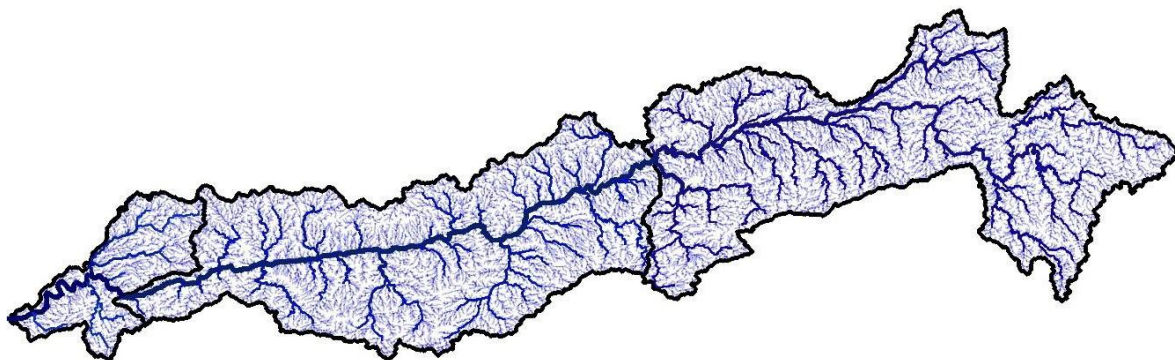




National River Conservation Directorate
Ministry of Jal Shakti, Department of Water
Resources,
River Development & Ganga Rejuvenation
Government of India

Agricultural Profile of Narmada River Basin



JUNE 2025



© cNarmada, cGanga and NRCD, 2025

Agricultural Profile of Narmada River Basin



© cNarmada, cGanga and NRCD, 2025

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

Team

Prof. Pritee Sharma
Prof. Udit Bhatia
Dr. Divyanshu Kumar Dixit
Ms. Adrija Datta

cNarmada, IIT Indore
cNarmada, IIT Gandhinagar
cNarmada, IIT Indore
cNarmada IIT Gandhinagar

PREFACE

The Agricultural Profile Report of Narmada River Basin represents a comprehensive effort to map, analyse, and interpret the evolving dynamics of agriculture in one of India's most significant river basins. The report is collaborative effort of IIT Gandhinagar and IIT Indore under the aegis of the Centres for Narmada River Basin Management and Studies (cNarmada)—and supervised by cGanga at IIT Kanpur—this report was conceptualized and supported by the National River Conservation Directorate (NRCD), Ministry of Jal Shakti.

The basin's agricultural core is constituted by districts such as Hoshangabad, Sehore, Harda, Narsinghpur, and Raisen in Madhya Pradesh, which consistently report net cropped areas exceeding 700,000 hectares and cropping intensities well above 150%. These districts have benefitted from both canal irrigation and groundwater extraction, supporting major crops like soybean–wheat and paddy–wheat. For instance, Harda alone increased its soybean area from 102,000 ha in 1970 to 184,000 ha in 2017, also emerging as the basin's most productive district with wheat yields surpassing 4,100 kg/ha. On the other hand, tribal and upland districts like Mandla, Dindori, Shahdol, and Seoni exhibit relatively low and stagnant cropping intensities—often below 110%—due to terrain constraints, fragmented landholdings, and limited irrigation. In Jobat Tehsil (Alirajpur district), yield gap analysis for rainfed maize reveals a staggering 11.39 t/ha gap between actual and water-limited yield, underlining the productivity constraints in marginalized areas.

The report reveals that, temporally cropping intensity increased remarkably across the basin. In Balaghat and Betul, for instance, intensity rose from around 100% to 181% and 178% respectively showcasing how irrigation and input access have transformed land use. This transition, however, is uneven. Eastern Plateau districts, particularly in Chhattisgarh and eastern Madhya Pradesh, lag in both intensity and productivity, necessitating region-specific strategies.

With the increasing crop intensity, the use of chemical fertilizers and pesticides has grown in parallel. Hoshangabad and Khargone top nitrogen usage, but potash remains severely underutilized across the basin, often below 10% of total NPK consumption, as seen in Panchmahal and Shahdol. These trends have environmental ramifications: nitrate levels in Omkareshwar and Hoshangabad have breached 60 mg/L, exceeding WHO safety thresholds, while sediment samples from Sehore and Barwani show alarming concentrations of chromium and nickel, linked to fertilizer residues.

This report also highlights the socio-economic structure of agriculture, emphasizing the preponderance of marginal and small landholdings, especially in districts like Jabalpur and Mandla where more than 60% landholdings are marginal.

Amid these challenges, the report also documents positive transitions. Adoption of micro-irrigation—especially in districts like Bharuch, Khargone, Dhar, and Narsinghpur—has enabled both water savings (30–50%) and yield gains (15–25%), especially in cotton, vegetables, and banana. In Khargone, for instance, drip systems have expanded rapidly, contributing to yield improvements and income diversification.

Thus, this report provides a district-disaggregated, temporal, and multi-dimensional profile of agriculture in the Narmada Basin. By incorporating agricultural aspects with, socio-economic aspects such as labour force and livestock, it offers a foundation for evidence-based policy and planning for the Narmada River Basin.

Centres for Narmada River Basin Management and Studies (cNarmada)

IIT Gandhinagar, IIT Indore

TABLE OF CONTENTS

1	<i>Introduction</i>	1
1.1	Geographic and Physiographic Features	1
1.2	Administrative Jurisdiction and Demography	1
1.3	Ecological Significance and Biodiversity	1
2	<i>Geographical Delineation of Significant Agricultural Areas</i>	2
2.1	Identification and Mapping of Agriculturally Dominant Areas in the Basin	2
2.2	Area under agriculture by district or zone.	3
2.3	Agro-climatic zones and their suitability for different crops	4
3	<i>Cropping Pattern and Intensity</i>	7
3.1	Major crops grown and seasonal cycles (Kharif, Rabi, Zaid)	7
3.2	Cropping intensity index	9
4	<i>Crop Production and Average Yield</i>	13
4.1	Crop Area and Yield of Major Crops	13
4.2	Sub-basin wise crop production of different crop	17
4.3	Comparison with state and national averages	25
4.4	Yield gaps and productivity constraints.	28
5	<i>Agricultural Land Distribution and Farming Practices</i>	30
5.1	Types of farming systems: subsistence, commercial, rainfed and irrigated	30
6	<i>Irrigated Land and Major Irrigation Sources</i>	37
6.1	Area under irrigation by source: canals, wells, tanks, lift irrigation	37
6.2	Status of groundwater extraction and drawdown levels	40
6.2.1	District-Level Patterns	40
6.2.2	Causes of Drawdown	41
7	<i>Irrigation Pattern and Techniques</i>	43
7.1	Traditional vs Modern Irrigation Practices	43

7.2	Water-Use Efficiency (WUE) and Cropping Choices	44
7.3	Adoption of Micro-Irrigation Systems (Drip & Sprinkler)	46
7.3.1	District-Wise and Crop-Wise Highlights	46
8	<i>Chemical Fertilizer and Plant Protectant Use</i>	48
8.1	Trends in fertilizer and pesticide use	48
8.2	Regional Disparities and Over/Underutilization	50
8.3	Environmental and Health Concern	55
8.3.1	Water Pollution	55
8.3.2	Soil Degradation	55
8.3.3	Health Risks	56
9	<i>Agricultural Management Practices and Sustainable Agricultural Practices</i>	57
10	<i>Agricultural Manpower, Land, and Livestock Holdings</i>	59
10.1	Labour availability and workforce characteristics.	59
10.2	Land ownership patterns and tenancy	61
10.2.1	Livestock holdings and mixed farming practices	62
11	<i>Government Schemes and Institutional Support in the Narmada River Basin</i>	66
11.1	Overview of Major agriculture related Government Schemes	66
12	<i>Conclusion and Policy Recommendations</i>	69
12.1	Agrarian Core and Cropping Intensity and Irrigation	69
12.2	Fertilizer and Pesticide Use and Agricultural Manpower	70
12.3	Crop Planning, Yield Gaps	71
12.4	Application	71

Table	Caption	Page No
1:	Seasonal Cropping Cycles in the Narmada Basin.....	7
2:	Major Crops by Season	8
3:	Cropping Patterns Across Zones	9
4:	Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023	18
5:	Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023 (cont.).....	19
6:	Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023	20
7:	Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023	21
8:	Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023	22
9:	Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023	23
10:	Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023	24
11:	Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023	24
12:	Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023	25
13:	Farming System and Their Coverage	30
14:	Illustrative Water use efficiency gains under micro-irrigation	45
15:	State-wise micro-irrigation uptake relevant to the Narmada Basin (2015-24).....	47
16:	Environmental Risks from Agrochemical Use.....	56
17:	M-KISAN Beneficiaries (State-wise) – 2023–2024	66
18:	Central Assistance Released PMKSY in Narmada Basin States (₹ in Crore)	67
Table 19:	Extension Programmes and No. of Participants in the Basin States (2021-22).....	68
Table 20:	Number of Soil Health Cards Issued to Farmers in Narmada Basin States.....	68

Figure	Caption	Page No
1.	Net cropped area in the districts Narmada basin	2
2:	Area statistics in the districts Narmada basin.....	4
3:	Agro-climatic regions in Narmada basin	5
4:	Area percentage (%) of agro-climatic regions in Narmada basin	6
5:	Temporal pattern of district wise cropping intensity in Narmada basin.....	10
6:	Year wise cropping intensity of all districts in Narmada basin	11
7:	Changes in cropping intensity of all districts in 2017 in Narmada basin w.r.t 1966.....	12
8:	Temporal pattern of crop wise area distribution in Narmada basin.....	13
9:	Temporal pattern of rice and wheat yield distribution in Narmada basin.....	15
10:	Temporal pattern of sorghum and maize yield distribution in Narmada basin	16
11:	Temporal pattern of oil seeds yield distribution in Narmada basin.....	17
12:	Temporal comparison of crop wise area and yield distribution in Narmada basin	26
13:	Temporal comparison of crop wise area and yield distribution in Narmada basin	27
14:	Productivity constraints for GYGA stations in Narmada basin	29
15:	Crop wise irrigated area in Narmada basin	32
16:	Crop wise irrigated area in Narmada basin	33
17:	Crop wise irrigated area in Narmada basin	33
18:	18: Different area wise landholdings ditribution across Narmada River Basin.....	35
19:	Large area landholdings across Narmada River Basin	36
20:	Marginal and Small landholding fragmentation patterns in Narmada basin	36
21:	District wise area under irrigation by canal and tank source of irrigation in Narmada basin.....	38
22:	District wise area under irrigation by tube wells and wells of irrigation in Narmada basin.....	39
23:	District wise nitrogen fertilizer consumption in Narmada basin	48
24:	District wise phosphate and potash fertilizer consumption in Narmada basin.....	49
25:	District wise fertilizer share of Nitrogen in Narmada basin	51
26:	District wise fertilizer share of Phosphate in Narmada basin	52
27:	District wise fertilizer share of Potash in Narmada basin	53
28:	District wise male and male labour availability	59
29:	District wise male and female labour availability.....	60
30:	District wise temporal livestock holdings statistics	62
31:	District wise temporal livestock holdings statistics.....	63
32:	District wise temporal livestock holdings statistics.....	64

1 Introduction

The Narmada Basin is one of India's most prominent river basins, both in terms of its physical expanse and its multifaceted socio-ecological significance. It is situated in central India and stretches across the states of Madhya Pradesh, Maharashtra, Gujarat, and Chhattisgarh, covering an approximate area of 98,800 square kilometers. The Narmada River, often referred to as the "lifeline of Madhya Pradesh," originates from Amarkantak Plateau in the Anuppur district of Madhya Pradesh at an elevation of around 1,057 meters and flows westward for over 1,300 kilometers before draining into the Arabian Sea near Bharuch in Gujarat.

1.1 Geographic and Physiographic Features

Geographically, the basin traverses a diverse range of landscapes, from the forested highlands of the Satpura and Vindhya ranges in the east and central sections, to the fertile plains of western Madhya Pradesh and Gujarat. The basin exhibits a mix of plateau regions, valleys, gorges, and floodplains, contributing to its rich ecological and geomorphological heterogeneity. The river is bounded by the Vindhya ranges to the north and the Satpura ranges to the south, shaping a distinct longitudinal basin.

1.2 Administrative Jurisdiction and Demography

Administratively, the Narmada Basin spans partially or entirely in four states with major representation in Madhya Pradesh, where districts such as Hoshangabad, Jabalpur, Sehore, Narsinghpur, and Barwani are deeply embedded in basin-related water management and agricultural activity. In Gujarat, districts like Vadodara and Bharuch represent the downstream extent, playing a key role in the basin's deltaic and estuarine dynamics. Maharashtra contributes through upper catchments in districts like Nagpur and Buldhana, while Chhattisgarh covers limited eastern zones, notably in Bilaspur and Kabirdham.

1.3 Ecological Significance and Biodiversity

Ecologically, the Narmada Basin hosts a wide array of ecosystems ranging from dense tropical forests, riparian wetlands, and agricultural plains, making it a vital biodiversity corridor. It includes key conservation landscapes such as the Pachmarhi Biosphere Reserve, Satpura National Park, and Bori Wildlife Sanctuary, which are home to endemic and endangered species like the Indian giant squirrel, tiger, and Indian pangolin.

2 Geographical Delineation of Significant Agricultural Areas

2.1 Identification and Mapping of Agriculturally Dominant Areas in the Basin

Based on the analysis of net cropped area from 1970 to 2017, agriculturally dominant districts

w

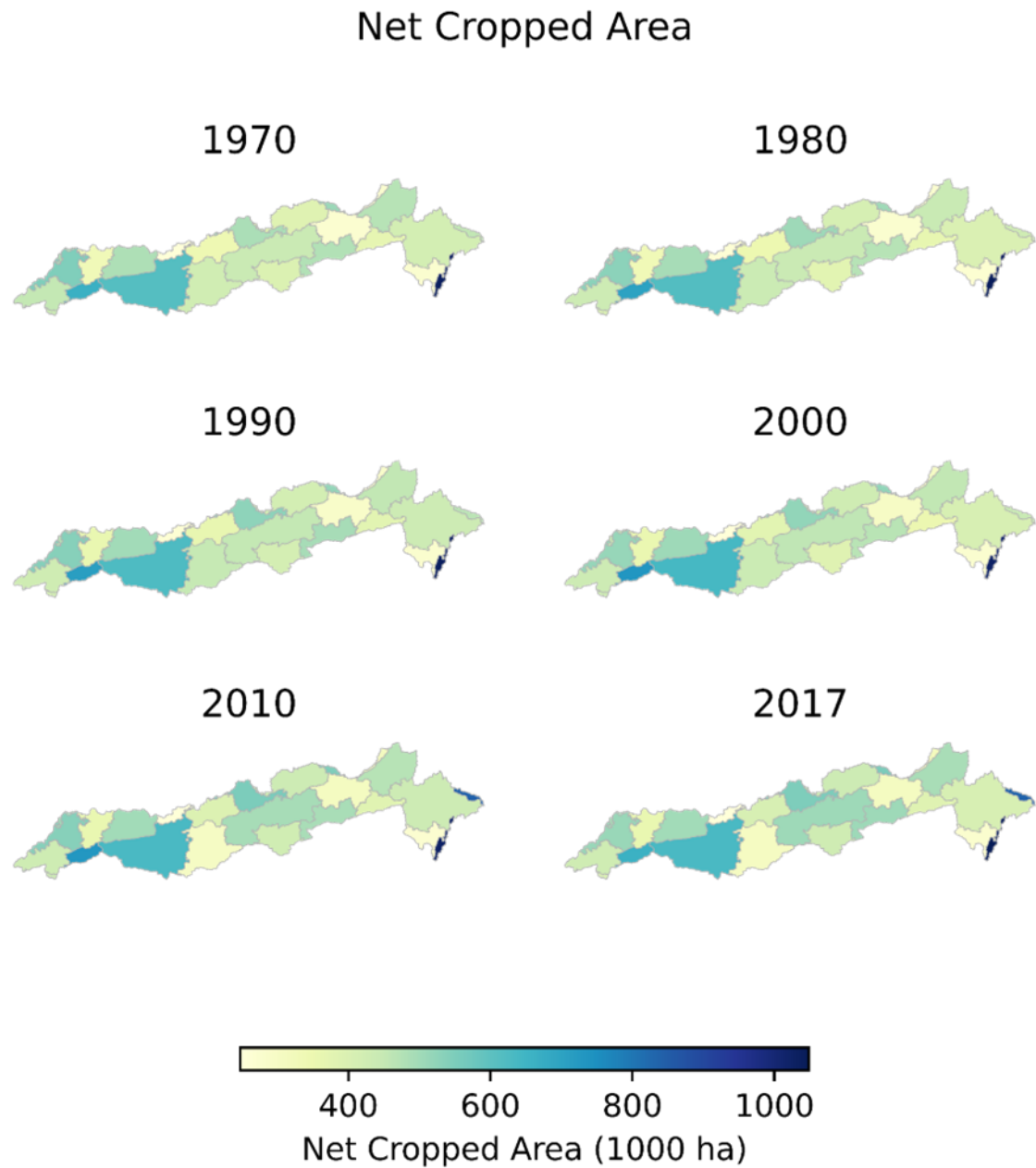


Figure 1. Net cropped area in the districts Narmada basin

within the Narmada Basin were identified using both absolute values and temporal consistency.

The most prominent zones include Jalgaon, Vadodara, Bharuch, Indore, and Hoshangabad, each maintaining net cropped areas exceeding 800–1000 thousand hectares across all reference years. These districts collectively represent the core agricultural belt of the basin, contributing a significant share of the basin’s cultivated land. Districts such as Jabalpur, Chhindwara, Dewas, Narsinghpur, and Sagar also demonstrate sustained agricultural intensity and are considered secondary agriculturally dominant zones. Mapping these districts reveals a spatial concentration of agricultural dominance in the central and western parts of the basin, with peripheral and forested districts exhibiting lower cropping extents. These spatial patterns are critical for guiding irrigation investments, input provisioning, and agro-climatic planning within the basin.

