectare) and Chhindwara (2042 kg per hectare), reflecting their integration into irrigated rabi systems. Lower yields in eastern districts indicate climatic and management constraints. Fig. 27 shows that soybean yields, though moderate across most districts, are relatively higher in Chhota Udaipur (1752 kg per hectare), Vadodara (1375 kg per hectare), and Surat (1388 kg per hectare). Lower yields in several districts suggest rainfed dependence and sensitivity to monsoon variability.

Table 3. District-wise Yield of Different Crops

	Yield (kg/ha.)											
District	**Rice**	**Wheat**	**Sorghum**	**Pearl Millet**	**Maize**	**Barley**	**Chickpea**	**Groundnut**	**Rapeseed and Mustard**	**Soyabean**	**Sugarcane**	**Cotton**
Jabalpur	2578	4320	1913	1727	1969	NA	2072	1941	1406	920	30924	180
Balaghat	2297	1648	NA	NA	2271	2000	1409	1048	1306	1000	53301	NA
Chhindwara	1596	5454	1526	1143	3803	NA	2743	2533	2042	1212	84578	433
Narsinghpur	2097	4864	1728	1500	2101	NA	1684	2389	1675	705	66265	169
Seoni	1871	4319	1333	1000	3737	NA	1350	1055	1131	762	39522	132
Mandla	1932	1945	1143	NA	2149	1667	1183	1000	1168	604	35298	NA
Sagar	1516	3327	1877	1267	2233	2411	1618	1313	1255	560	42941	150
Damoh	1333	2441	667	2000	2524	1529	1468	738	1098	667	28529	NA
Indore	1330	5149	1824	2714	1551	2000	1766	1099	1333	1497	25000	97
Dewas	1333	4363	1518	NA	1441	NA	1414	1809	2022	662	40962	160
Dhar	367	3604	1493	1504	3747	2000	1507	1905	1458	980	30844	320
Jhabua	1055	2845	808	600	1831	2267	1193	1232	967	758	27500	164
Khargone	1068	4104	1339	528	3045	NA	1283	1566	1246	512	42938	154
Khandwa	422	3204	893	526	1727	NA	1571	1318	3400	421	31871	140
Sehore	4379	3625	2328	2250	2009	2500	1642	1918	1444	499	53733	NA
Raisen	2108	4073	2134	1538	1379	4000	1622	1352	1129	449	15685	36
Betul	1814	2618	1127	2100	1890	NA	1230	1066	1039	393	56313	101
Hoshangabad	2911	4720	1408	1000	2294	2750	1909	1800	1577	663	52599.28	NA

Bharuch	1852	1992	1093	2786	1586	NA	660	2667	NA	1396	70000	481
Vadodara	2057	2352	1213	2393	1873	NA	1569	2667	1889	1375	63898	827
Panchmahal	1765	2247	1526	1971	1750	NA	1273	2431	1931	1318	NA	584
Surat	2407	2576	1197	1700	1607	NA	1568	2690	1926	1388	73500	703
Bhopal	1217	3018	1474	2143	1625	2500	1664	2182	1435	693	27619	NA
Dahod	1196	2141	NA	2872	1525	NA	1095	2532	1917	990	NA	428
Narmada	999	3336	1379	2241	1903	NA	1118	2729	NA	1438	70000	598
Dindori	1743	1581	1000	1000	2453	1000	916	1400	860	647	24000	NA
Harda	1341	3509	1143	500	951	3000	2234	1000	1339	546	28823.53	125
Barwani	129	4112	1685	1034	4466	3214	1675	1283	NA	978	47494	294
Katni	3007	3466	1417	500	2260	2535	2216	1429	1367	1000	34615	191
Anuppur	2035	1617	983	2000	1864	1150	971	1155	414	723	25556	NA
Burhanpur	1673	3599	2377	824	5320	NA	2021	2259	NA	945	68445	323
Alirajpur	1180	2301	775	1020	1196	NA	1645	1172	714	464	NA	227
Chhota Udaipur	1650	3126	1163	2857	2132	NA	1568	2612	NA	1752	NA	809