2.2 Area under agriculture by district or zone.

The analysis of net cropped area across 27 districts within the Narmada Basin over the years 1970 to 2017 reveals clear spatial gradients in agricultural land use intensity. Because this study captures long-term changes, the 1966 district shapefile was used to ensure historical consistency. As a result, small portions of some districts—such as Durg, Bilaspur, Jalgaon, Damoh, and Panchmahal—are included in the analysis. Districts like Durg, Dhule and Khargone consistently recorded the highest net cropped areas, exceeding 1,000 thousand hectares in recent decades. These regions represent the primary agricultural hubs of the basin, having sustained extensive cultivation over time.

Other districts including Indore, Jabalpur, Hoshangabad, Chhindwara, and Narsinghpur also reported high cropped areas ranging from 700 to 900 thousand hectares, with steady increases from the 1970s through the 2010s. These are agriculturally intensive districts with developed irrigation and land use infrastructure.

A second tier of districts—such as Betul, Dewas, Raisen, Sagar, Sehore, and Mandla—showed moderate net cropped area, typically in the range of 400 to 600 thousand hectares. These areas reflect stable cultivation patterns but with lower land availability or productivity compared to the leading zones.

In contrast, several districts recorded consistently low net cropped area. These include Shahdol, Durg, Bilaspur, Panch Mahals, Seoni, and Khargone (West Nimar), with values often below 300 thousand hectares, particularly in the earlier decades. These districts may face terrain limitations, forest cover, or infrastructure constraints that restrict agricultural expansion.

Notably, a general trend of increasing net cropped area is visible across most districts from 1970 to 2010, with minor reductions or plateaus in 2017 in some locations. The spatial pattern confirms that agriculture remains the dominant land use in the central and southern parts of the basin, while peripheral districts show relatively lower agricultural intensities.

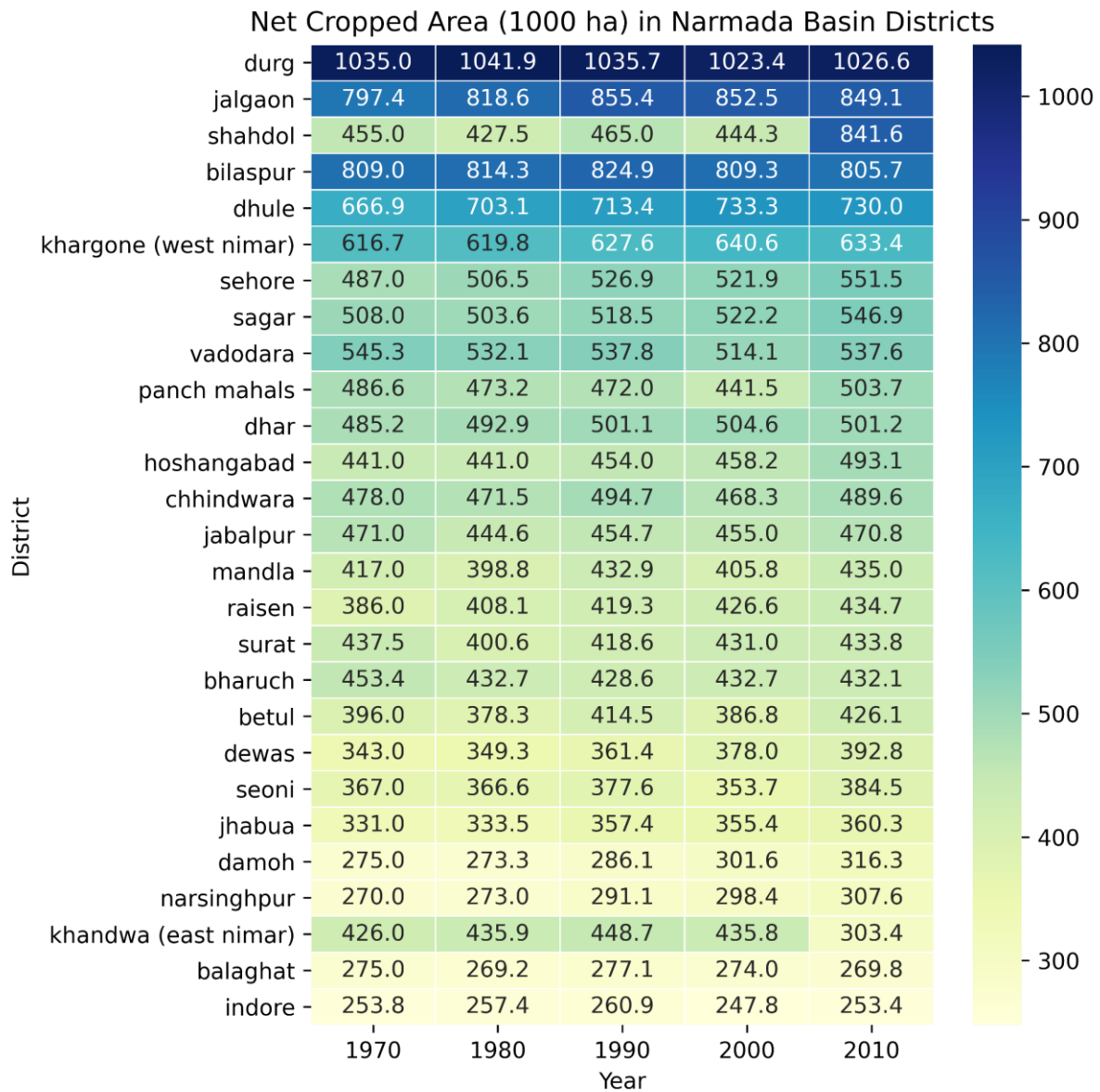


Figure 2: Area statistics in the districts Narmada basin

2.3 Agro-climatic zones and their suitability for different crops

The Narmada Basin spans four major agro-climatic zones, each characterized by distinct physiographic, edaphic, and climatic conditions influencing cropping patterns. The spatial

distribution and relative contribution of each zone to the basin are visualized in the figures above.

The Central Plateau and Hills Region dominates the basin, accounting for 53% of the total area. This zone is agriculturally robust, with moderate to deep black soils and favorable rainfall, making it highly suitable for crops like soybean, wheat, pulses, maize, and horticultural produce. Districts like Hoshangabad, Jabalpur, Narsinghpur, and Chhindwara fall under this zone and consistently report high productivity levels.

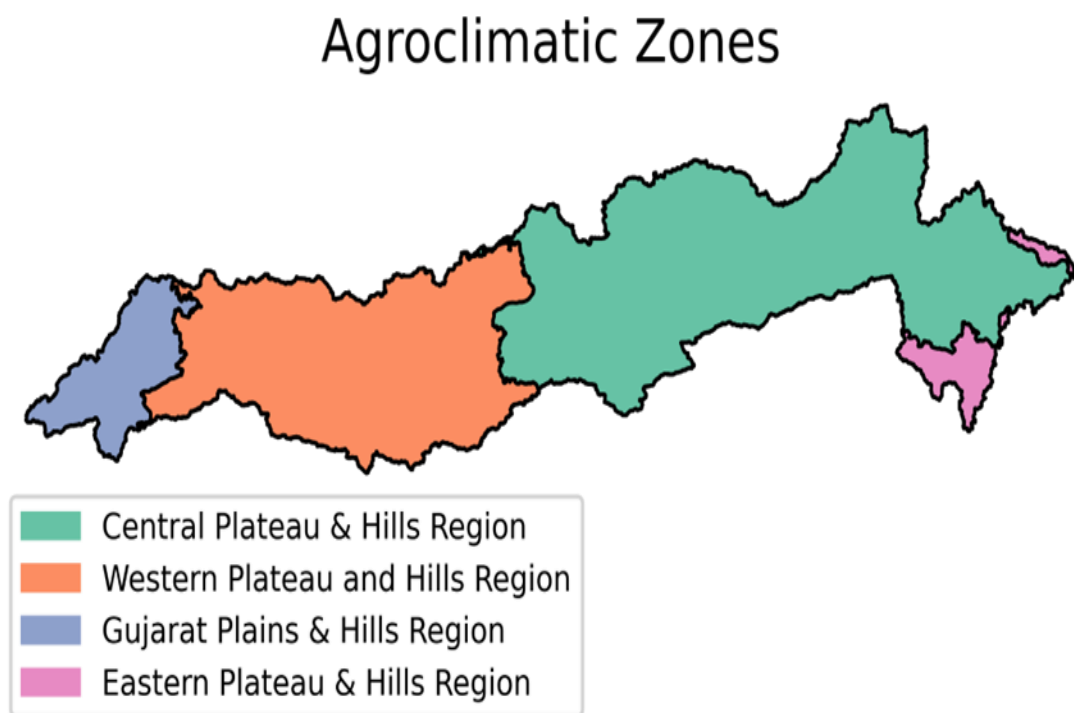


Figure 3: Agro-climatic regions in Narmada basin

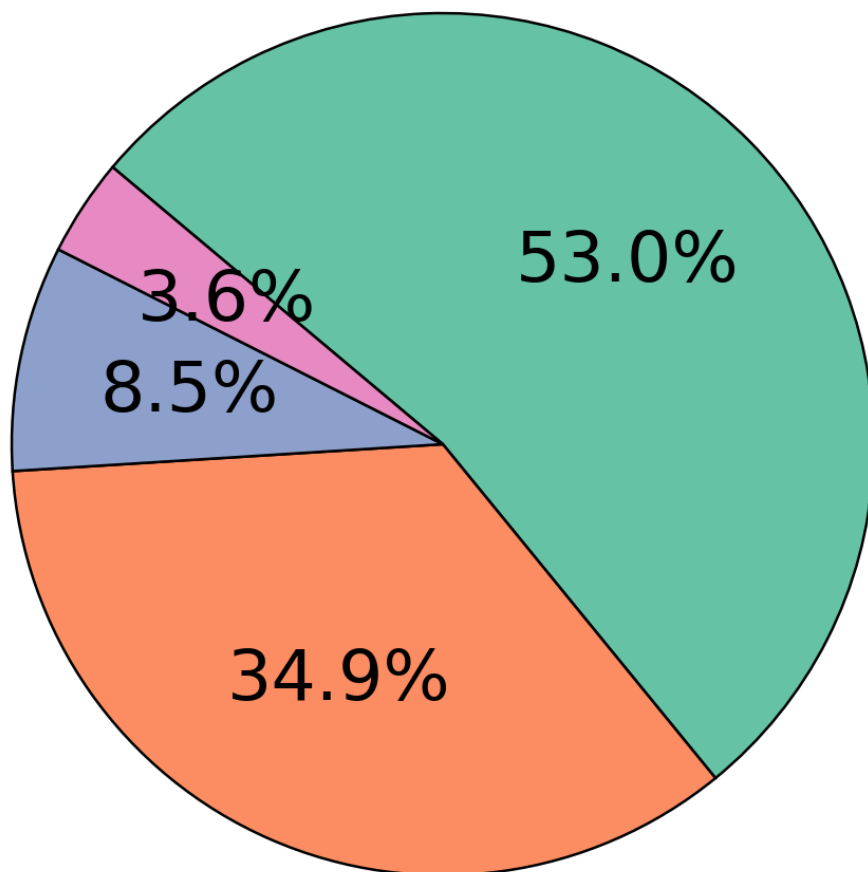


Figure 4. Area percentage (%) of agro-climatic regions in Narmada basin

The Western Plateau and Hills Region, covering 34.9% of the basin, is marked by gently undulating topography and medium to shallow soils. While it faces moderate climatic constraints, the region supports coarse cereals, oilseeds (soybean, groundnut), and pulses. It includes districts such as Dewas, Betul, Raisen, and parts of Sehore.

The Gujarat Plains and Hills Region, though covering only 8.5% of the basin, plays a significant agricultural role due to well-developed irrigation infrastructure and fertile alluvial soils. Key crops in this region include cotton, groundnut, tobacco, and wheat, with high cropping intensities. The prominent districts include Vadodara and Bharuch.

The Eastern Plateau and Hills Region is the smallest contributor, comprising just 3.6% of the basin area. This zone is typified by steeper slopes, shallow soils, and lower agricultural intensity. It is best suited for rainfed pulses, millets, and forest-based cropping systems. It includes parts of Shahdol and Bilaspur districts, which are comparatively less agriculturally developed. This agro-climatic differentiation is critical for region-specific agricultural planning, input allocation, and promotion of resilient cropping systems.

3 Cropping Pattern and Intensity

3.1 Major crops grown and seasonal cycles (Kharif, Rabi, Zaid)

The Narmada Basin, owing to its varied agro-climatic zones and soil types, supports a wide diversity of crops across all three agricultural seasons—Kharif (monsoon), Rabi (winter), and Zaid (summer). The cropping intensity and crop types vary spatially across Central Plateau & Hills, Western Plateau, Eastern Hills, and Gujarat Plains.

Table 1: Seasonal Cropping Cycles in the Narmada Basin

Season	Time Period	Climatic Features	Major Activities
Kharif	June – October	Monsoon rainfall, high humidity	Sowing of rainfed crops, paddy transplanting
Rabi	November – March	Dry, cooler climate	Sowing post-harvest, irrigation-dependent
Zaid	April – June	Hot and dry, pre-monsoon	Short-duration vegetables, fodder, cash crops

Source: Government of India. (2021). Agricultural Statistics at a Glance 2021. Available at: <https://eands.dacnet.nic.in>

Table 2: Major Crops by Season

Khareef season

Crop Type	Examples	Agro-Climatic Suitability
Cereals	Paddy (lowlands), Maize, Jowar, Bajra	Central & Western Plateau, Gujarat Plains (irrigated)
Pulses	Arhar (Tur), Moong, Urd	Central Plateau, Eastern Hills
Oilseeds	Soybean, Groundnut, Sesame	Soybean: Western & Central Plateau, Groundnut: Gujarat Plains
Commercial Crops	Cotton	Gujarat Plains (Vadodara, Bharuch), Western MP (Khargone)
Rabi Season		
Cereals	Wheat, Barley	Central MP (Hoshangabad, Narsinghpur, Sehore), Irrigated zones
Pulses	Gram (Chana), Lentil, Peas	Rainfed districts and lighter soils (e.g., Betul, Damoh)
Oilseeds	Mustard, Linseed	Sehore, Dewas, Sagar
Vegetables	Onion, Garlic, Carrot	Irrigated pockets across the basin
Zaid Season		
Vegetables	Cucumber, Bitter Gourd, Bottle Gourd	Alluvial and irrigated zones (mostly Gujarat & canal-fed MP)
Fodder	Sorghum, Berseem, Sudan Grass	Scattered across irrigated districts
Cash Crops	Watermelon, Muskmelon	River-adjacent belts (Bharuch, parts of Jabalpur)

Source: NBSS&LUP (National Bureau of Soil Survey and Land Use Planning). (2012)

Table 3: Cropping Patterns Across Zones

Agro-Climatic Zone	Dominant Crops
Central Plateau & Hills	Soybean–Wheat, Paddy–Wheat, Maize–Chickpea
Western Plateau and Hills	Soybean–Gram, Jowar–Wheat, Cotton
Gujarat Plains & Hills	Groundnut–Wheat, Paddy–Onion, Cotton–Castor
Eastern Plateau & Hills	Paddy–Lentil, Maize–Mustard, Rainfed pulses

Source: Planning Commission, Government of India. (2001). Agro-Climatic Regional Planning: An Overview.

3.2 Cropping intensity index

The series of maps (Fig.5) shows a clear and steady increase in cropping intensity across the Narmada Basin from 1966 to 2017. In the earlier decades, most districts had low intensity, indicating predominantly single-season cropping. Over time, particularly after 1990, central districts like Hoshangabad, Sehore, Raisen, and Indore began showing higher values due to expanded irrigation and improved agricultural practices. By 2017, a majority of the basin recorded cropping intensities above 150%, reflecting widespread adoption of multiple cropping systems. This shift highlights the growing agricultural intensification and better land utilization across the basin over five decades.

The Fig.6 captures the rise in cropping intensity across Narmada basin districts from 1966 to 2017, highlighting a significant transformation in land use intensity. Districts like Balaghat and Betul show a marked increase from around 108% and 101% in 1966 to 181% and 178% respectively by 2017, indicating widespread adoption of double and triple cropping. Similarly, Khargone and Khandwa moved from near 105–110% to above 165% by 2017, reflecting improved irrigation and input use. Core agricultural districts such as Hoshangabad, Sehore, and Raisen maintained consistently high values, sustaining cropping intensities above 130% in recent decades. In contrast, eastern and forested districts like Shahdol and Seoni exhibit more modest growth, with intensity increasing slowly from near 100% to around 110–115%. Overall,

the data points to a clear trend of agricultural intensification, particularly in the central and western basin, with 2017 marking the peak of land use efficiency in most regions. This steady increase in cropping intensity across most districts indicates a basin-wide trend toward

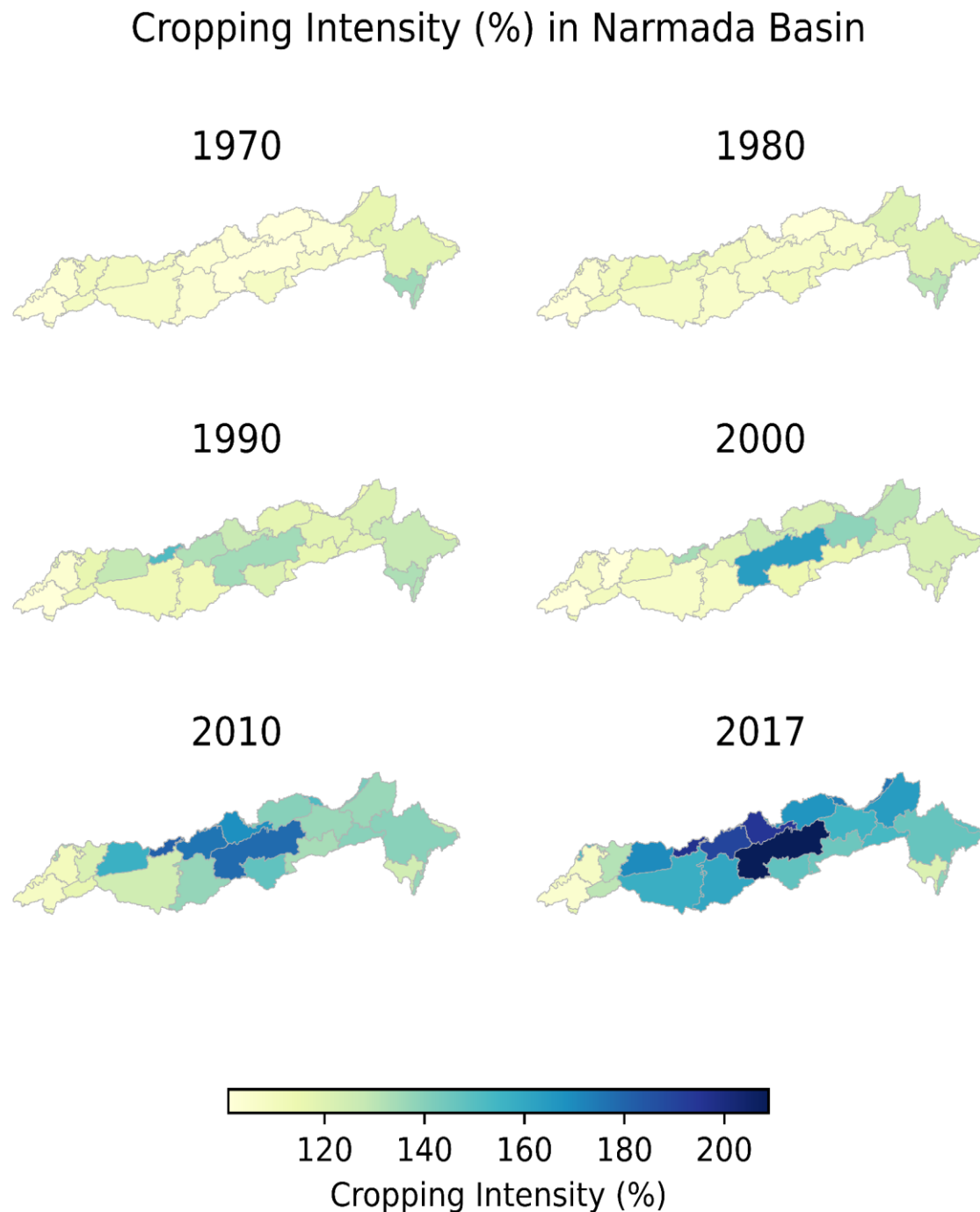


Figure 5: Temporal pattern of district wise cropping intensity in Narmada basin

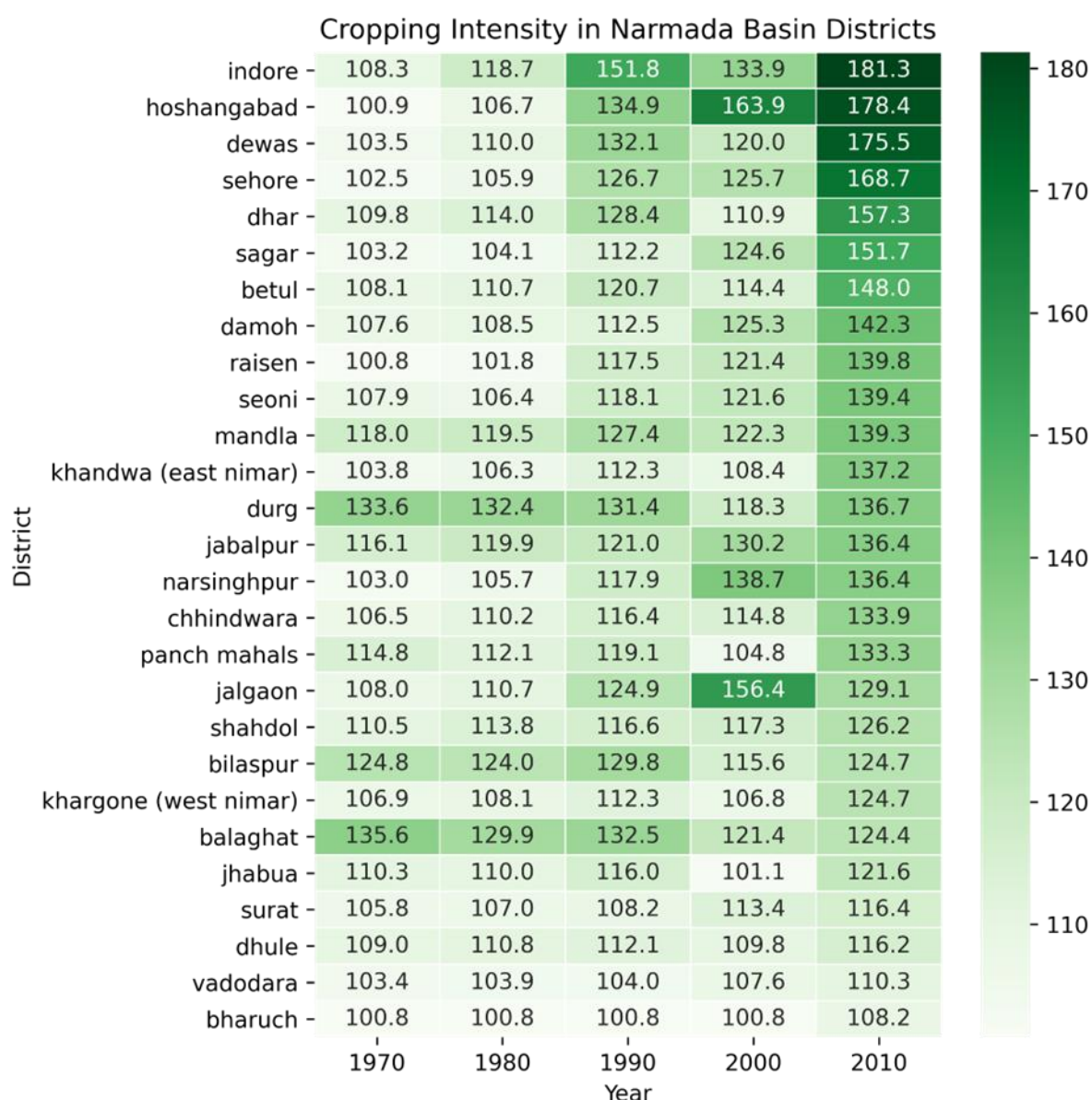


Figure 6: Year wise cropping intensity of all districts in Narmada basin

intensive land use, driven by improvements in irrigation, technology, and access to inputs. The high values in 2017 across multiple districts signal a near-saturation of agricultural land use, with double or even triple cropping becoming common in central and western parts of the basin.

In 1966, most districts reported cropping intensities close to or just above 100%, reflecting predominantly single-season farming with limited irrigation support. By 2017, nearly all districts show a substantial rise, with many exceeding 130% and several reaching or surpassing 160%, such as Balaghat, Betul, Khandwa, and Khargone. This dramatic shift indicates a transition towards more intensive, multi-season cropping patterns, supported by expanded irrigation infrastructure, increased fertilizer and input use, and a policy push for double cropping.

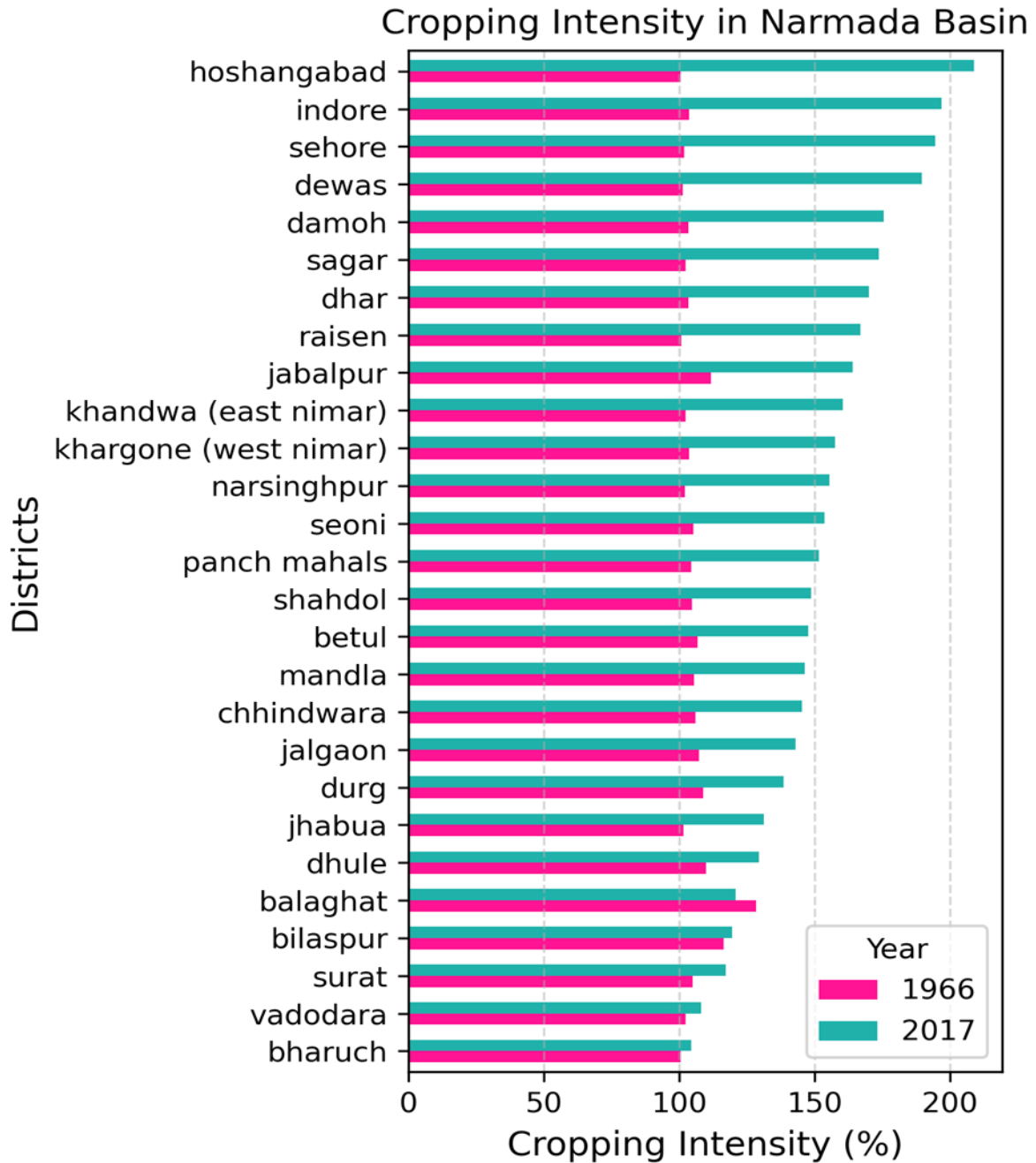


Figure 7: Changes in cropping intensity of all districts in 2017 in Narmada basin w.r.t 1966

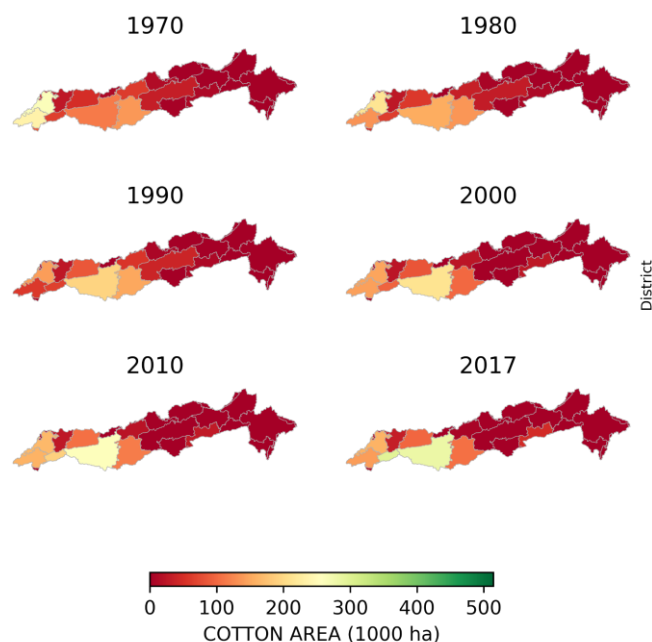
The growth is especially pronounced in central and western districts of Madhya Pradesh, which now form the agricultural core of the basin. In contrast, a few districts on the periphery—likely constrained by ecological or infrastructural factors—show more modest increases. The plot succinctly reflects the broader trend of agricultural intensification and improved land productivity across the basin over five decades.

4 Crop Production and Average Yield

4.1 Crop Area and Yield of Major Crops

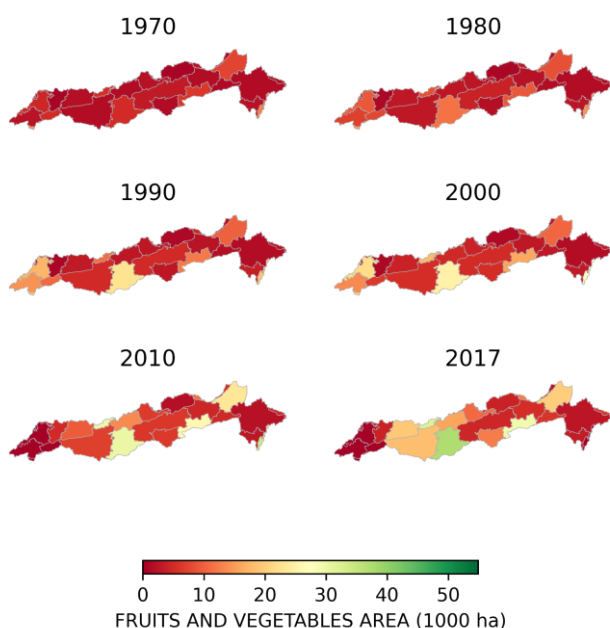
District-wise analysis reveals clear patterns of crop dominance and transitions over time. Harda

COTTON AREA (1000 ha) in Narmada Basin



District	1970	1980	1990	2000	2010	2017
khargone / west nimar	98.0	132.6	166.5	183.8	225.2	243.4
vadodara / baroda	133.1	108.9	71.8	75.1	84.7	81.1
khandwa / east nimar	91.3	90.1	99.7	66.2	76.3	70.0
bharuch	113.2	63.6	28.6	68.7	76.2	68.0
dhar	29.8	36.4	51.7	50.6	64.7	59.6
dhule	8.0	7.9	8.2	11.9	23.5	36.9
jhabua	12.5	11.3	11.6	10.4	13.0	15.8
chhindwara	2.6	2.6	2.8	7.5	8.5	14.3
dewas	34.3	20.2	31.3	13.5	12.1	3.4
panchmahal	0.9	0.9	0.4	0.2	0.2	0.4
surat	2.0	1.1	0.1	0.1	0.1	0.3
betul	1.0	0.8	0.4	0.3	0.1	0.1
indore	2.4	0.1	0.1	0.0	0.0	0.1
hoshangabad	32.8	31.6	38.8	1.4	0.2	0.0
jalgaon	0.0	0.0	0.0	0.0	0.0	0.0
durg	0.0	0.0	0.0	0.0	0.0	0.0
jabalpur	0.0	0.0	0.0	0.0	0.0	0.0
mandla	0.0	0.0	0.0	0.0	0.0	0.0
narsinghpur	0.1	0.0	0.0	0.0	0.0	0.0
damoh	0.0	0.0	0.0	0.0	0.0	0.0
raisen	0.2	0.0	0.0	0.0	0.0	0.0
sagar	0.0	0.0	0.0	0.0	0.0	0.0
sehore	4.3	1.9	2.8	0.0	0.0	0.0
seoni / shivani	0.0	0.0	0.0	0.0	0.0	0.0
shahdol	0.0	0.0	0.0	0.0	0.0	0.0
bilaspur	0.0	0.0	0.0	0.0	0.0	0.0
balaghat	0.0	0.0	0.0	0.0	0.0	0.0

FRUITS AND VEGETABLES AREA (1000 ha) in Narmada Basin



District	1970	1980	1990	2000	2010	2017
khandwa / east nimar	3.4	7.6	15.1	16.7	20.1	24.9
khargone / west nimar	1.4	2.4	4.2	4.6	6.0	15.7
dhar	1.1	1.8	1.9	2.4	5.8	11.8
jabalpur	4.3	4.9	5.8	6.1	13.6	11.8
chhindwara	1.9	2.8	3.6	4.8	7.8	8.8
dewas	0.8	1.5	1.5	2.5	7.5	8.8
indore	1.4	2.3	3.0	4.8	8.1	8.6
narsinghpur	1.6	2.0	2.2	2.8	4.3	5.2
betul	0.5	0.7	1.0	2.0	2.4	4.7
hoshangabad	3.2	4.0	4.8	4.9	6.0	4.3
sehore	0.7	0.9	1.0	1.4	2.3	3.7
raisen	0.4	0.5	0.5	0.6	1.0	2.2
mandla	1.3	1.3	1.3	1.3	1.7	2.1
jhabua	0.2	0.4	0.4	0.5	2.2	1.8
seoni / shivani	0.3	0.4	0.5	0.8	1.2	1.5
balaghat	0.5	0.6	0.9	0.8	0.6	0.8
sagar	0.1	0.1	0.2	0.2	0.4	0.5
shahdol	0.1	0.1	0.1	0.1	0.2	0.2
damoh	0.1	0.1	0.1	0.2	0.3	0.1
surat	0.3	0.3	0.4	0.5	0.0	0.0
jalgaon	0.0	0.0	0.0	0.0	0.0	0.0
panchmahal	0.0	0.0	0.1	0.1	0.0	0.0
durg	0.4	0.5	0.6	0.9	1.1	0.0
dhule	0.6	1.0	1.3	0.8	0.0	0.0
bilaspur	0.0	0.0	0.0	0.0	0.0	0.0
bharuch	1.1	3.4	6.8	6.4	0.0	0.0
vadodara / baroda	2.2	4.7	8.8	11.1	0.0	0.0

Figure 8: Temporal pattern of crop wise area distribution in Narmada basin

consistently shows the largest area under soybean cultivation, increasing from ~102 to 184 thousand ha between 1970 and 2017, confirming it as a soybean hub. Sehore and Hoshangabad also show large soybean areas, with steady growth across years, reaching above 120 thousand ha. In contrast, Seoni, Mandla, and Dindori report significant rice areas early on (~77–80 thousand ha in 1970–1990), though a gradual decline is observed, suggesting shifts to alternate kharif crops. Wheat is most dominant in Hoshangabad, Sehore, and Raisen, where rabi area surpasses 200–350 thousand ha by 2017, showing strong canal irrigation and double cropping.