Source: ICRISAT, 2019

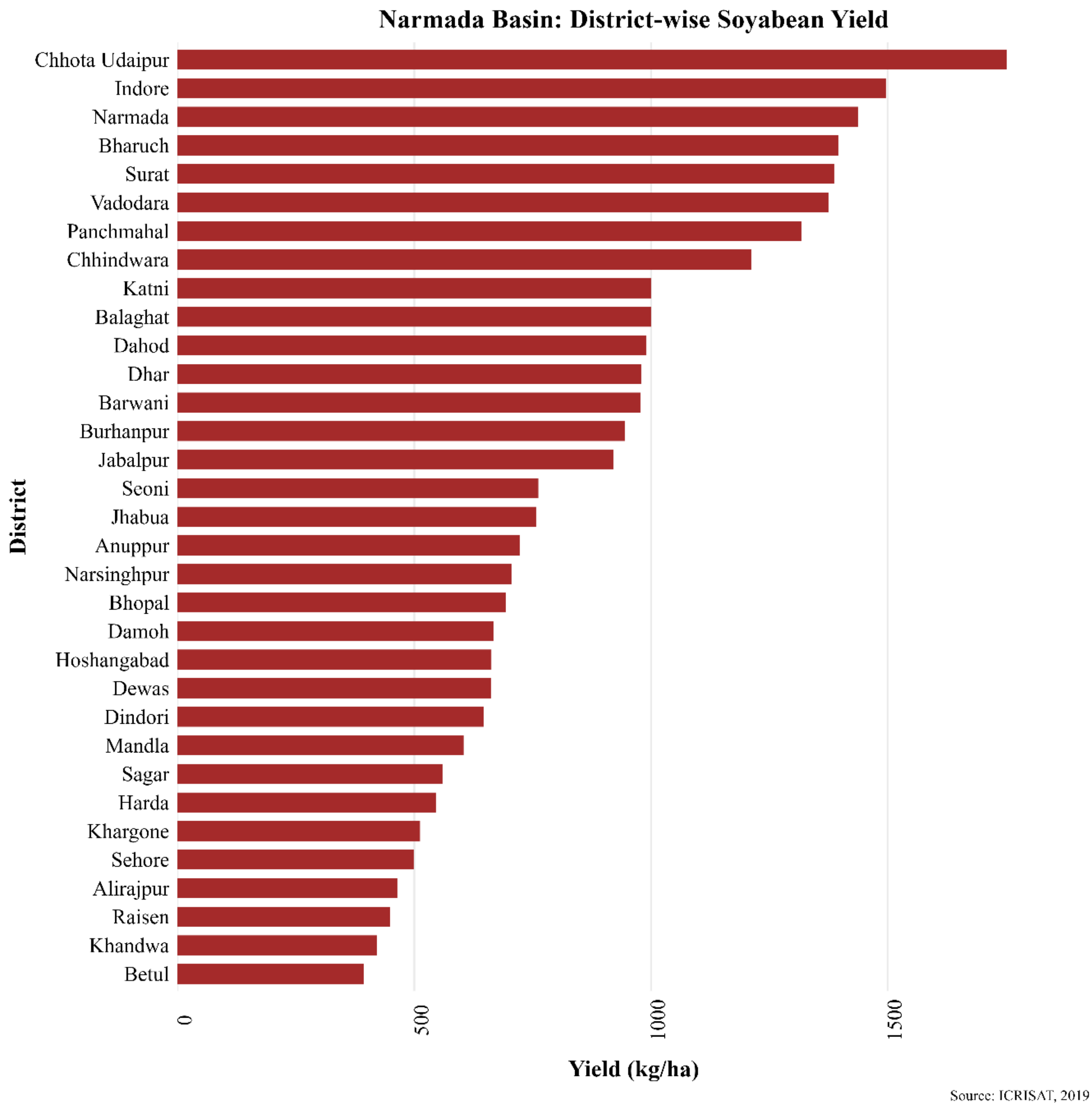


Fig. 27. Narmada Basin: District-wise Soyabean Yield

7.4 Commercial Crops

Sugarcane presents the strongest spatial concentration of high yields, with exceptionally high productivity in Chhindwara (84578 kg per hectare), Surat (73500 kg per hectare), Bharuch and Narmada (70000 kg per hectare), and Burhanpur (68445 kg per hectare). These districts benefit from assured canal irrigation, long growing periods, and proximity to sugar mills. Lower sugarcane yields in districts such as Indore (25000 kg per hectare) reflect either limited cultivation or suboptimal water availability. Cotton yields are highest in Vadodara (827 kg per hectare), Chhota Udaipur (809 kg per hectare), Surat (703 kg per hectare), and Narmada district (598 kg per hectare) (Table 3). These districts fall within the irrigated cotton belt of the lower basin, supported by warm temperatures and controlled irrigation. Lower cotton yields in central districts indicate secondary crop status or partial rainfed conditions.

Thus, the yield structure of the Narmada River Basin shows a clear alignment between high crop productivity and irrigation access, particularly in the middle and lower basin plains. Wheat, sugarcane, cotton, and groundnut achieve high yields in districts with canal command areas and developed groundwater use. In contrast, upland and forested districts remain dominated by rainfed crops with lower yield levels and greater inter-annual variability.

These patterns underline the strong role of irrigation structure, physiography, and agro-climatic zoning in shaping crop performance across the basin and provide a quantitative basis for understanding regional disparities in agricultural productivity.

7.5 Trend of Yield of Major Crops

The agricultural structure of the Narmada River Basin has undergone a significant transformation between 1970 and 2017 (ICRISAT, 2019), characterized by a transition toward high-intensity grain production in the central plains. Table 4 shows that wheat serves as the primary driver of this growth, with the basin heartland showing explosive productivity gains. Across the top five districts, Hoshangabad witnessed a staggering growth rate of 698%, followed by Dewas (319%), Khandwa (253%), Narsinghpur (244%), and Khargone (225%). In contrast, the lower-performing districts in the basin and surrounding areas, which likely face topographical or soil constraints, showed much slower progress; these include Sagar (404%), Shahdol (334%), Surat (120%), Panchmahal (99%), and Durg (76%). While these bottom districts have high percentage growth because they started from nearly negligible bases, their absolute yields remain far below the basin’s high performing "wheat belt".

Rice cultivation trends in the Narmada Basin reveal a more localized but intense specialization, particularly in the upper reaches of the basin. Narsinghpur and Mandla have emerged as the leading hubs, with Narsinghpur showing a 339% growth rate and Mandla following with a massive 403% increase since 1970. Other top performers include Raisen (323%), Jabalpur (285%), and Hoshangabad (135%), the latter showing slower growth due to its already high starting yield. On the lower end of the productivity spectrum, districts like Shahdol (193%), Surat (104%), Sagar (61%), Durg (41%), and Panchmahal (22%) have struggled to modernize rice production at the same pace, reflecting the geographical diversity of the basin's agricultural output.

Table 4. Narmada Basin: Trend of Wheat Yield

WHEAT YIELD (Kg per ha)

District	1970	1980	1990	2000	2010	2017
hoshangabad	522.3	991.7	1569.5	2287.9	3661.2	4169.7
narsinghpur	987.9	1280.2	2111.9	3187.2	3214.1	3397.3
khargone / west nimar	992.9	1243.9	1988.8	1609.7	2386.5	3226.9
khandwa / east nimar	700.5	776.7	1210.2	914.4	1282.9	2474.6
dewas	548.2	565.2	1086.6	887.4	1011.1	2299.8
mandla	729.5	693.0	643.9	335.4	621.6	2176.6
dhar	553.5	649.0	1275.9	737.6	1429.8	2119.3
jabalpur	390.1	457.6	589.8	741.6	1218.9	2014.7
raisen	384.4	555.2	806.6	721.2	846.8	1817.6
vadodara / baroda	590.0	1077.0	1092.1	1117.2	1421.3	1363.5
jhabua	429.3	742.3	990.8	371.1	863.2	1289.5
sehore	248.7	282.8	566.3	669.6	576.6	1187.8
indore	306.1	354.3	697.3	467.1	680.7	1140.6
chhindwara	190.0	134.2	507.7	454.5	1022.0	1029.3
betul	276.1	411.9	420.2	486.3	453.3	1020.4
bharuch	556.7	343.8	407.5	792.9	1080.7	940.2
seoni / shivani	97.3	109.0	169.1	154.4	231.6	661.2
balaghat	116.1	202.2	236.1	173.3	375.5	615.5
dhule	121.9	124.1	126.0	119.9	280.0	262.0
damoh	35.2	43.7	61.9	63.1	145.3	213.0
sagar	25.1	26.6	39.2	30.5	42.6	126.5
shahdol	22.9	22.0	28.7	25.7	27.8	99.3
surat	26.4	73.5	35.4	59.9	71.6	58.0
panchmahal	28.0	35.1	45.4	45.0	48.6	55.8
durg	21.9	25.4	22.9	19.6	33.2	38.5
jalgaon	0.1	0.1	0.1	0.1	0.2	0.2
bilaspur	0.0	0.0	0.0	0.0	0.0	0.0

Maize trends indicate a shift toward commercialization in the western basin districts, where yields have consistently improved to support industrial and fodder needs. The top five districts for Maize productivity in 2017 were Khargone (321% growth), Dhar (230%), Shahdol (145%), Hoshangabad (132%), and Khandwa (104%). While Mandla remains a top five producer in terms of total yield, its growth rate has been relatively stagnant at 49%. Interestingly, Maize productivity has actually declined or plateaued in several districts outside the primary basin area: the lower five districts include Panchmahal (-2.8% decline), Sagar (-32% decline), Surat (72%), Durg (48%), and Seoni (326% from a low base). This divergence suggests that Maize is becoming a more specialized crop within specific climatic pockets of the Narmada region.