Khargone and Barwani, in the western basin, lead in cotton expansion, with areas exceeding 100 thousand ha by 2017—an indication of market-driven crop shift. Districts like Dewas, Shajapur, and Ujjain exhibit moderate soybean and wheat presence but show a relatively balanced crop mix including pulses. Betul and Narsinghpur reflect diversified patterns with rice, soybean, and wheat all contributing significantly, with clipped areas ranging 50–100 thousand ha, depending on the year and crop. Vadodara and Bharuch in Gujarat show dominance in cotton and pulses post-1990, supported by Narmada canal expansion. Horticulture crops like fruits and vegetables remain minor across most districts but gradually rise in Indore, Bhopal, and Jabalpur, reaching up to 10–25 thousand ha by 2017. Overall, soybean and wheat dominate the Narmada basin's cropped area, with soybean leading in kharif and wheat in rabi. Rice remains regionally important, especially in Seoni and Mandla, while cotton's footprint is expanding westward. Pulses and horticulture are emerging in smaller pockets, adding diversity to the region's cropping system.

We observe notable patterns in district-level crop output. Harda emerges again as a production powerhouse, especially for soybean and wheat, reaching values like ~4518.9 and ~4169.7 (likely in 1000 tons), marking it as the most productive district in the basin. Sehore, Hoshangabad, and Dewas also contribute substantially, with production values above 3000 for wheat and soybean, indicating high cropping intensity and good yield. Seoni, Mandla, and Dindori report significant rice and pulse production in earlier years, though their contribution declines relative to western districts by 2017. Khargone and Barwani stand out with rapidly increasing cotton production, exceeding 2200–2300 units in recent years, likely due to black soil, Bt cotton adoption, and irrigation expansion. Narsinghpur and Raisen show diversified output across multiple crops, reflecting balanced area allocation and reliable irrigation. In Gujarat, Vadodara and Bharuch record high cotton and pulse production in later years (~2000+), suggesting benefits from Narmada canal irrigation. Meanwhile, districts like

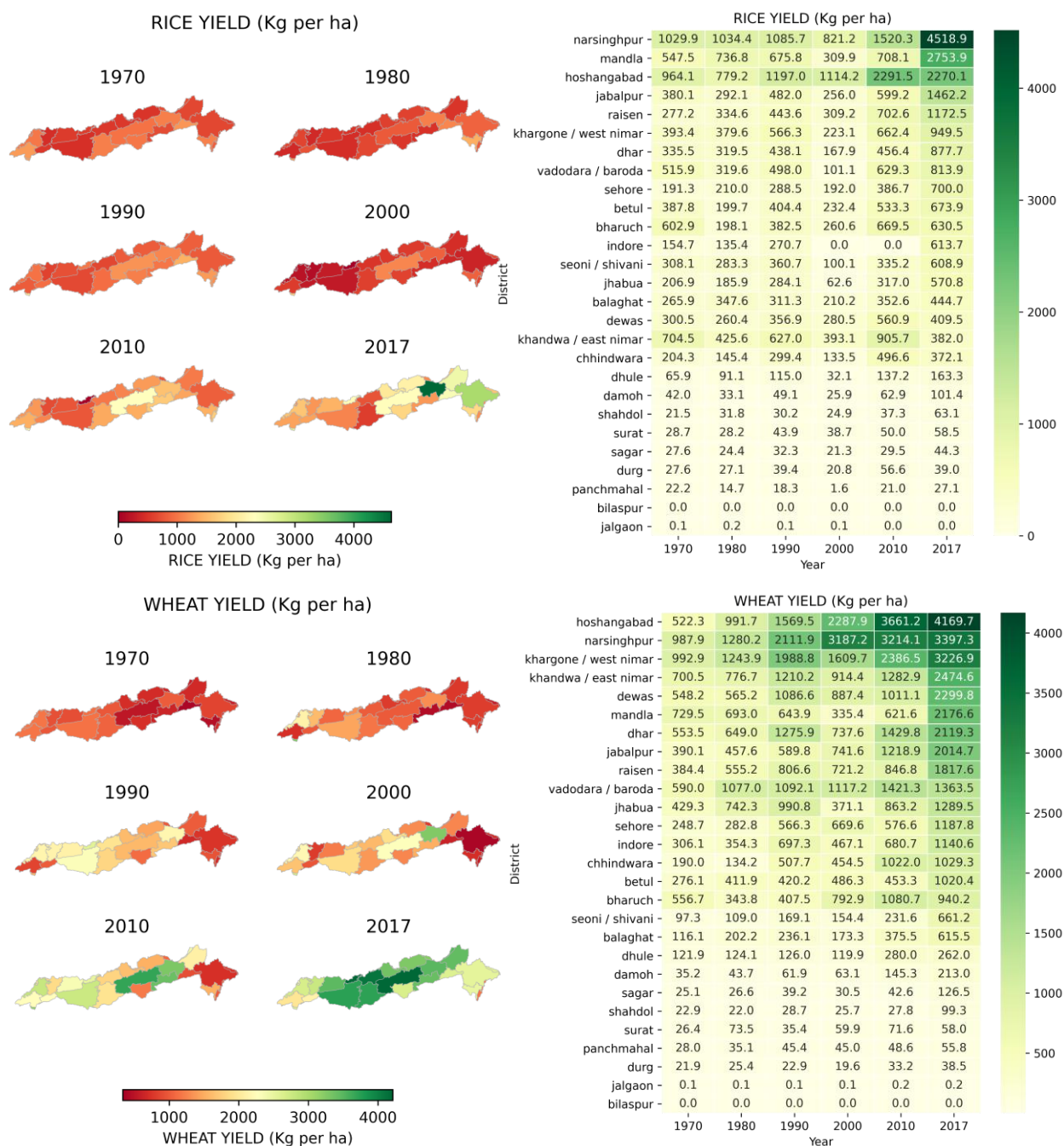


Figure 9: Temporal pattern of rice and wheat yield distribution in Narmada basin

Shajapur, Rajgarh, and Betul have steady but moderate production across categories, acting as supporting contributors. Interestingly, Indore, Jabalpur, and Bhopal show notable increases in vegetable and fruit production, with horticulture output reaching 700–900 in some cases, suggesting economic crop diversification in peri-urban areas.

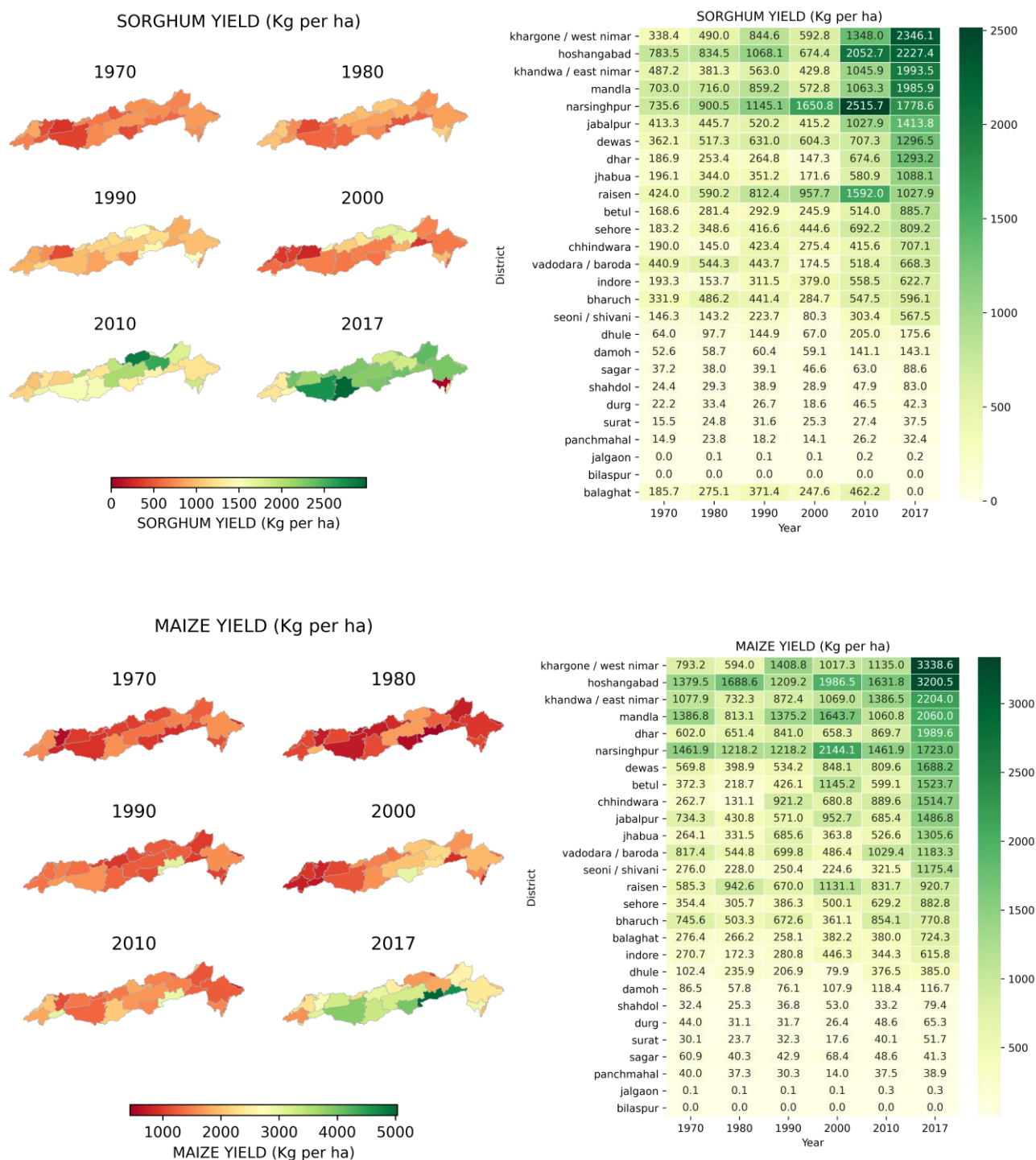


Figure 10: Temporal pattern of sorghum and maize yield distribution in Narmada basin

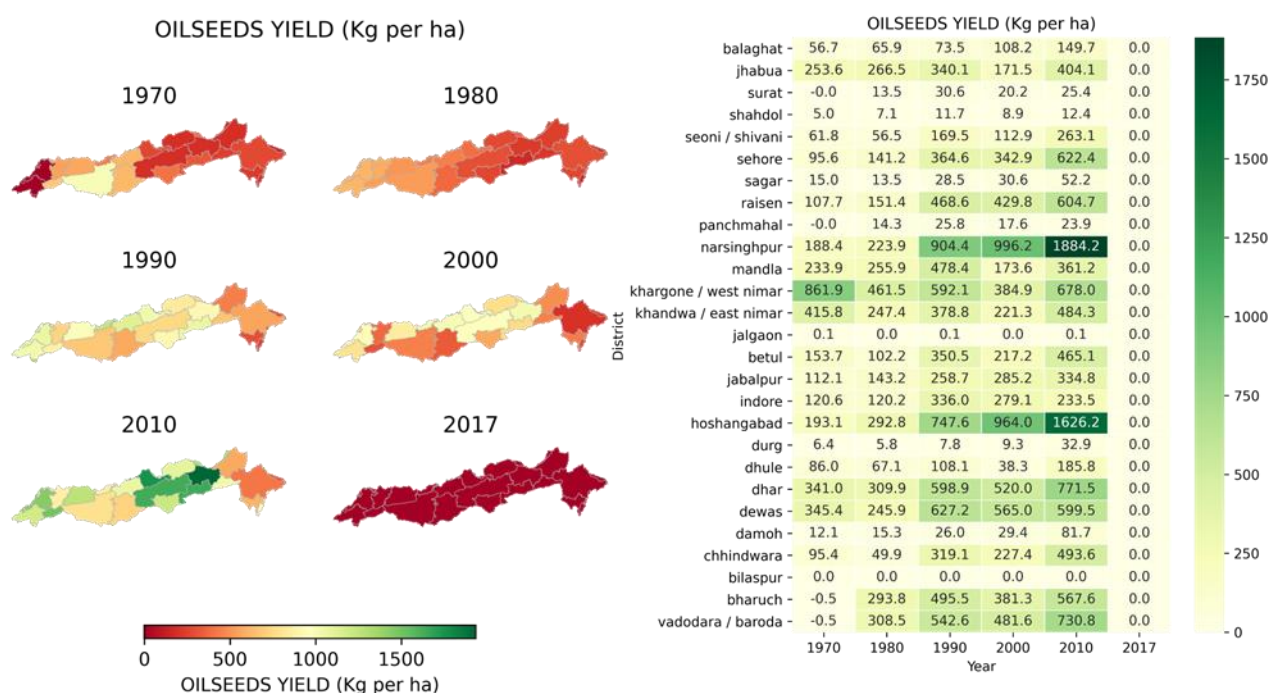


Figure 11: Temporal pattern of oil seeds yield distribution in Narmada basin

Lastly, tribal and hilly districts like Alirajpur, Jhabua, and Dindori show lower production values, especially in recent years, which might reflect limited irrigation or market access. Overall, soybean and wheat dominate total production in the basin, with cotton emerging as a strong third crop. Rice is still important in select districts, while pulses and horticulture contribute to diversity and resilience. The data indicate how the Narmada Basin supports both staple grains and high-value crops, shaped by district-specific agro-ecological and infrastructural conditions.

4.2 Sub-basin wise crop production of different crop

In terms of sub-basin wise crop production, Table 4 to Table 12 shows district wise distribution of different crops in Rabi and Kharif season. It is important to note that there a few common districts across the sub-basins for example, Alirajpur comes under Middle Narmada Basin as well in the Lower Narmada Basin also. In that case, such districts' data has been incorporated into in one basin only as per their major proportion to the respective sub-basin.

Table 4: Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023

District	Arhar/Tur			Groundnut			Maize			Niger seed			Rice		
	Kharif			Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Kabirdham	4725	3289	0.7	993	2162	2.18	1381	3793	2.75	138	31	0.22	133437	284508	2.13
Rajnandgaon	881	620	0.7	-	-	-	195	765	3.92	1	1	1	185611	358544	1.93
Anuppur	2050	1384	0.68	105	184	1.75	7347	17009	2.32				135881	320000	2.36
Balaghat	306	392	1.28	-	-	-	1486	4696	3.16	300	75	0.25	306354	897617	2.93
Betul	9095	6949	0.76	2626	5331	2.03	171998	584449	3.4	-	-	-	33807	96349	2.85
Chhindwara	17674	22711	1.28	5075	11557	2.28	360504	1312235	3.64	-	-	-	35664	104852	2.94
Damoh	4088	3728	0.91	56	126	2.25	2145	6097	2.84	-	-	-	91167	345067	3.78
Dindori	2073	985	0.48	30	54	1.8	15822	38163	2.41	5380	1323	0.25	159580	352672	2.21
Hoshangabad	789	1006	1.28	-	-	-	29013	91246	3.15	-	-	-	237086	1019470	4.3
Jabalpur	4130	4646	1.12	35	74	2.11	28620	81368	2.84	-	-	-	181663	673606	3.71
Katni	1015	988	0.97	-	-	-	801	2450	3.06	-	-	-	122956	484447	3.94
Mandla	1840	1489	0.81	-	-	-	14685	44688	3.04	3000	1164	0.39	194475	603845	3.11
Narsinghpur	17552	20185	1.15	-	-	-	63711	172212	2.7	-	-	-	87429	340011	3.89
Raisen	14861	12111	0.81	40	98	2.45	4429	9701	2.19	-	-	-	285453	1016498	3.56
Sagar	2227	2385	1.07	379	671	1.77	26915	79803	2.97	-	-	-	54558	142669	2.61
Seoni	1646	1972	1.2	499	1113	2.23	161587	450827	2.79	600	200	0.33	240842	805376	3.34
Umaria	5390	3746	0.69	-	-	-	4727	10792	2.28	200	74	0.37	89196	188650	2.12

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 5: Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023 (cont.)