Table 5. Narmada Basin: Trend of Rice Yield

RICE YIELD (Kg per ha)

District	1970	1980	1990	2000	2010	2017
narsinghpur	1029.9	1034.4	1085.7	821.2	1520.3	4518.9
mandla	547.5	736.8	675.8	309.9	708.1	2753.9
hoshangabad	964.1	779.2	1197.0	1114.2	2291.5	2270.1
jabalpur	380.1	292.1	482.0	256.0	599.2	1462.2
raisen	277.2	334.6	443.6	309.2	702.6	1172.5
khargone / west nimar	393.4	379.6	566.3	223.1	662.4	949.5
dhar	335.5	319.5	438.1	167.9	456.4	877.7
vadodara / baroda	515.9	319.6	498.0	101.1	629.3	813.9
sehore	191.3	210.0	288.5	192.0	386.7	700.0
betul	387.8	199.7	404.4	232.4	533.3	673.9
bharuch	602.9	198.1	382.5	260.6	669.5	630.5
indore	154.7	135.4	270.7	0.0	0.0	613.7
seoni / shivani	308.1	283.3	360.7	100.1	335.2	608.9
jhabua	206.9	185.9	284.1	62.6	317.0	570.8
balaghat	265.9	347.6	311.3	210.2	352.6	444.7
dewas	300.5	260.4	356.9	280.5	560.9	409.5
khandwa / east nimar	704.5	425.6	627.0	393.1	905.7	382.0
chhindwara	204.3	145.4	299.4	133.5	496.6	372.1
dhule	65.9	91.1	115.0	32.1	137.2	163.3
damoh	42.0	33.1	49.1	25.9	62.9	101.4
shahdol	21.5	31.8	30.2	24.9	37.3	63.1
surat	28.7	28.2	43.9	38.7	50.0	58.5
sagar	27.6	24.4	32.3	21.3	29.5	44.3
durg	27.6	27.1	39.4	20.8	56.6	39.0
panchmahal	22.2	14.7	18.3	1.6	21.0	27.1
bilaspur	0.0	0.0	0.0	0.0	0.0	0.0
jalgaon	0.1	0.2	0.1	0.1	0.0	0.0

Year

Oilseed production was a major pillar of the basin's agricultural structure through the late 20th century, though the sources indicate a potential shift or reporting gap in 2017 where yields are recorded as 0.0 across all districts. Calculating growth up to the last active reporting period in 2010, the top five districts for oilseed productivity were Narsinghpur (900% growth), Hoshangabad (742%), Betul (203%), Dhar (126%), and Dewas (74%). These districts transformed the basin into a critical region for oilseed processing. The lower five districts during this period included Chhindwara (417%), Sagar (248%), Shahdol (148%), Durg (414%), and Surat (starting from 0.0). The high growth percentages in the bottom tier again reflect a transition from subsistence farming to managed oilseed cultivation, albeit at much lower total output levels than the basin's core.

Table 6. Narmada Basin: Trend of Maize Yield

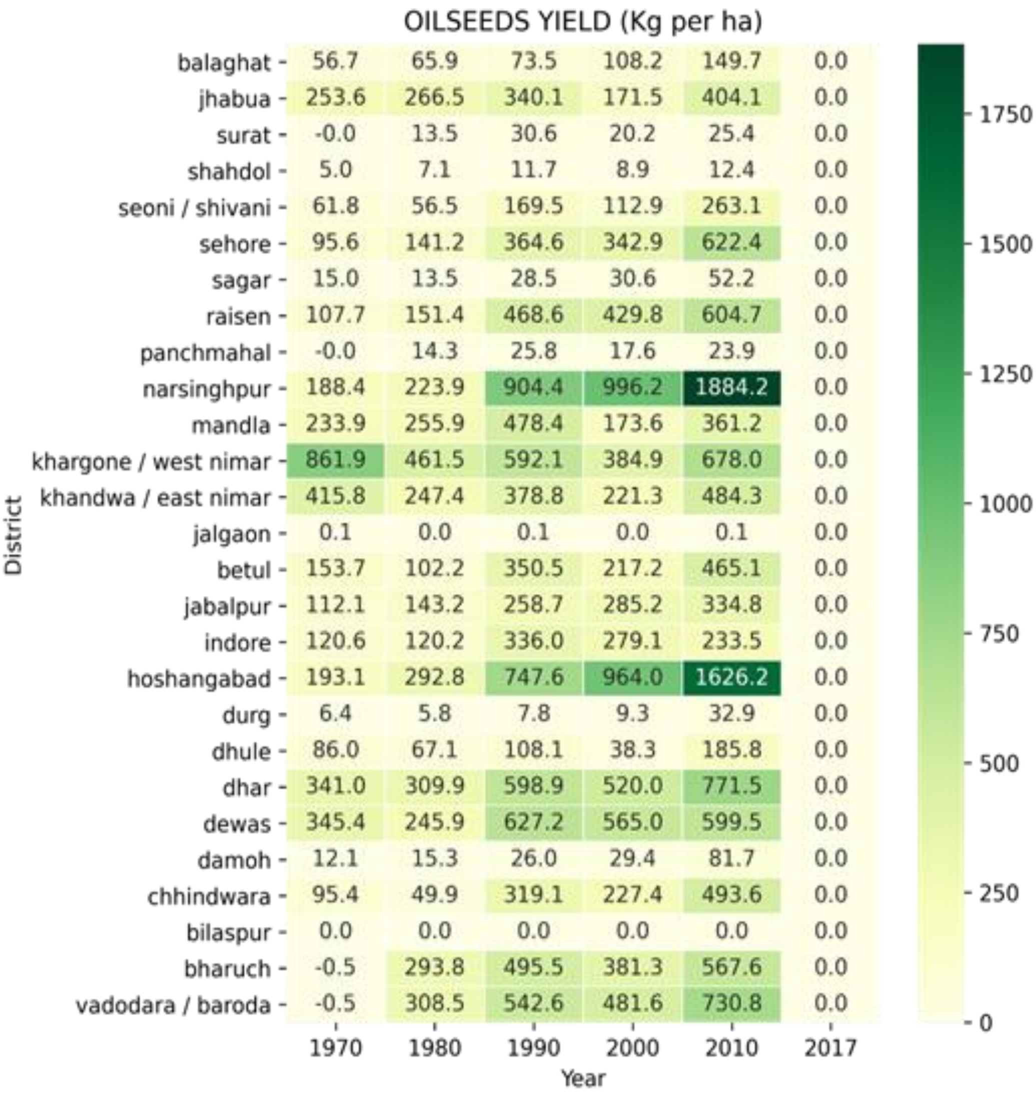
MAIZE YIELD (Kg per ha)