District	Sesamum			Small millets			Soyabean			Urad			Moong(Green Gram)		
	Kharif			Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Kabirdham	163	73	0.45	6652	3184	0.48	7136	7101	1	688	269	0.39	-	-	-
Rajnandgaon	102	74	0.73	231	174	0.75	2643	2600	0.98	145	53	0.37	4	3	0.75
Anuppur	311	96	0.31	17800	14774	0.83	3770	3091	0.82	739	464	0.63	-	-	-
Balaghat	24	17	0.71	5900	5546	0.94	25	26	1.04	146	88	0.6	-	-	-
Betul	176	74	0.42	630	425	0.67	216394	220722	1.02	512	178	0.35	80	41	0.51
Chhindwara	83	38	0.46	13160	14015	1.06	20202	30323	1.5	1369	705	0.51	188	103	0.55
Damoh	1679	1270	0.76				21586	20399	0.95	187483	127488	0.68	2694	2236	0.83
Dindori	45	19	0.42	24926	25923	1.04	6676	5715	0.86	1625	895	0.55	-	-	-
Hoshangabad	350	343	0.98	160	100	0.63	33700	35722	1.06	606	321	0.53	1210	496	0.41
Jabalpur	209	129	0.62	3700	3411	0.92	176	164	0.93	13772	9283	0.67	266	168	0.63
Katni	6451	4083	0.63	614	677	1.1	82	102	1.24	715	590	0.83	37	31	0.84
Mandla	292	171	0.59	28700	33579	1.17	62	55	0.89	875	402	0.46	-	-	-
Narsinghpur	405	359	0.89	173	102	0.59	25321	34082	1.35	27708	16043	0.58	951	618	0.65
Raisen	353	184	0.52	-	-	-	49604	34822	0.7	12750	5036	0.39	1560	883	0.57
Sagar	1437	507	0.35	110	55	0.5	237373	303837	1.28	203244	146335	0.72	1405	955	0.68
Seoni	249	130	0.52	4500	3960	0.88	1282	1182	0.92	2038	897	0.44	14	8	0.57
Umaria	3082	1365	0.44	6780	5878	0.87	1223	841	0.69	1854	853	0.46	-	-	-

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 6: Area, Production & Yield of Different Crops under Narmada Upper Basin, 2022-2023

District	Gram			Khesari			Linseed			Masoor			Peas & beans (Pulses)		
	Rabi			Rabi			Rabi			Rabi			Rabi		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Kabirdham	81268	74789	0.92	10681	5764	0.54	32	9	0.28	1866	687	0.37	497	183	0.37
Rajnandgaon	34665	30111	0.87	14349	7562	0.53	160	53	0.33	2798	1162	0.42	149	70	0.47
Anuppur	16500	12210	0.74	-	-	-	5686	3639	0.64	20800	14414	0.69	1830	1317	0.72
Balaghat	55800	58981	1.06	-	-	-	711	441	0.62	400	211	0.53	559	311	0.56
Betul	61800	63530	1.03	-	-	-	13	0	0	1100	781	0.71	1498	1138	0.76
Chhindwara	55200	112056	2.03	-	-	-	15	14	0.93	2600	2894	1.11	4366	3222	0.74
Damoh	109900	203315	1.85	-	-	-	531	455	0.86	45500	66885	1.47	982	738	0.75
Dindori	24600	31980	1.3	-	-	-				39400	49447	1.26	3394	2423	0.71
Hoshangabad	64400	129444	2.01	-	-	-	29	19	0.66	770	1109	1.44	22	13	0.59
Jabalpur	23500	41713	1.78	-	-	-	158	130	0.82	4600	7558	1.64	18609	23969	1.29
Katni	32600	55811	1.71	-	-	-	182	157	0.86	4200	4738	1.13	258	331	1.28
Mandla	24000	32472	1.35	-	-	-	2242	1480	0.66	29500	30385	1.03	4410	2469	0.56
Narsinghpur	78800	129153	1.64	-	-	-	4	3	0.75	31200	39000	1.25	2360	2192	0.93
Raisen	113420	231377	2.04	-	-	-	1	1	1	31520	41291	1.31	148	140	0.95
Sagar	104800	135821	1.3	-	-	-	323	246	0.76	85500	80627	0.94	1615	1562	0.97
Seoni	48000	97920	2.04	-	-	-	2559	1663	0.65	15000	12150	0.81	1961	1243	0.63
Umaria	18090	29849	1.65	-	-	-	2124	1272	0.6	5250	4274	0.81	1985	1211	0.61

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 7: Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023

District	Arhar/Tur			Castor seed			Cotton(lint)			Groundnut			Jowar		
	Kharif			Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonnes/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (tone/ha.)	Area (Hectare)	Production (Bales)	Yield (Bales/ha.)	Area (Hectare)	Production (Tonnes)	Yield (Ton/ha.)	Area (ha.)	Production (Tonnes)	Yield (Tonnes/ha.)
Chhotaudepur	14999	16029	1.07	2016	4517	2.24	103793	391288	3.77	541	1395	2.58	20	27	1.35
Alirajpur	2438	1702	0.7	-	-	-	22403	22739	1.01	13262	26259	1.98	3034	4279	1.41
Barwani	1258	1377	1.09	-	-	-	90095	179289	1.99	5679	12186	2.15	16662	42072	2.53
Bhopal	98	84	0.86	-	-	-				73	151	2.07	13	22	1.69
Burhanpur	4460	4059	0.91	-	-	-	26342	51499	1.96	107	170	1.59	1905	6364	3.34
Dewas	471	404	0.86	-	-	-	561	813	1.45	58	110	1.9	238	453	1.9
Harda	91	125	1.37	-	-	-							121	162	1.34
Indore				-	-	-	67	49	0.73	145	306	2.11	99	190	1.92
Jhabua	1819	1255	0.69	-	-	-	23997	28700	1.2	3780	8558	2.26	945	1117	1.18
Khandwa	2171	1604	0.74	-	-	-	45901	60498	1.32	386	723	1.87	149	211	1.42
Khargone	4127	3302	0.8	-	-	-	191341	252953	1.32	713	1718	2.41	2075	4175	2.01
Sehore	976	644	0.66	-	-	-				88	159	1.81	109	248	2.28
Dhule	3097	1992	0.64	-	-	-	258513.52	545985.2	2.11	9662.07	9495.88	0.98	7495.29	8389.48	1.12
Nandurbar	12760	6165	0.48	-	-	-	129061	212362.09	1.65	1568.99	1408.17	0.9	20421.04	24058.03	1.18

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 8: Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023

District	Bajra			Sesamum			Small millets			Other Cereals		
	Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Chhotaudepur	-	-	-	-	-	-	-	-	-	-	-	-
Alirajpur	6644	7673	1.15	25	10	0.4	146	91	0.62	-	-	-
Barwani	5406	6179	1.14							-	-	-
Bhopal	2	3	1.5	21	9	0.43	1830	1700	0.93	-	-	-
Burhanpur	5	6	1.2	-	-	-	-	-	-	-	-	-
Dewas	-	-	-	-	-	-	-	-	-	-	-	-
Harda	1	1	1	35	20	0.57	-	-	-	-	-	-
Indore	3	8	2.67	-	-	-	-	-	-	-	-	-
Jhabua	7	4	0.57	-	-	-	165	119	0.72	-	-	-
Khandwa	9	5	0.56	34	11	0.32	70	43	0.61	-	-	-
Khargone	88	67	0.76	-	-	-	-	-	-	-	-	-
Sehore	14	26	1.86	300	186	0.62	-	-	-	-	-	-
Dhule	50093	55786	1.11	309.37	80.56	0.26	-	-	-	668	434.2	0.65
Nandurbar	6327	7348	1.16	0.58	0.2	0.34	-	-	-	4504.35	1576.52	0.35

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 9: Area, Production & Yield of Different Crops under Narmada Middle Basin, 2022-2023

District	Rapeseed & Mustard			Linseed			Masoor			Peas & beans (Pulses)			Other Cereals		
	Rabi			Rabi			Rabi			Rabi			Rabi		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Chhotaudepur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alirajpur	520	405	0.78	-	-	-	-	-	-	-	-	-	-	-	-
Barwani	520	521	1	1	1	1	-	-	-	-	-	-	-	-	-
Bhopal	1780	2225	1.25	2	1	0.5	300	377	1.26	17	14	0.82	-	-	-
Burhanpur	520	411	0.79	-	-	-	-	-	-	-	-	-	-	-	-
Dewas	836	985	1.18	1	0	0	400	460	1.15	132	109	0.83	-	-	-
Harda	1365	1029	0.75	1	0	0	200	80	0.4	29	17	0.59	-	-	-
Indore	525	683	1.3	3	1	0.33	140	154	1.1	284	218	0.77	-	-	-
Jhabua	545	649	1.19	1	1	1	-	-	-	130	89	0.68	-	-	-
Khandwa	878	623	0.71	2	0	0	-	-	-	143	76	0.53	-	-	-
Khargone	1057	1348	1.28	-	-	-	-	-	-	-	-	-	-	-	-
Sehore	961	1023	1.06	12	12	1	4500	2867	0.64	51	44	0.86	-	-	-
Dhule	-	-	-	-	-	-	-	-	-	-	-	-	366	347.7	0.95
Nandurbar	-	-	-	-	-	-	-	-	-	-	-	-	448.4	231.43	0.52

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 10: Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023

District	Arhar/Tur			Bajra			Castor seed			Cotton(lint)		
	Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Bales)	Yield (Bales/Hectare)
Bharuch	77870	87895	1.13	25	44	1.76	2472	4528	1.83	91694	288319	3.14
Dohad	7930	4293	0.54	-	-	-	-	-	-	349	812	2.33
Narmada	19943	22014	1.1	10	18	1.8	703	1575	2.24	52477	178027	3.39
Panch mahals	15572	24364	1.56	222	394	1.77	5214	8772	1.68	12214	47614	3.9
Surat	8852	10670	1.21	-	-	-	72	161	2.24	4301	12444	2.89
Vadodara	27166	36528	1.34	-	-	-	40484	91899	2.27	81686	438117	5.36

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 11: Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023

District	Groundnut			Jowar			Moong(Green Gram)			Rice		
	Kharif			Kharif			Kharif			Kharif		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Bharuch	29	75	2.59	360	494	1.37	310	182	0.59	9846	17289	1.76
Dohad	471	1215	2.58	-	-	-	68	40	0.59	42773	54527	1.27
Narmada	12	31	2.58	2536	3662	1.44	168	98	0.58	11687	12001	1.03
Panch mahals	277	714	2.58	-	-	-	210	123	0.59	45582	77237	1.69
Surat	701	1808	2.58	6845	8088	1.18	418	245	0.59	41219	94633	2.3
Vadodara	9	23	2.56	-	-	-	32	19	0.59	30260	62531	2.07

Source: Directorate of Economics and Statistics (DES) (2022-23)

Table 12: Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023

Area, Production & Yield of Different Crops under Narmada Lower Basin, 2022-2023															
District	Gram			Jowar			Onion			Other Rabi pulses			Wheat		
	Rabi			Rabi			Rabi			Rabi			Rabi		
	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)	Area (Hectare)	Production (Tonnes)	Yield (Tonne/Hectare)
Bharuch	1,567	1,688	1.08	2,160	2,586	1.2	10	275	27.5	31,740	22,694	0.71	19,375	38,764	2
Dohad	44,69	58,617	1.31				713	19,641	27.55				58,456	157,663	2.7
Narmada	1,241	2,109	1.7	686	1,082	1.58	2	55	27.5	53	22	0.42	1,723	4,750	2.76
Panch mahals	1,804	3,065	1.7	-	-	-	-	-	-	-	-	-	11,780	26,962	2.29
Surat	1,255	2,132	1.7	2,359	2,936	1.24	511	14,077	27.55	352	229	0.65	4,236	10,873	2.57
Vadodara	514	873	1.7	180	284	1.58	199	5,482	27.55	174	130	0.75	27,73	78,447	2.83

Source: Directorate of Economics and Statistics (DES) (2022-23)

4.3 Comparison with state and national averages

A detailed comparison of average crop yields between the Narmada Basin and the national averages from 1966 to 2017 reveals a persistent and multifaceted yield gap across key crops such as rice, wheat, maize, sorghum, oilseeds, and cotton. While India witnessed a substantial rise in agricultural productivity during this period—largely driven by the Green Revolution, improved irrigation, better seed varieties, and input intensification—the Narmada Basin exhibited relatively slower gains. For instance, rice yields in the basin generally remained below 1000 kg/ha until 2010, whereas the national average climbed steadily from about 700 kg/ha in 1966 to over 2200 kg/ha by 2017. Wheat followed a similar trajectory, with national

yields surpassing 2300 kg/ha in recent years, while the basin reached only around 1400 kg/ha.

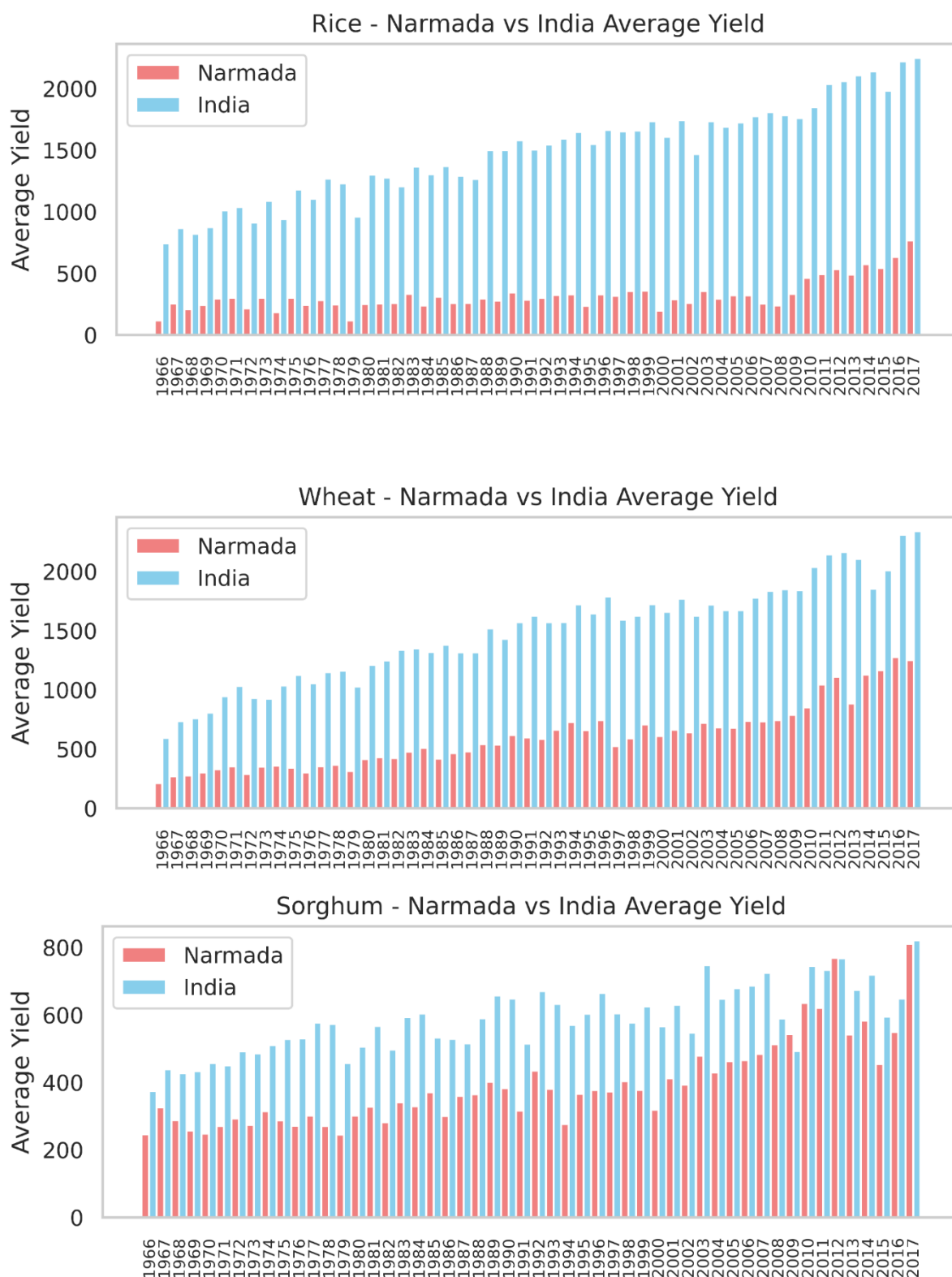


Figure 12: Temporal comparison of crop wise area and yield distribution in Narmada basin

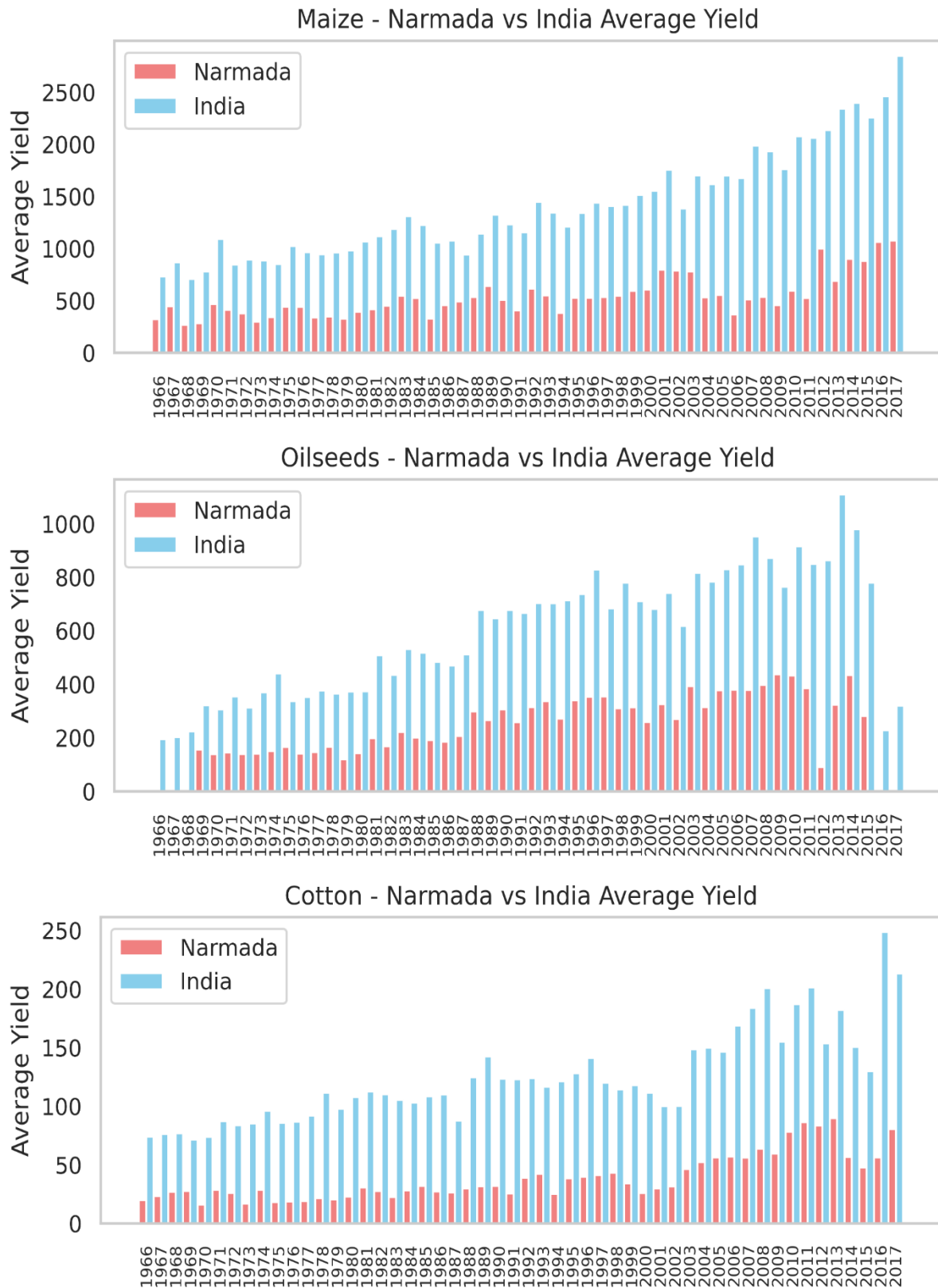


Figure 13: Temporal comparison of crop wise area and yield distribution in Narmada basin

In the case of maize, national productivity has exceeded 2500 kg/ha—reflecting adoption of hybrids and market-linked production—compared to under 1200 kg/ha in the basin. Oilseeds and cotton also show marked disparities, with basin yields often being 30–50% lower than national levels. These differences are indicative of structural constraints in the basin, such as limited access to irrigation infrastructure, reliance on rainfed farming, lower mechanization, and slower diffusion of high-yielding or genetically improved varieties. Despite these gaps, crops like sorghum show relatively closer alignment with national trends, possibly due to its adaptability to semi-arid climates and traditional cultivation practices in the region. Furthermore, the post-2005 period hints at gradual improvement in basin productivity for several crops, reflecting the possible impact of government schemes, targeted investments, or improved market access.