District	1970	1980	1990	2000	2010	2017
khargone / west nimar	793.2	594.0	1408.8	1017.3	1135.0	3338.6
hoshangabad	1379.5	1688.6	1209.2	1986.5	1631.8	3200.5
khandwa / east nimar	1077.9	732.3	872.4	1069.0	1386.5	2204.0
mandla	1386.8	813.1	1375.2	1643.7	1060.8	2060.0
dhar	602.0	651.4	841.0	658.3	869.7	1989.6
narsinghpur	1461.9	1218.2	1218.2	2144.1	1461.9	1723.0
dewas	569.8	398.9	534.2	848.1	809.6	1688.2
betul	372.3	218.7	426.1	1145.2	599.1	1523.7
chhindwara	262.7	131.1	921.2	680.8	889.6	1514.7
jabalpur	734.3	430.8	571.0	952.7	685.4	1486.8
jhabua	264.1	331.5	685.6	363.8	526.6	1305.6
vadodara / baroda	817.4	544.8	699.8	486.4	1029.4	1183.3
seoni / shivani	276.0	228.0	250.4	224.6	321.5	1175.4
raisen	585.3	942.6	670.0	1131.1	831.7	920.7
sehore	354.4	305.7	386.3	500.1	629.2	882.8
bharuch	745.6	503.3	672.6	361.1	854.1	770.8
balaghat	276.4	266.2	258.1	382.2	380.0	724.3
indore	270.7	172.3	280.8	446.3	344.3	615.8
dhule	102.4	235.9	206.9	79.9	376.5	385.0
damoh	86.5	57.8	76.1	107.9	118.4	116.7
shahdol	32.4	25.3	36.8	53.0	33.2	79.4
durg	44.0	31.1	31.7	26.4	48.6	65.3
surat	30.1	23.7	32.3	17.6	40.1	51.7
sagar	60.9	40.3	42.9	68.4	48.6	41.3
panchmahal	40.0	37.3	30.3	14.0	37.5	38.9
jalgaon	0.1	0.1	0.1	0.1	0.3	0.3
bilaspur	0.0	0.0	0.0	0.0	0.0	0.0

Year

To understand this agricultural evolution, imagine the Narmada River Basin as a multi-speed engine: while the central "cylinders" like Hoshangabad and Narsinghpur are firing at maximum capacity to produce wheat and rice, the peripheral districts are still shifting gears, slowly moving away from traditional methods toward more modern, high-yield agricultural structures.

Table 7. Narmada Basin: Trend of Oilseeds Yield



8 Input Use Structure

The analysis of fertilizer consumption in the Narmada River Basin between 1970 and 2017 reveals a pattern of massive agricultural intensification. The data indicates that the basin's productivity growth, particularly the record-breaking wheat and rice yields discussed previously, has been fueled by a multi-fold increase in chemical inputs, with Nitrogen serving as the primary driver of this trend.

8.1 Nitrogen Consumption Trends

Nitrogen (N) is the most heavily consumed fertilizer in the basin, showing an explosive upward trajectory. Hoshangabad stands as the clear leader in the region, with its consumption skyrocketing from a mere 557.23 tons in 1970 to 87,117.01 tons in 2017. This correlates directly with the district's status as a high-productivity wheat hub. Khargone (West Nimar) follows a similar pattern, reaching 74,408.48 tons by 2017. The spatial pattern shown in the heatmaps indicates that the central and western districts of the basin have become "nitrogen-dense," while eastern or peripheral districts like Sagar (803.02 tons) and Mandla (9,628.74 tons) maintain significantly lower consumption levels. A major "leap" in nitrogen use occurred between 2000 and 2010, where consumption in many districts more than doubled (Fig. 28).

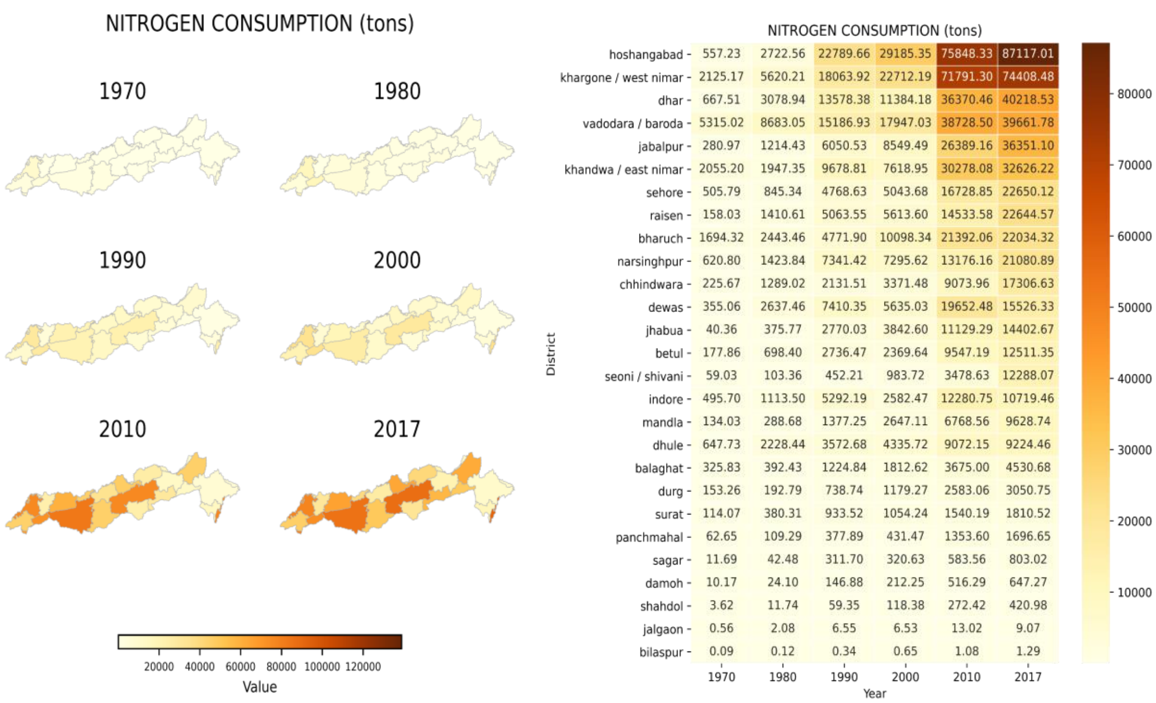


Fig. 28. Trend of Nitrogen use in Narmada Basin

The top five districts in terms of percentage growth are led by Jhabua, which saw its nitrogen use explode by approximately 35,585%, rising from 40.36 tons in 1970 to 14,402.67 tons in 2017. This is followed by Hoshangabad (15,534%), Raisen (14,229%), Jabalpur (12,837%), and Chhindwara (7,568%), all of which transitioned into high-intensity agricultural zones. Conversely, the lower five districts for growth include Vadodara, which had the slowest relative increase at 646%, followed by Bharuch (1,200%), Dhule (1,324%), Bilaspur (1,333%), and Jalgaon (1,519%). It is important to note that while Vadodara and Bharuch have low percentage growth, they started with much higher baseline consumption in 1970 compared to districts like Jhabua.

8.2 Phosphate Consumption Trends

Fig. 29 shows that phosphate (P) consumption follows a similar growth pattern to Nitrogen but at a slightly lower total volume. Once again, Hoshangabad and Khargone are the dominant consumers, with 2017 figures of 50,700.86 tons and 35,798.61 tons, respectively. Interestingly, while most districts showed consistent growth, Dewas experienced a notable decline in phosphate use in the final period, dropping from 18,528.95 tons in 2010 to 8,766.10 tons in 2017. In the upper basin, districts like Jabalpur have seen steady, substantial increases, reaching 17,901.54 tons by 2017, which aligns with its high rice and wheat output.

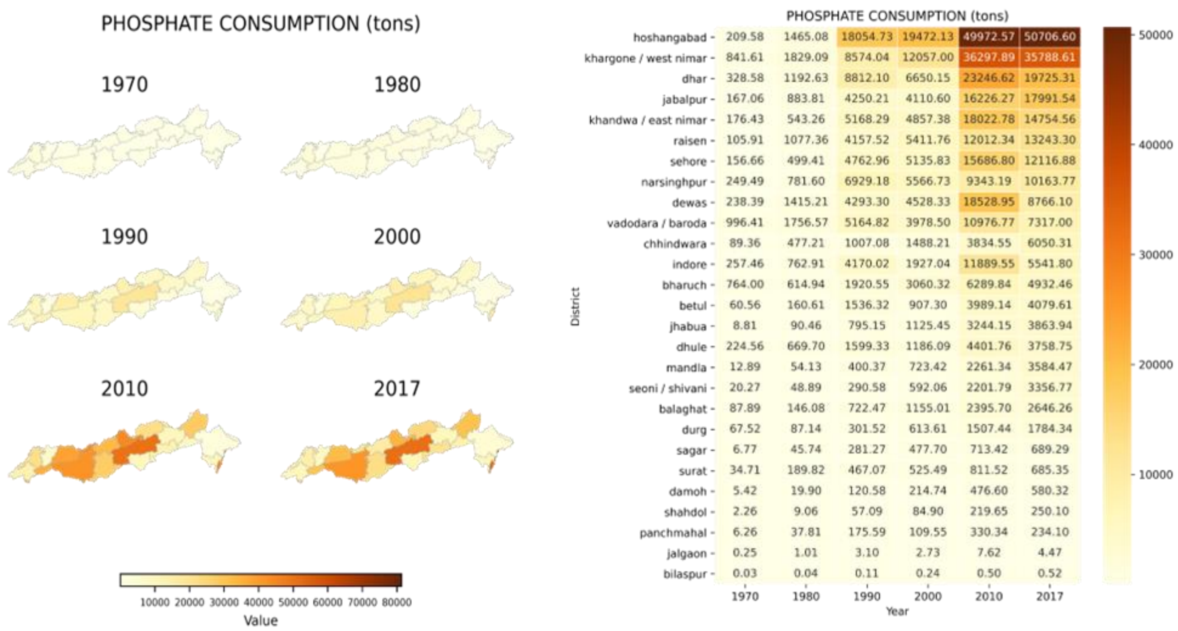


Fig. 29. Trend and Pattern of Phosphate use in Narmada Basin

8.3 Potash Consumption Trends

Potash (K) consumption is the lowest of the three primary fertilizers in terms of absolute tonnage, and its geographic distribution differs from N and P. Unlike the other fertilizers where Hoshangabad leads, Khargone (12,927.96 tons) and Khandwa (11,523.63 tons) are the primary consumers of Potash in the basin as of 2017. This suggests a specific soil requirement or crop-specific demand (likely for cotton or oilseeds) in the western basin districts. Notably, the data reveals a recent cooling trend in Potash use; between 2010 and 2017, several top-tier districts including Khargone, Khandwa, and Hoshangabad saw a slight decrease in Potash consumption. Peripheral districts like Bilaspur and Shahdol report negligible potash use, remaining below 15 tons throughout the entire 47-year period.