4.4 Yield gaps and productivity constraints.

Yield gap analysis across three GYGA stations in the Narmada Basin—Harsud (Irrigated Wheat), Harsud (Rainfed Wheat), and Jobat Tehsil (Rainfed Maize)—reveals significant spatial and management-related differences in productivity constraints. The yield gap is assessed by comparing actual yield (YA) with both water-limited yield potential (YW) and potential yield under optimal conditions (YP), providing insight into water-related and broader agronomic limitations. At Harsud (Rainfed Wheat), the actual yield is 1.09 t/ha, compared to a water-limited potential of 4.12 t/ha, resulting in a YW–YA gap of 3.03 t/ha. The total gap to potential yield (YP – YA) reaches 6.04 t/ha, indicating that while water stress accounts for roughly half the yield loss, the remaining gap stems from broader limitations such as nutrient stress, pest/disease pressure, or suboptimal management. This suggests an urgent need for both improved water availability and enhanced agronomic practices. For Jobat Tehsil (Rainfed Maize), the actual yield is 1.48 t/ha, while the YW is as high as 12.87 t/ha, producing a striking YW–YA gap of 11.39 t/ha. The gap to potential yield is even higher at 12.00 t/ha, making this site an outlier in terms of untapped productivity. These results point to severe water stress and systemic underperformance, potentially linked to minimal input use, limited extension access, and climate-induced constraints. In contrast, Harsud (Irrigated Wheat) reports a higher actual yield of 3.17 t/ha, with a potential yield (YP) of 5.59 t/ha. While water-limited yield (YW) was not reported for this irrigated scenario, the total yield gap of 2.42 t/ha suggests that further gains are possible through improved cultivar choice, better nutrient management, and enhanced on-farm practices under irrigation.

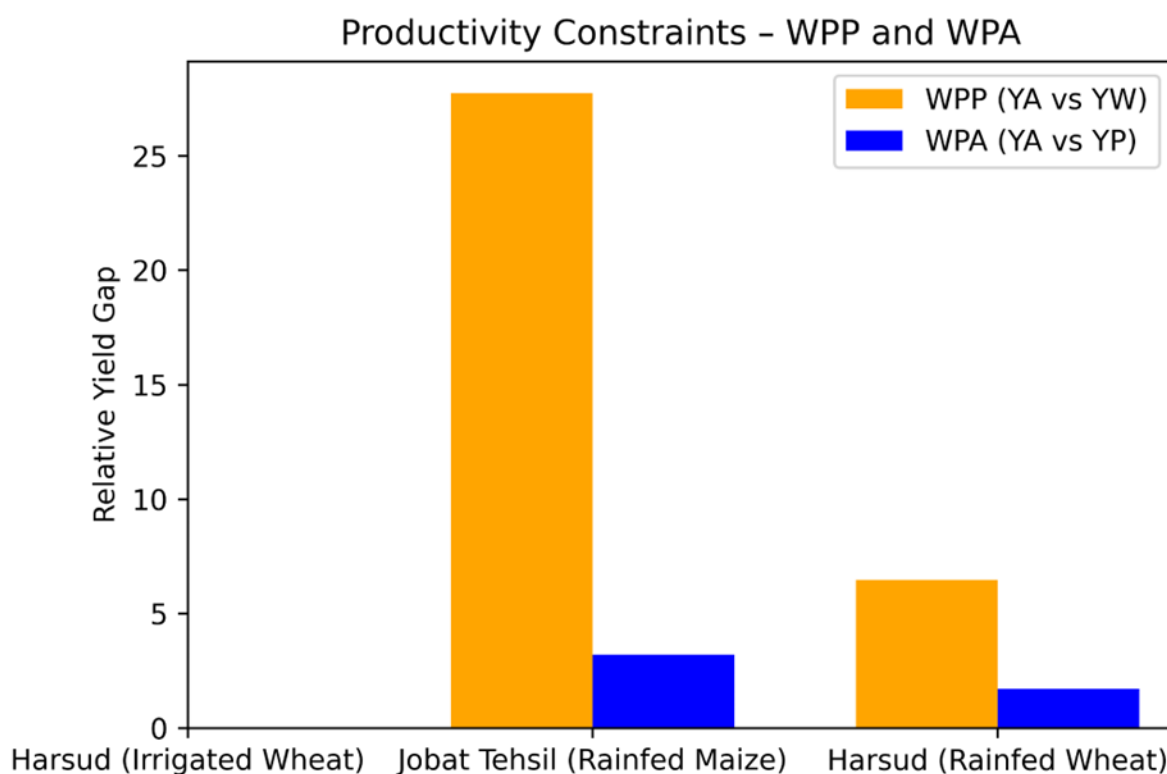


Figure 14: Productivity constraints for GYGA stations in Narmada basin

The Water Productivity Penalty (WPP) quantifies the percentage of yield lost relative to the water-limited potential (YW), while the Yield Potential Penalty (WPA) measures the total loss compared to full potential yield (YP). These values highlight the efficiency of current production relative to attainable benchmarks. At Jobat Tehsil, WPP is high at 27.7%, meaning that nearly one-third of yield potential under water-limited conditions is not being realized. However, the WPA is just 3.2%, indicating that once water limitations are addressed, only marginal gains would come from additional technological improvements. This suggests that water availability or management is the dominant constraint and addressing it could close nearly the entire yield gap at this site. In contrast, Harsud (Rainfed Wheat) shows a much lower WPP of 6.5% and WPA of just 1.7%, indicating relatively efficient yield realization under both water-limited and full potential conditions. This implies that rainfed wheat systems at this site are performing well relative to their potential, with only modest scope for improvement. In summary, the data suggest that Jobat Tehsil requires targeted water management interventions, whereas rainfed wheat at Harsud is comparatively efficient.

5 Agricultural Land Distribution and Farming Practices

5.1 Types of farming systems: subsistence, commercial, rainfed and irrigated

The Narmada River Basin, spanning approximately 98,800 km², extends across four major states in India—Madhya Pradesh (82%), Gujarat (12%), Maharashtra (4%), and Chhattisgarh (2%). Agriculture is the primary livelihood in this region, and the basin exhibits a diversity of farming systems shaped by agro-climatic zones, topography, irrigation availability, and socioeconomic conditions.

Table 13: Farming System and Their Coverage

Farming System	Dominant Zones	Area Coverage (%)	Crops Grown	Key Features
Rainfed	Upper & Lower Hills, Uplands (MP, CG)	~50%	Millets, pulses, oilseeds	Monsoon-dependent; low-input, risk-prone
Irrigated	Canal-command areas (MP, Gujarat)	~45%	Paddy, wheat, cotton, vegetables	Assured water; supports double/triple cropping
Subsistence	Tribal & highland regions	~20% (within rainfed)	Mixed traditional crops	Primarily for self-consumption
Commercial	Plains near canals and towns	~25–30%	Sugarcane, cotton, hybrid vegetables	Market-oriented, uses modern inputs
Integrated/Watershed	Watershed project areas (all zones)	Growing	Agroforestry, livestock + cropping	Sustainable, resource-conserving

Source: ICAR–CRIDA (Central Research Institute for Dryland Agriculture). (2015).

▪ Rainfed Agriculture

Rainfed farming dominates in the upper catchment areas and undulating lands. Approximately 50% of cultivated land is rainfed.

- Kharif crops: Maize, soybean, millets, tur (pigeon pea), and cotton

- Rabi crops: Chickpea, wheat, sunflower

▪ **Irrigated Agriculture**

The Narmada Valley is home to extensive irrigation infrastructure including:

- Sardar Sarovar Project (Gujarat): ~2 million hectares irrigated
- Indira Sagar & Omkareshwar Projects (Madhya Pradesh): ~1.23 million hectares combined

Irrigated lands support intensive cropping systems such as: Paddy–Wheat, Soybean–Gram, Vegetable–Vegetable–Green Fodder.

▪ **Subsistence Farming**

Practiced by tribal communities in districts like Mandla, Dindori, and Nandurbar.

Characterized by:

- Small landholdings (<1 ha)
- Mixed cropping: maize + pulses, or sorghum + legumes
- Minimal external input use

Note: Government programs like the Tribal Sub-Plan and Integrated Tribal Development Programmes (ITDP) are active here.

▪ **Commercial Farming**

- Found near urban centers and canal-fed plains (e.g., Narsinghpur, Barwani, Bharuch)
- Large landholdings (>4 ha) and contract farming models for cotton, vegetables, and floriculture
- Mechanization and agrochemicals are widely adopted

Example: In Bharuch district (Gujarat), 38% of farmers grow cotton commercially under contract-farming frameworks (Source: NABARD District Irrigation Plans, 2018).

▪ **Integrated / Watershed-Based Farming**

Implemented in uplands and rain-shadow areas under schemes like:

- Watershed Development Programme (WDP)
- PMKSY – Watershed Component

Combines: Soil and water conservation, Agroforestry and horticulture, Animal husbandry (goats, backyard poultry).

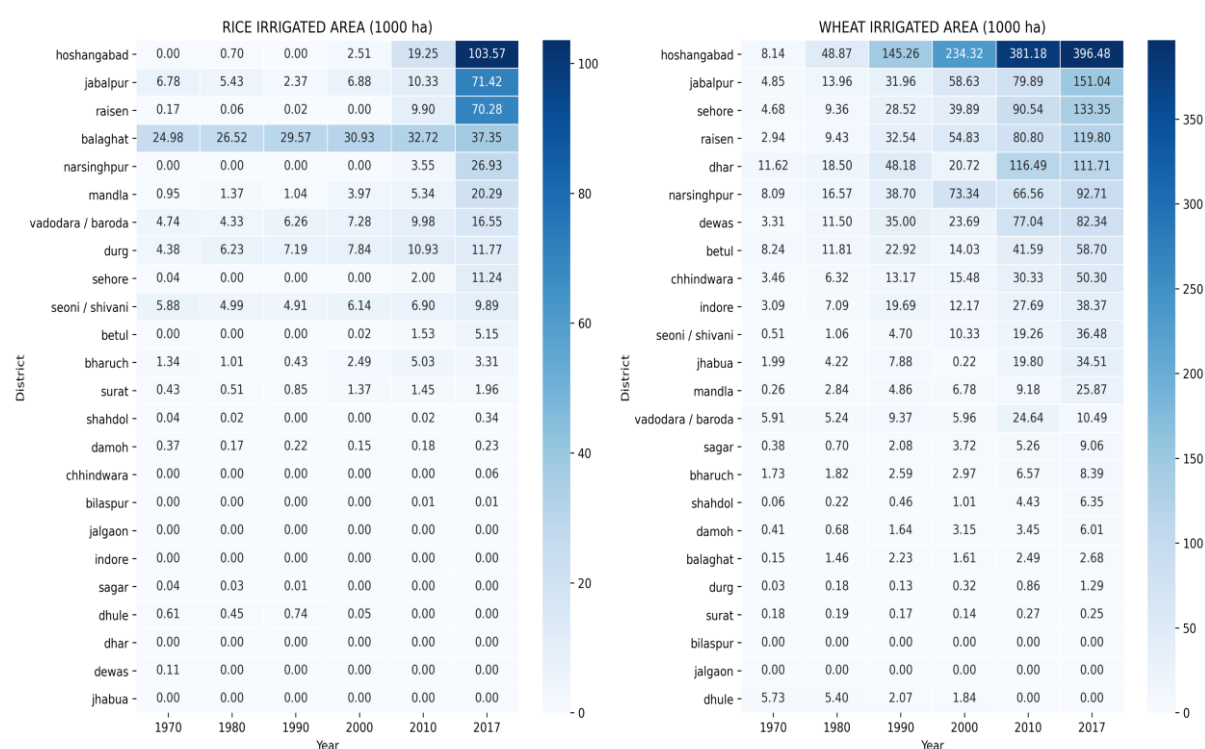


Figure 15: Crop wise irrigated area in Narmada basin

Case: In Dindori district, an integrated project under IWMP increased cropping intensity from 120% to 180% and reduced soil erosion by 60% (Source: Ministry of Rural Development – Watershed Cell).

The Narmada Basin supports a mosaic of farming systems with both traditional subsistence and modern commercial characteristics. With increasing investments in irrigation and integrated watershed management, the region is gradually transitioning towards more resilient and productive agriculture. However, rainfed systems still dominate large tracts, especially in tribal and upland areas, requiring continued policy support.