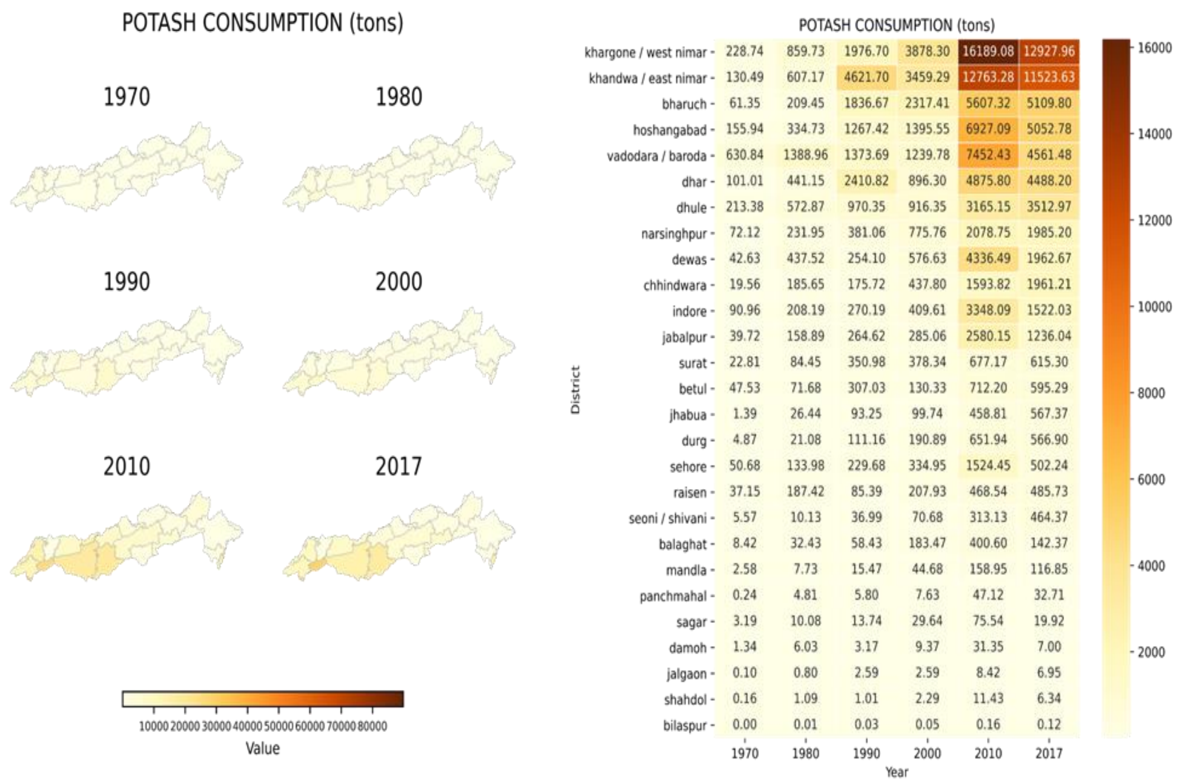


Fig. 30. Trend and Pattern of Potash use in Narmada Basin

The overarching pattern in the Narmada River Basin is one of regional concentration. The "Input Use" heatmaps illustrate a clear darkening of the central-western corridor, signifying that districts like Hoshangabad, Khargone, Dhar, and Narsinghpur have transformed into high-input industrial agricultural zones. Conversely, the eastern basin districts (such as Mandla and Dindori) and the outer fringes (like Sagar or Damoh) show a much lighter footprint, indicating a less intensive agricultural structure. Thus, Narmada River Basin's agriculture as a high-performance race car: between 1970 and 2017, the farmers have been pumping exponentially more "fuel" (Nitrogen and Phosphate) into the engine to achieve record-breaking speeds (yields). However, in recent years, they have begun to tap the brakes slightly on specific "additives" like Potash, perhaps as soil saturation or economic factors come into play.

9 Challenges and Emerging Trends

The agricultural structure of the Narmada River Basin is currently at a crossroads, where decades of intensification and productivity gains are meeting significant ecological and structural limits. While the central plains have emerged as a national granary, several systemic challenges threaten the long-term sustainability of the basin's primary livelihood.

9.1 Critical Resource and Structural Challenges

Groundwater Depletion and Energy Demand: Despite the expansion of large-scale canal projects, a vast portion of the basin remains tethered to private groundwater extraction. In high-productivity districts like Narsinghpur and Hoshangabad, the heavy reliance on tubewells has led to significant seasonal drawdowns, with water levels in some blocks dropping by 3 to 8 meters over the last two decades (*Agriculture Profile Report, cNaramda, 2025*). This intensive pumping, often incentivized by subsidized or flat-rate electricity, creates a high energy demand and puts the basin at risk of long-term aquifer exhaustion.

Land Fragmentation: The basin is characterized by a high degree of land fragmentation. Over 85% of farmers are marginal or smallholders owning less than 2 hectares. In districts like Jabalpur and Mandla, more than 60% of landholdings are marginal (*Agriculture Profile Report, cNaramda, 2025)*. This fragmentation restricts the adoption of large-scale mechanization and complicates access to institutional credit and formal irrigation infrastructure.

Staggering Yield Gaps: A profound productivity divide exists between irrigated and rainfed systems. In Jobat Tehsil (Alirajpur), the yield gap for rainfed maize is a massive 11.39 t/ha between actual and water-limited potential. These gaps highlight systemic underperformance in marginalized tribal and upland areas due to limited input access and moisture stress.

9.2 Environmental Risks and Nutrient Imbalances

Agrochemical Overuse and Imbalance: The drive for higher yields has led to an explosive and imbalanced use of chemical fertilizers. Nitrogen (N) consumption in Hoshangabad skyrocketed from 557 tons in 1970 to over 87,000 tons in 2017. Conversely, potash (K) remains severely underutilized, often accounting for less than 10% of total NPK consumption in districts like Panchmahal and Shahdol. However, the presented data is in absolute number, and it can be bias due to large area of the particular district.

Pollution and Soil Health: This imbalance has significant environmental costs. Nitrate levels in Omkareshwar and Hoshangabad have breached 60 mg/L, exceeding WHO safety thresholds. Furthermore, river sediments in Sehore and Barwani show alarming concentrations of heavy metals like chromium and nickel linked to fertilizer residues. Soil health is also declining, with pH drops recorded in districts like Dhar and Dewas.

9.3 Emerging Trends and Positive Transitions

Modernization of Irrigation: To combat the inefficiencies of traditional flood irrigation (where efficiency is only 35–45%), there is a rapid shift toward Pressurized Irrigation Network Systems (PINS) and Underground Pipelines (UGPL). Micro-irrigation (drip and sprinkler) has expanded significantly, particularly in Bharuch, Khargone, and Dhar. For example, drip irrigation in Bharuch has enabled water savings of 45–55% and yield gains of 25–30% in banana cultivation.

Crop Diversification toward High-Value Chains: There is a visible transition toward market-oriented agriculture. The western basin is becoming a cotton stronghold, while districts like Indore, Jabalpur, and Bhopal have significantly increased land dedicated to fruits and vegetables. Between 2010 and 2017, horticultural areas in these districts reached between 10,000 and 25,000 hectares.

Integration of Mixed Farming Systems: Livestock rearing is emerging as a critical risk-diversification strategy, especially for smallholders. Districts like Khargone, Mandla, and Jhabua maintain high livestock densities, and the integration of crop residues with ruminant rearing is being promoted to enhance nutrient cycling and income stability in rainfed zones (*Agriculture Profile Report, cNaramda, 2025*).

Sustainable Management Practices: Innovative techniques such as the System of Rice Intensification (SRI) are gaining traction in the upper basin. Progressive farmers in Mandla have achieved paddy yields of 75 quintals/ha through SRI, nearly quadrupling traditional outputs while reducing water needs (*Agriculture Profile Report, cNaramda, 2025)*.

10 Policy Implications and Recommendations

The agricultural management of the Narmada River Basin must transition from a focus on sheer volume to a framework of resource efficiency and ecological sustainability. To maximize land and water utility, the report recommends encouraging zone-specific crop selections through agro-climatic crop zoning, ensuring that water-intensive crops like sugarcane and rice are limited to areas with high-efficiency canal command.

Addressing the "Rainfall Divide" and groundwater stress requires urgent water-energy reforms, specifically the replacement of flat-rate electricity systems with smart meters and the expansion of solar-powered irrigation under schemes like PM-KUSUM to decouple energy usage from excessive pumping.

To reverse the documented soil acidification and pH decline (Agricultural Profile Report, cNarmada, 2025), policy must prioritize balanced fertilizer use by incentivizing organic inputs and increasing accessibility to potash and micronutrients, thereby correcting the current nitrogen-heavy NPK ratio. Furthermore, as over 85% of the basin's farmers are marginal or smallholders, there is a critical need to expand capital subsidies for pressurized and micro-irrigation systems to overcome high upfront costs and technical barriers. Institutional support should focus on models of community governance, such as irrigation committees at the Panchayat level and the formation of Farmer Producer Organizations (FPOs), to formalize land leasing and provide smallholders with better access to credit and mechanization. Finally, targeting female land ownership, which remains below 15% across the basin states, through gender-specific land access reforms is essential for long-term socio-economic equity.

11 Conclusion

The Narmada River Basin has undergone a dramatic structural transformation over the past five decades, evolving from a single-season farming landscape into a high-intensity agricultural corridor. Districts like Harda, Hoshangabad, and Narsinghpur now form the basin’s "agrarian core," consistently producing record-breaking yields of wheat and soybean supported by massive investments in irrigation and chemical inputs. However, this intensification has been uneven; while the central and western plains thrive, eastern tribal and upland districts like Mandla and Dindori remain underserved, facing stagnant cropping intensities and staggering yield gaps.

This growth has also introduced perilous ecological trends, including significant groundwater drawdowns and nutrient imbalances that threaten long-term soil health and water quality. The shift toward micro-irrigation and mixed farming, integrating livestock with crop production, offers a promising pathway to diversify livelihoods and improve nutrient cycling. Ultimately, the basin’s agricultural trajectory must be guided by ecological integrity and equity rather than productivity targets alone. By bridging the gap between intensive production hubs and marginalized rainfed zones, the Narmada Basin can serve as a national model for climate-resilient and sustainable river basin agriculture.

Appendix 1. Cropping Intensity

District	Gross Cropped Area	Net Area Sown	Crop Intensity (%)
Bharuch	245578	168346	145.88
Alirajpur	228716	158726	144.09
Anuppur	457830	289453	158.17
Balaghat	413049	229252	180.17
Barwani	835935	463860	180.21
Betul	335530	298614	112.36
Bhopal	286576	153662	186.5
Burhanpur	174191	96443	180.62
Chhindwara	911512	508552	179.24
Chhotaudepur	254485	210525	120.88
Damoh	629384	320028	196.67
Dewas	834993	417599	199.95
Dhar	965428	502610	192.08
Dindori	333834	213005	156.73
Dohad	404963	225937	179.24
Harda	529669	193236	274.1
Hoshangabad	936725	324642	288.54
Indore	494466	250688	197.24
Jabalpur	608332	274109	221.93
Jhabua	309214	182307	169.61
Katni	441127	236793	186.29
Khandwa	624162	316254	197.36
Khargone	785023	397894	197.29
Mandla	389525	228730	170.3
Narmada	128193	112304	114.15
Narsinghpur	737275	302424	243.79
Panch mahals	260096	176656	147.23
Raisen	823484	426358	193.14
Sagar	1135984	563153	201.72
Sehore	883884	396587	222.87
Seoni	757283	400362	189.15
Surat	305981	222666	137.42
Vadodara	368031	270383	136.11

Source: ICRISAT, 2024

Appendix 2. Proportion of Different Crops to Cropped Area (%)

District	Rice	Jowar	Bajra	Maize	Wheat	Total Cereals	Gram	Arhar	Other Pulses
Bharuch	4.64	0.86	0.08	0.09	5.55	11.22	0.36	19.1	11.08
Chhota Udepur	5.71	0.05	0.06	14.13	0.28	20.24	0.28	5.93	2.08
Dahod	9.82	0	0.01	34.15	14.64	63.71	9.33	1.66	2.8
Narmada	8.81	2.32	0.19	6.06	1.24	18.62	0.85	13.9	0.81
Panch mahals	19.34	0	0.91	32.8	5.77	58.98	0.74	6.31	0.66
Surat	18.69	3.01	0.01	1.03	1.05	23.79	0.42	2.98	1.51
Vadodara	10.55	0.57	2.03	0.81	6.43	20.39	0.12	5.37	0.34
Alirajpur	2	1.46	3.26	19.37	16.1	42.19	6.56	1.26	10.07
Anuppur	60.3	0.09	0	2.39	8.34	73.17	3	1.06	16.33
Balaghat	63.56	0	0	0.18	11.35	75.28	8.52	0.05	11.33
Barwani	0.02	3.64	1.36	20.51	28.95	54.48	5.2	0.36	4
Betul	4.23	0.14	0	21.91	35.26	61.67	6.56	0.98	0.19
Bhopal	5.22	0	0	0.05	50.82	56.1	1.04	0.01	1.23
Burhanpur	0.15	0.88	0.01	15.69	10.77	27.52	9.92	2.69	1.91
Chhindwara	3.8	0.1	0	39.7	35.54	79.49	4.23	1.87	1.83
Damoh	14.49	0	0	1.03	25.86	41.39	14.13	0.9	33.25
Dewas	0.02	0.03	0	3.02	36.59	39.66	9.18	0.06	0.14
Dhar	0	0.09	0.12	4.59	40.13	44.92	5.38	0.07	0.14
Dindori	43.87	0	0	4.1	17.4	68.98	2.15	0.89	21.06
Harda	0.68	0	0	2.46	20.14	23.29	15.32	0.01	27.23
Hoshangabad	25.62	0.01	0	3	28.44	57.08	5.69	0.07	32.36
Indore	0	0	0	0.26	46.48	46.75	0.48	0	0.03
Jabalpur	29.09	0	0	7.33	33.67	70.79	2.78	0.87	22.63
Jhabua	1.22	0.31	0.01	20.34	32.71	54.59	6.1	0.72	0.52
Katni	48.45	0	0	0.14	45.49	94.31	3.36	0.25	0.8
Khandwa	0.08	0.01	0	2.55	32.8	35.43	12.12	0.16	3.08
Khargone	0	0.06	0	7.74	27.84	35.65	16.87	0.3	1.07
Mandla	50.64	0	0	3.06	20.5	76.67	1.92	0.36	18.59
Narshimapura	12.25	0.01	0	9.58	21.27	43.12	9.52	2.46	30.15
Raisen	39.55	0	0	0.63	35.98	76.16	10.47	1.31	5.8
Sagar	4.41	0.02	0.01	4.98	27.68	37.1	6.12	0.25	26.46
Sehore	5.37	0	0	1.75	38.48	45.6	4.58	0.05	11.76
Seoni	26.9	0	0	24.78	37.29	89.17	3.49	0.11	4.03