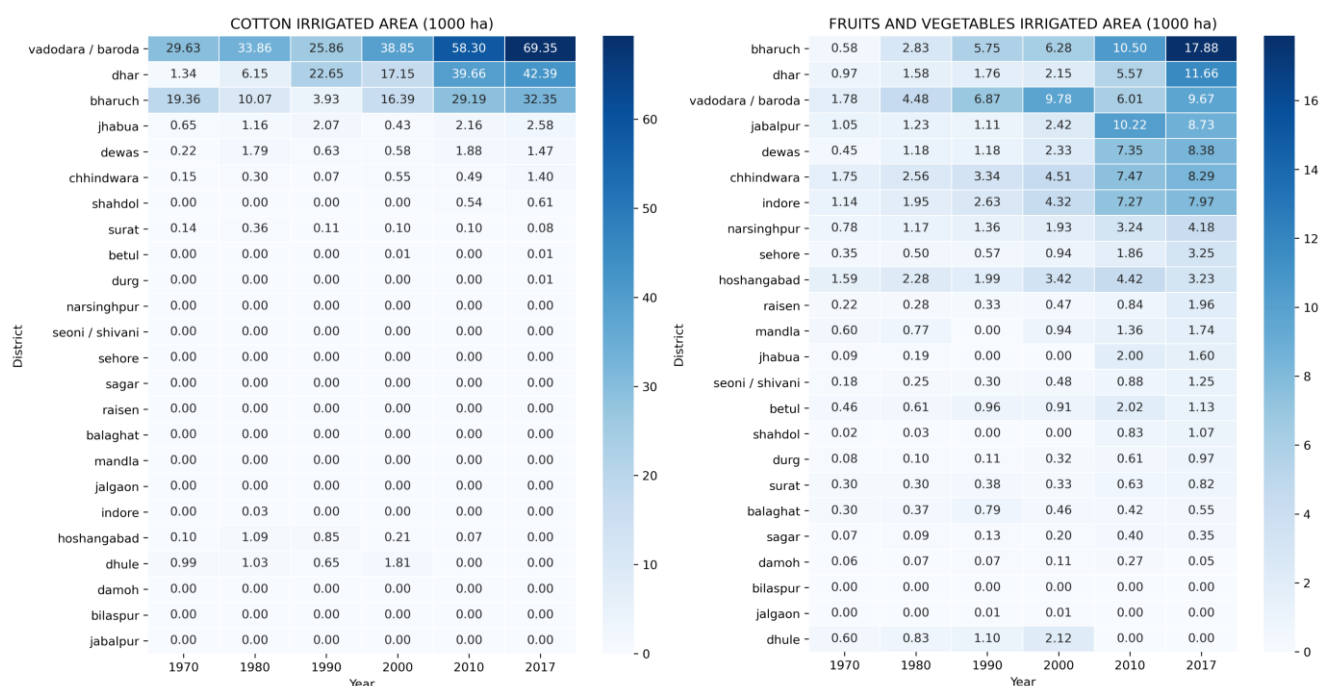


Figure 16: Crop wise irrigated area in Narmada basin

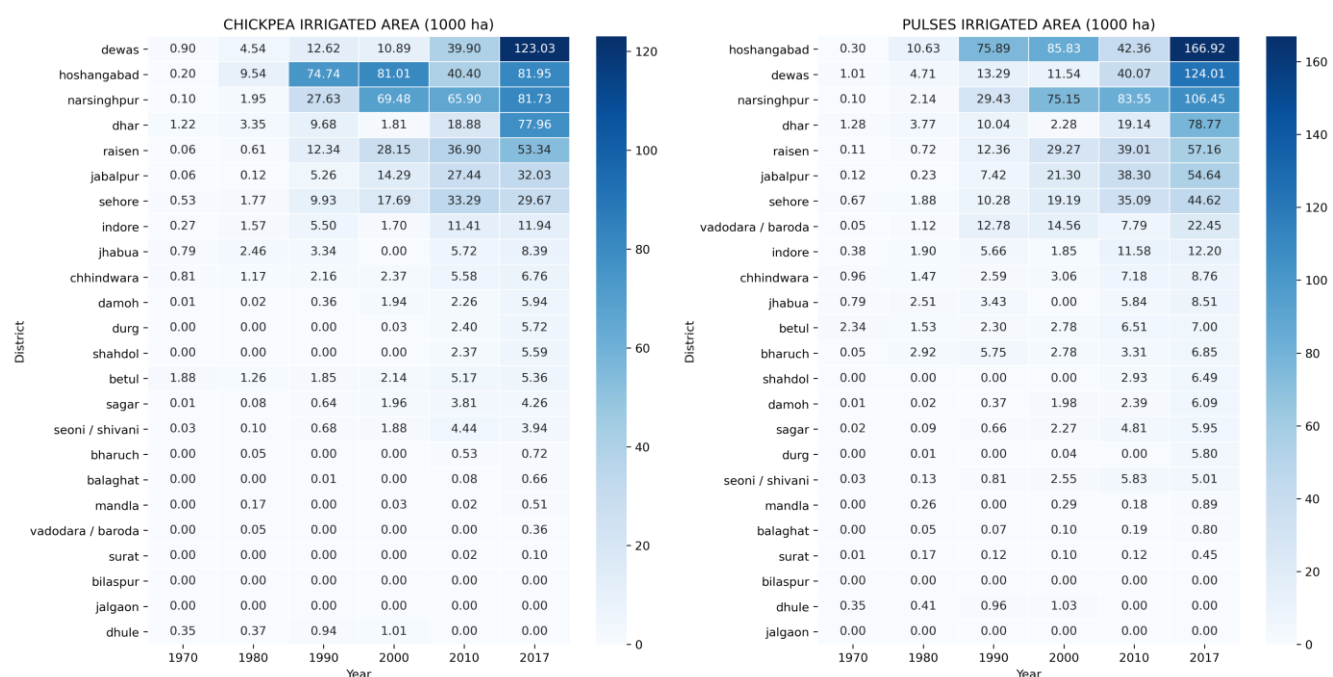


Figure 17: Crop wise irrigated area in Narmada basin

The irrigated area under rice has seen a significant and consistent expansion, particularly from the year 1990 onwards. In the earlier decades, rice cultivation was either negligible or modest across most districts. However, the 2000s marked a sharp increase, and by 2017, several districts—such as Hoshangabad, Narsinghpur, Jabalpur, Mandla, and Barwani—reported more than 30 to 100 thousand hectares of irrigated rice area. This upward trend correlates with the operationalization of major irrigation infrastructure like the Indira Sagar and Sardar Sarovar projects. These projects have enabled assured water supply for paddy cultivation, which is typically water-intensive and largely confined to regions with strong canal command systems. The data clearly suggests that rice has become the dominant kharif crop in several canal-irrigated zones of the basin.

A similar pattern is observed in the case of wheat, which exhibits steady and widespread growth in irrigated area across all decades. Unlike rice, wheat benefits from post-monsoon irrigation, often through groundwater or canal tail-end flows. By 2017, wheat had become one of the most extensively irrigated crops in the basin, with peak coverage exceeding 350 to 400 thousand hectares in districts like Narsinghpur and Hoshangabad. Other districts such as Raisen and Sehore also showed large irrigated areas under wheat, indicating its critical role in the rabi cropping system. The data highlights wheat's status as the preferred winter crop, especially in regions with dual irrigation sources or capacity for groundwater abstraction.

The data for maize indicates a relatively recent but clear expansion in irrigated area, especially from the year 2000 onward. Initially, maize had limited irrigated coverage, but by 2010 and especially 2017, it emerged as a prominent crop in certain districts. Chickpea (gram) shows moderate but consistent growth in irrigated area throughout the basin. Unlike wheat or rice, chickpea often benefits from residual soil moisture and minimal irrigation, especially when sown after paddy or maize. Many districts now report chickpea coverage between 5 and 17 thousand hectares. Its expansion, though less dramatic, is notable because it reflects the adoption of pulses as part of an integrated cropping system. Regions where wheat is not dominant—such as parts of Dewas, Seoni, Raisen, and Jabalpur—have seen a gradual increase in irrigated chickpea, suggesting a balanced rotation between cereals and pulses.

The irrigated area under fruits and vegetables has shown a clear and gradual increase across several districts, particularly between 1990 and 2017. Early years such as 1970 and 1980 saw very limited area under these crops, typically under 5,000 hectares in most districts. However, by 2000 and especially in the period between 2010 and 2017, many districts show figures

ranging from 5,000 to nearly 18,000 hectares. This indicates a growing shift toward horticultural intensification in areas with access to assured irrigation. The spatial dispersion also implies that fruits and vegetables are not restricted to a specific sub-region but are moderately distributed across canal command as well as groundwater-rich areas.

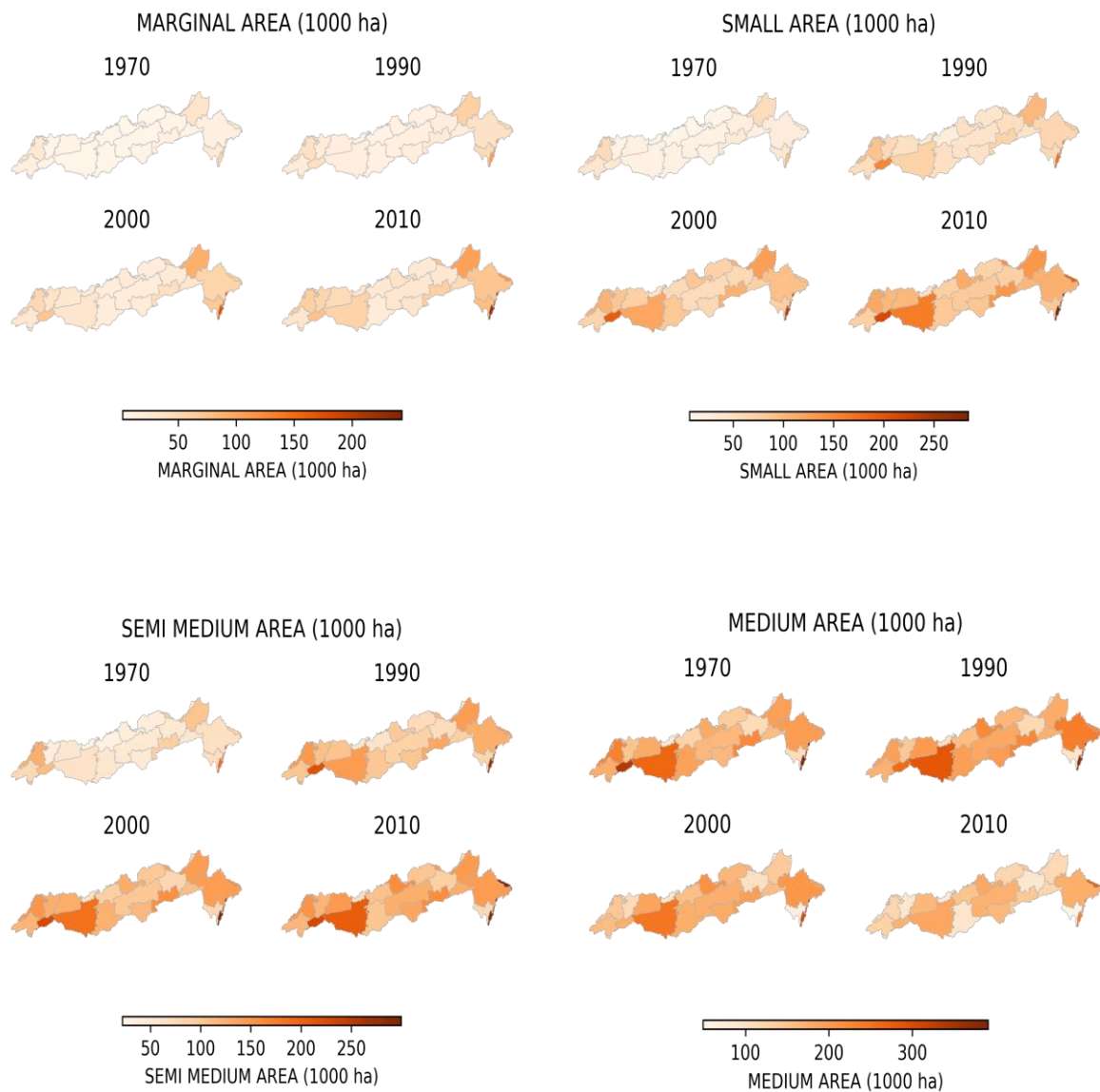


Figure 18: Figure 18: Different area wise landholdings ditribution across Narmada River Basin

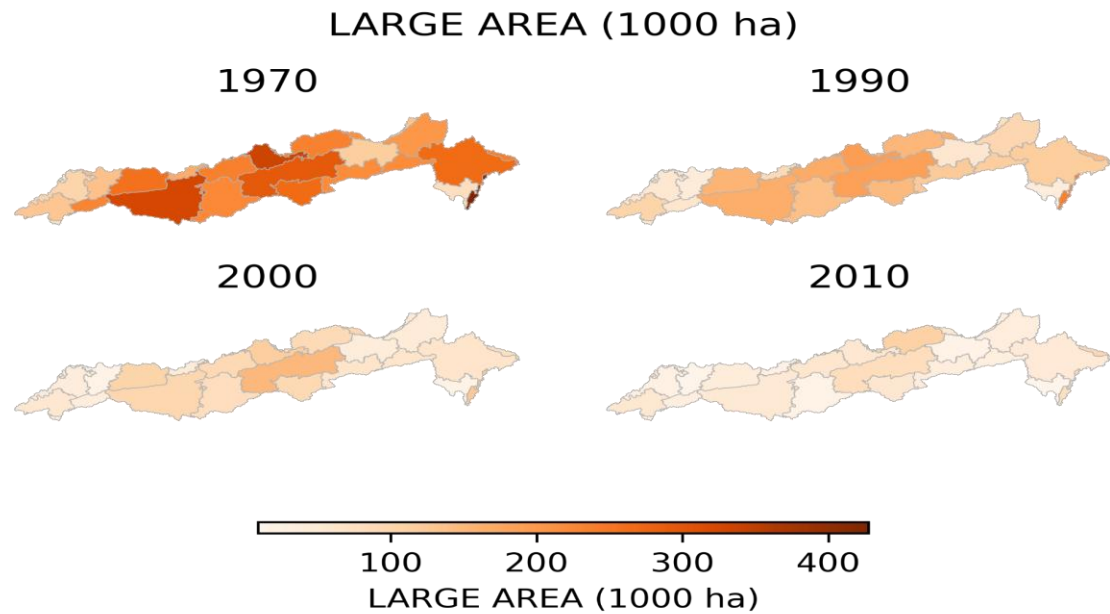


Figure 19: Large area landholdings across Narmada River Basin



Figure 20: Marginal and Small landholding fragmentation patterns in Narmada basin

The landholding patterns across the Narmada basin districts reveal a striking and consistent trend of fragmentation and skewed distribution, as seen in the heatmaps of various operational

holding categories. Marginal holdings (<1 ha) dominate in many districts, with values exceeding 60 ha in places like Madla and Jabalpur, peaking at 61.86 ha in 2010. A similar upward trajectory is visible in small holdings (1–2 ha), where the area under such holdings increased from 13.12 in 1970 to 138.97 in 2010 in Khargone district. The distribution for semi-medium (2–4 ha) and medium (4–10 ha) holdings also shows a shift, with some districts recording over 100 ha under these categories, particularly in 2000 and 2010, indicating moderate land consolidation in a few pockets.

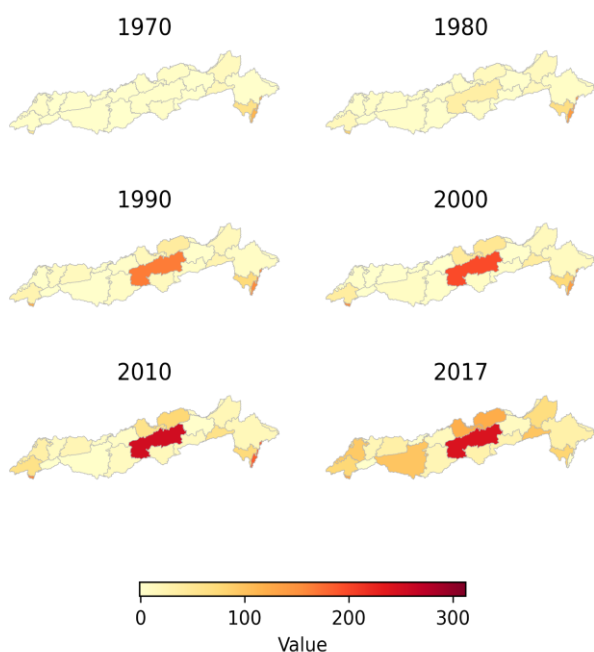
However, the large holding class (>10 ha) shows an opposite trend: initially significant in Hoshangabad district, with values like 292.12 ha in 1970, it sharply declined to 80.46 ha by 2010, underscoring the structural shift away from large-scale farming. Overall, the patterns indicate increasing fragmentation in most districts, reflecting pressures from population growth, inheritance, and possibly distress land sales. The heavy dominance of marginal and small holdings underscores significant constraints for mechanization, irrigation investment, and economies of scale. While the presence of semi-medium holdings in certain districts provides potential leverage for sustainable intensification, the continued erosion of large holdings points toward declining land concentration but also reduced resilience among large landowners.

6 Irrigated Land and Major Irrigation Sources

6.1 Area under irrigation by source: canals, wells, tanks, lift irrigation

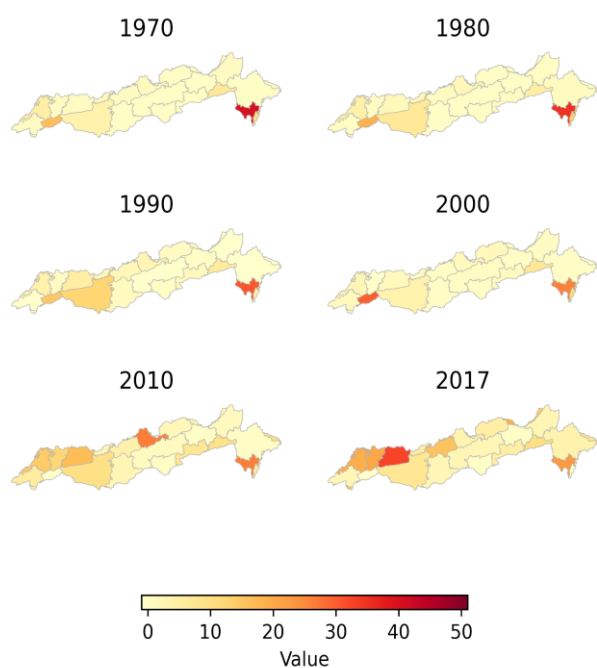
A few districts experienced dramatic increases in canal irrigation — Hoshangabad expanded from 1.49 thousand hectares in 1970 to over 250 thousand hectares by 2000, maintaining 243.21 thousand hectares in 2010. Raisen rose from 2.66 to 67.90 thousand hectares, and Vadodara reached 47.45 thousand hectares, reflecting command area benefits from projects like Indira Sagar and Sardar Sarovar. In tank irrigation, Balaghat peaked at 9.93 thousand hectares in 1970, declining to 5.67 by 2010, while Khargone rose from 3.28 to 10.79 thousand hectares in 1990 before dropping to 6.65 — suggesting localized, unsustained investments. Overall, tank irrigation shows a declining trend, with revitalization needed through programs like WDC–PMKSY and ITDP.