Source: ICRISAT, 2023-24

Appendix 3. Continuation of Appendix 1

District	Total Pulses	Total Food Grain	Sugarcane	Condiments and Spices	Fruits	Potato	Total Vegetables	Total Food Crop	Groundnut
Bharuch	30.55	41.77	16.83	0.31	3.72	0	4.86	67.5	0.07
Chhota Udepur	8.29	28.53	0	0.34	4.88	0	8.91	42.66	0.14
Dahod	13.79	77.51	0	1.86	1.88	0	6.74	87.98	0.29
Narmada	15.56	34.17	4.98	0.27	10.71	0	4.74	54.88	0.13
Panch mahals	7.71	66.69	0.03	0.08	2.08	0.01	8.78	77.66	0.14
Surat	4.9	28.7	28.37	0.24	4.53	0	19.78	81.63	0.28
Vadodara	5.82	26.21	0.08	0.52	5.17	0.09	12.15	44.14	0
Alirajpur	17.89	60.08	0	0.09	0.02	0	0.25	60.45	6.56
Anuppur	20.39	93.55	0.01	0.02	0	0.01	0.35	93.93	0.03
Balaghat	19.9	95.18	0.47	0.05	0.07	0	0.47	96.23	0
Barwani	9.55	64.03	1.04	0.43	0.9	0	1.11	67.5	1.47
Betul	7.74	69.41	3.12	0.03	0.07	0.02	0.39	73.02	0.26
Bhopal	2.27	58.37	0	0.15	0.09	0	0.18	58.79	0.03
Burhanpur	14.51	42.03	3.67	0.76	27.95	0	0.41	76.28	0.21
Chhindwara	7.92	87.42	0.71	0.1	0.73	0.23	1.08	90.04	0.59
Damoh	48.28	89.67	0	0.02	0.01	0.04	0.37	90.07	0.01
Dewas	9.37	49.03	0.01	0.77	0.03	0.97	2.09	51.92	0.02
Dhar	5.59	50.51	0.12	1.89	0.34	0.16	0.97	53.82	0.1
Dindori	24.1	93.08	0.01	0.01	0	0.01	0.09	93.19	0.01
Harda	42.57	65.85	0	0.27	0.01	0	0.08	66.22	0
Hoshangabad	38.12	95.2	0.23	0.02	0.04	0	0.09	95.58	0
Indore	0.51	47.26	0	0.49	0.02	1.47	2.46	50.24	0.02
Jabalpur	26.27	97.06	0.33	0.04	0.1	0	1.61	99.14	0
Jhabua	7.33	61.92	0	0.25	0.06	0	0.34	62.58	1.13
Katni	4.41	98.72	0.02	0.01	0.04	0.04	0.27	99.06	0
Khandwa	15.36	50.79	0.07	0.23	0.22	0.06	1.27	52.58	0.03
Khargone	18.24	53.89	0.46	2.92	0.69	0.01	0.71	58.66	0.15
Mandla	20.88	97.55	0.09	0.07	0	0.02	0.28	97.99	0
Narshimapura	42.13	85.25	6.81	0.13	0.01	0.01	0.66	92.85	0.16
Raisen	17.58	93.74	0.15	0.01	0.03	0	0.17	94.1	0
Sagar	32.82	69.92	0	0.18	0	0.02	0.39	70.5	0.04
Sehore	16.38	61.98	0	0.21	0.01	0	0.19	62.4	0.01
Seoni	7.63	96.81	0.06	0.06	0.01	0.02	0.28	97.22	0.09

Source: ICRISAT, 2023-24

Appendix 4. Continuation of Appendix 1

District	Soyabean	Soyabean.	Total Oilseeds	Cotton	Total Drugs Narcotics and Plantation Crop	Fodder Crops	Total Non-Food Crop
Bharuch	0	0	2.73	28.73	0	0.74	32.5
Chhota Udepur	0	0	6.93	43.94	0	6.3	57.34
Dahod	0	0	7.37	0.25	0.01	3.9	12.02
Narmada	0	0	2.16	42.76	0.01	0	45.12
Panch mahals	0	0	3.58	4.74	0.27	13.67	22.34
Surat	0	0	4.35	1.84	0	11.45	18.37
Vadodara	0	0	13.6	24.1	2.61	15.07	55.86
Alirajpur	23.33	0.01	29.92	9.53	0	0.09	39.55
Anuppur	1.58	0	6.03	0	0	0.03	6.07
Balaghat	0	0	3.62	0	0	0	3.77
Barwani	7.7	0	9.24	23.22	0	0.02	32.5
Betul	24.91	0.01	26.77	0.17	0.01	0.02	26.98
Bhopal	40.47	0.03	41.14	0	0	0.02	41.21
Burhanpur	7.64	0.01	7.87	15.76	0.01	0.01	23.72
Chhindwara	1.65	0	3.74	6.17	0	0.01	9.96
Damoh	9.45	0	9.92	0	0	0	9.93
Dewas	46.73	0.01	47.83	0.07	0	0.12	48.08
Dhar	33.17	0.01	33.29	12.82	0	0.04	46.18
Dindori	1.67	0	6.81	0	0	0	6.81
Harda	33.29	0.02	33.77	0	0	0	33.78
Hoshangabad	4.29	0	4.41	0	0	0	4.42
Indore	49.4	0.02	49.43	0.02	0.02	0.22	49.76
Jabalpur	0.19	0	0.69	0	0	0.08	0.86
Jhabua	28.12	0.02	29.26	7.77	0	0.35	37.42
Katni	0	0	0.9	0.01	0	0.01	0.94
Khandwa	39.65	0.01	39.91	7.44	0.01	0.01	47.42
Khargone	12.8	0	13.18	28.01	0.01	0.07	41.34
Mandla	0	0	1.97	0	0	0.01	2.01
Narshimapura	6.83	0	7.13	0	0	0.02	7.15
Raisen	5.65	0	5.89	0	0	0.01	5.9
Sagar	28.91	0.01	29.45	0	0	0.03	29.5
Sehore	37.4	0.01	37.54	0	0.01	0.05	37.6
Seoni	0.1	0	2.33	0.03	0.01	0.15	2.78

Source: ICRISAT, 2023-24