Irrigation by CANALS AREA (1000 ha)



District	1970	1980	1990	2000	2010	2017
hoshangabad	1.49	33.67	164.88	196.28	250.82	243.21
khargone (west nimar)	0.43	2.59	0.86	6.15	1.86	84.61
raisen	2.66	7.04	22.40	28.24	43.26	67.90
vadodara / baroda	1.43	1.07	1.07	1.02	16.80	47.45
sehore	0.60	1.63	5.07	14.87	20.65	42.27
jabalpur	7.07	7.01	8.70	7.74	10.71	39.84
bharuch	1.15	7.09	11.60	18.60	29.29	36.86
mandla	1.12	3.95	5.41	9.59	12.90	25.47
seoni / shivani	3.88	3.62	6.21	9.69	15.13	24.54
balaghat	14.93	16.37	18.52	18.39	18.05	19.80
dhar	0.43	2.01	7.18	0.60	12.16	19.56
khandwa (east nimar)	0.13	0.47	3.79	1.17	6.82	13.79
betul	1.19	2.22	4.52	1.85	5.60	10.76
jhabua	0.00	2.23	3.99	0.00	4.37	8.83
narsinghpur	0.00	0.49	1.07	1.31	0.90	8.65
chhindwara	0.03	0.33	1.50	1.01	3.69	7.65
dewas	0.22	2.02	1.96	0.00	3.38	7.58
surat	0.96	1.85	2.69	3.49	3.58	2.85
damoh	0.40	0.35	0.54	0.59	0.63	1.53
panch mahals	0.19	0.32	0.60	0.13	0.74	1.42
shahdol	0.10	0.23	0.19	0.17	0.76	0.79
sagar	0.08	0.22	0.29	0.27	0.36	0.53
indore	0.32	0.62	0.43	0.00	1.49	0.13
durg	3.77	4.69	5.23	4.61	6.17	0.00
bilaspur	0.00	0.00	0.00	0.00	0.01	0.00
dhule	0.00	0.00	0.00	0.00	0.00	0.00
jalgaon	0.00	0.00	0.00	0.00	0.00	0.00

Irrigation by TANKS AREA (1000 ha)



District	1970	1980	1990	2000	2010	2017
dhar	0.49	0.91	3.10	0.79	10.17	19.96
vadodara / baroda	2.44	2.09	1.93	1.17	7.18	9.78
jhabua	0.28	0.23	0.23	0.00	5.68	9.47
dewas	0.45	0.39	1.23	0.08	2.23	8.89
khargone (west nimar)	3.28	5.96	10.79	3.07	8.20	6.65
balaghat	9.93	8.69	7.58	6.44	6.57	5.67
mandla	0.00	0.77	0.00	0.14	0.05	3.23
raisen	0.11	0.00	0.28	0.94	1.22	2.91
seoni / shivani	1.75	1.27	1.52	1.85	2.30	2.52
hoshangabad	0.10	0.20	0.00	0.53	0.90	2.34
indore	0.38	0.54	0.43	0.02	0.55	1.50
khandwa (east nimar)	0.00	0.00	0.60	0.09	1.61	1.50
jabalpur	0.47	0.23	0.00	0.35	0.64	1.47
chhindwara	0.12	0.21	0.33	0.28	2.22	1.42
sehore	0.46	0.67	0.89	0.49	9.47	1.25
bharuch	0.34	0.19	0.00	0.53	2.78	1.20
damoh	0.01	0.01	0.02	0.02	0.07	0.86
sagar	0.02	0.02	0.04	0.04	0.12	0.74
panch mahals	0.05	0.13	0.12	0.04	0.40	0.51
shahdol	0.00	0.02	0.00	0.00	0.41	0.33
surat	0.01	0.02	0.01	0.00	0.03	0.32
narsinghpur	0.10	0.00	0.19	0.06	0.01	0.01
bilaspur	0.00	0.00	0.00	0.00	0.00	0.00
betul	0.04	0.04	0.04	0.00	0.07	0.00
durg	0.31	0.46	0.12	0.34	0.18	0.00
dhule	2.04	2.32	1.82	3.70	0.00	0.00
jalgaon	0.00	0.00	0.00	0.00	0.00	0.00

Figure 21: District wise area under irrigation by canal and tank source of irrigation in Narmada basin

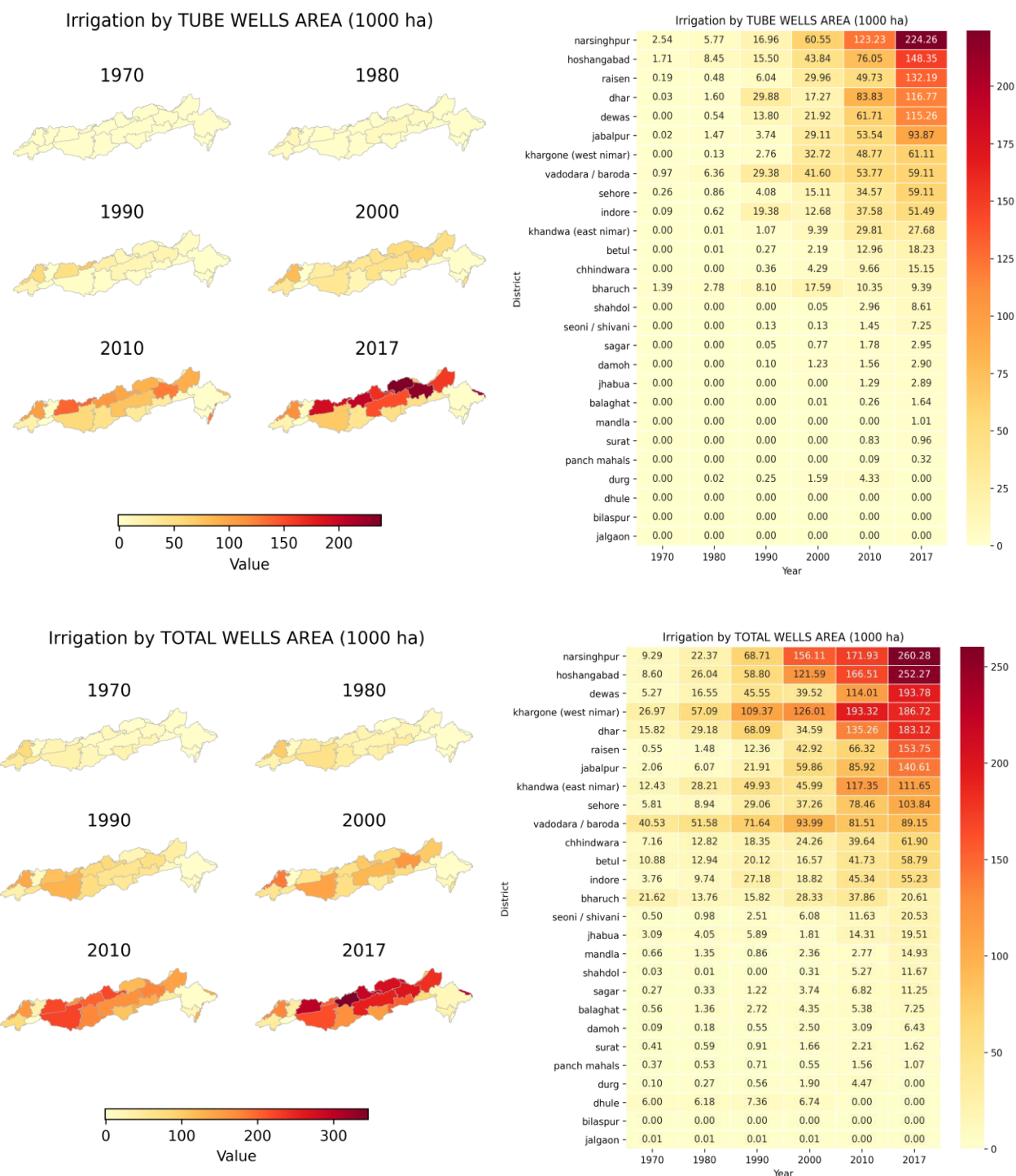


Figure 22: District wise area under irrigation by tube wells and wells of irrigation in Narmada basin

Lift irrigation expanded sharply in select districts — Narsinghpur rose from 2.54 to 224.26 thousand hectares, and Hoshangabad from 1.71 to 148.35, with strong adoption also in Raissen, Dhar, and Dewas. However, many districts remained below 1 thousand hectares, reflecting

unequal deployment and sustainability concerns. For open well irrigation, Narsinghpur and Hoshangabad again led, reaching 260.28 and 252.27 thousand hectares, respectively. Khargone (186.72) and Dhar (183.12) also saw large increases, while mid-range districts like Betul showed gradual growth, from 10.88 to 58.79 thousand hectares over four decades. These patterns reflect a combination of infrastructure investments, terrain, groundwater availability, and policy targeting. Districts like Hoshangabad, Narsinghpur, and Raisen lie within the command area of major canal and lift irrigation schemes, especially the Indira Sagar and Omkareshwar projects, which explains the sharp rise in both canal and lift irrigation. Their flat terrain and proximity to main canals make them suitable for large-scale irrigation infrastructure. In contrast, Balaghat and Khargone show localized growth in tank irrigation, likely due to topography that supports water harvesting structures and targeted interventions under watershed programs. The widespread expansion of open well irrigation, especially in Gujarat districts like Vadodara and Bharuch, is linked to farmer-led investments, better electrification, credit access, and permeable soils that favor groundwater extraction. Meanwhile, many tribal and hilly districts such as Dindori or Alirajpur show persistently low figures across all sources due to rugged terrain, shallow aquifers, lack of grid power, and weak infrastructure penetration. The disparities highlight the role of both natural suitability and state-led prioritization in shaping irrigation access and expansion over time.

6.2 Status of groundwater extraction and drawdown levels

Groundwater has emerged as a critical source of irrigation across the Narmada basin, particularly in regions where canal access is limited or unreliable. Over the past few decades, intensive extraction for agriculture, coupled with erratic monsoon patterns and insufficient recharge infrastructure, has led to significant drawdowns in groundwater levels across many districts. According to the Central Groundwater Board (CGWB) 2022 assessment, Madhya Pradesh has an overall groundwater extraction rate of 58.1% of its annual recharge, while Gujarat stands close behind at 54.5%. However, these state-level figures mask significant spatial variation. In Madhya Pradesh, about 8.2% of administrative blocks are classified as over-exploited, 1.6% as critical, and 19.2% as semi-critical. In Gujarat, 8.7% of blocks are over-exploited, with 3.9% critical and 9.5% semi-critical, leaving roughly three-fourths of areas technically safe, though not necessarily sustainable.

6.2.1 District-Level Patterns

In Khargone (Madhya Pradesh), one of the most groundwater-intensive districts in the basin, CGWB records show pre-monsoon water levels declining to 11.9 m below ground level (mbgl).

Long-term monitoring wells here show a drop of 3–8 meters over the last two decades, particularly in rabi season months. Hoshangabad and Narsinghpur, districts with expanding well irrigation (as seen in your heatmaps), also show widespread seasonal drawdown, with many wells exceeding 15–20 m depth in May. These districts, despite canal command area benefits, still show high groundwater use due to water-intensive crops like wheat and sugarcane. In Bharuch and Vadodara (Gujarat), CGWB data show significant fluctuations, with groundwater levels dropping from 5–7 m to over 15 m between pre- and post-monsoon seasons. Bharuch has multiple blocks categorized as semi-critical, especially in agriculturally intense belts where well irrigation dominates.

6.2.2 Causes of Drawdown

The major drivers of groundwater depletion in the basin include:

- Districts like Dhar, Khargone, and Hoshangabad have witnessed substantial expansion in well irrigation over the past two decades, primarily driven by private capital, widespread availability of subsidized electricity, and borewell proliferation. In Gujarat, for instance, over 40% of irrigation connections are linked to unmetered tubewells, accounting for nearly 49% of total agricultural electricity use. These wells support more than 70% of the state's groundwater irrigation and receive approximately 90% of farm power subsidies, enabling continuous and often unregulated extraction. This pattern is mirrored in parts of western Madhya Pradesh, where cheap or flat-rate electricity has further incentivized uncontrolled pumping, especially by medium and large landholders.
- The cropping pattern in these regions compounds the issue. Districts such as Khargone and Hoshangabad have large tracts under sugarcane, wheat, and summer vegetables—all highly water-intensive crops. These crops are often grown in regions lacking dependable surface water sources, forcing farmers to rely heavily on groundwater, particularly during the rabi and summer seasons. As a result, groundwater extraction levels in many blocks exceed 70% of the annual recharge, with some blocks categorized as over-exploited or critical.
- Hydrogeology further exacerbates this trend. The upper basin districts—including Dhar and parts of Betul and Sehora—lie in hard rock formations, which naturally restrict vertical percolation and storage. The fractured crystalline aquifers in these regions have limited recharge potential, making them particularly vulnerable to over-extraction.

Groundwater level trends in these areas show a decline of 3 to 8 meters over the last two decades, with pre-monsoon water tables commonly exceeding 12 meters depth.

- Despite this vulnerability, investment in watershed development and artificial recharge structures remains insufficient in many blocks. Meanwhile, the availability of free or flat-rate electricity continues to encourage groundwater use beyond sustainable limits. Unless addressed through a combination of groundwater governance, pricing reform, and aquifer recharge programs, these regions are likely to experience further drawdown and long-term water stress.
- Continued groundwater drawdown in the Narmada basin has serious implications for agricultural sustainability, rural water security, and equity. On average, groundwater levels in critical blocks have declined by 0.3–0.5 meters per year over the last two decades (CGWB, 2022). The cost of drilling a borewell has increased from ₹30,000 in the 1990s to over ₹1.5 lakh today in many districts, as wells must now reach depths of 200–300 feet, particularly in hard-rock zones like Khargone, Betul, and Dewas. This disproportionately affects marginal and smallholders, who often cannot afford deep drilling or submersible pumps.

Moreover, as aquifers are tapped deeper, salinity and fluoride levels tend to rise. In Gujarat, over 17% of groundwater samples tested in Bharuch and Panchmahal districts exceeded safe limits for total dissolved solids (TDS), compromising both crop yields and drinking water safety (CGWB Groundwater Quality Atlas, 2021).

To reverse or stabilize this trend, the region requires an integrated approach:

- Aquifer recharge interventions: Madhya Pradesh's current artificial recharge capacity stands at only 15–20% of estimated potential. Increasing this through check dams, percolation tanks, and recharge shafts could recover groundwater levels by 0.5–1.0 meters annually in critical zones (NIH–Roorkee study, 2020).
- Energy–groundwater decoupling: Adoption of solar pumps is growing, but unevenly. As of 2022, Gujarat had installed 46,000 solar irrigation pumps, while Madhya Pradesh lagged with only 8,200 units under the PM-KUSUM scheme (MNRE, 2023). Scaling solar with smart meters can curb excessive extraction while reducing diesel dependence.

- Crop planning reforms: In high-extraction districts, over 60% of irrigated area is under water-intensive crops such as wheat and sugarcane. Transitioning 15–20% of this area to pulses or oilseeds could reduce groundwater demand by 30–40%, according to ICAR-WTC studies.
- Community groundwater governance: Across India, fewer than 10% of gram panchayats have functional groundwater user groups or monitoring systems. Piloting village-level groundwater budgeting in over-exploited blocks (e.g., in Raisen and Narsinghpur) could promote equitable and sustainable use.

7 Irrigation Pattern and Techniques

7.1 Traditional vs Modern Irrigation Practices

Historically, irrigation practices across the Narmada basin have been shaped by a mix of community-managed water systems and large-scale state infrastructure. In the upper basin and tribal-dominated uplands, irrigation relied on rainwater harvesting tanks, open dug wells, and small gravity-fed diversions from seasonal streams. In the middle and lower basin, especially post-independence, irrigation expanded through large canal command systems associated with multipurpose projects like the Sardar Sarovar, Indira Sagar, and Omkareshwar dams. These networks consist of main canals, distributaries, and unlined field channels (minors and sub-minors), many of which were designed to operate under rotational water supply or "warabandi" principles.

Despite their broad reach, traditional canal-based systems have suffered from low efficiency and maintenance challenges. Field-level application efficiency in most canal-irrigated areas remains in the range of 35–45%, primarily due to seepage losses in unlined canals, evaporation from open conveyance structures, and non-optimized water scheduling. Tail-end farmers, especially in districts like Khargone, Barwani, and Raisen, often report unreliable and untimely water delivery, leading to increased reliance on wells and lift irrigation as a backup source (Source: cNarmada, cGanga, and NRCD Reports, 2024).

Since the early 2010s, both Gujarat and Madhya Pradesh have undertaken a deliberate push towards modernizing irrigation systems with an emphasis on efficiency, equity, and sustainability. A key intervention has been the adoption of pressurized irrigation network systems (PINS) and underground pipeline (UGPL) conveyance, particularly in the Sardar

Sarovar Narmada Nigam Limited (SSNNL) command area. These systems replace open minors with buried PVC or HDPE pipelines, drastically reducing water loss and improving delivery speed and control. Field evaluations (AERC, 2017) suggest that UGPL systems can reduce conveyance losses by 10–20% and free up 3–5% of command area for cultivation, since land previously used for field channels is returned to productive use.

At the farm level, modernization has taken the form of micro-irrigation technologies, particularly drip and micro-sprinkler systems. These technologies were accelerated under the Per Drop More Crop (PDMC) component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). PMKSY-PDMC provides substantial subsidies (up to 70–90% for small and marginal farmers) for on-farm drip or sprinkler kits. Adoption has been particularly high in horticulture zones of Gujarat, such as Bharuch, Vadodara, and Panchmahal, as well as in pockets of Dewas and Narsinghpur in Madhya Pradesh.

Data from the Ministry of Agriculture and Farmers' Welfare (2023) shows that by 2022, over 2.5 lakh hectares in Gujarat and nearly 1.2 lakh hectares in Madhya Pradesh had been brought under micro-irrigation through PMKSY support. Farmers have reported benefits such as reduced water use by 30–50%, increased crop yields by 15–20%, and improved flexibility in irrigation timing, especially for high-value vegetable and fruit crops. However, challenges remain in mainstreaming modern irrigation practices. Issues such as high upfront costs, limited awareness, operation and maintenance complexities, and lack of technical support still hinder widespread adoption, especially among smallholders and tribal communities. Furthermore, while UGPL and PINS offer efficiency gains, their capital-intensive nature limits deployment in non-command areas unless bundled with collective farming or cooperative infrastructure models.

In conclusion, the Narmada basin is undergoing a transitional phase in irrigation practices—from traditional, water-loss-prone surface irrigation to more efficient, pressurized, and localized systems. While policy and infrastructure support have catalyzed this shift, sustained adoption will depend on improving last-mile access to technology, building farmer capacity, and integrating water-use efficiency targets within broader rural development and climate resilience frameworks.

7.2 Water-Use Efficiency (WUE) and Cropping Choices

In the water-stressed yet intensively farmed Narmada basin, improving Water-Use Efficiency (WUE) is a critical adaptation strategy to cope with growing groundwater depletion, rising

irrigation costs, and changing rainfall patterns. Traditional flood irrigation methods, still prevalent in many districts, often result in high conveyance and application losses, low water productivity, and uneven crop performance. In contrast, micro-irrigation techniques—such as drip and sprinkler systems—have demonstrated significant potential for both water savings and yield enhancement, particularly when integrated with modern cropping systems.

Table 14: Illustrative Water use efficiency gains under micro-irrigation

Crop	Irrigation method	Saved water vs. canal (%)	Yield gain (%)	District example
Banana	Drip	45–55	25–30	Bharuch, GJ
Tomato	Drip	35–40	20–25	Dhar, MP
Wheat	Sprinkler	25–30	8–12	Narmada, GJ
Cotton	Drip	30–40	15–18	Khargone, MP

Source: Field trials compiled in the NITI Aayog/ICAR–NIAP micro-irrigation study (2023) and PINS performance evaluation in Gujarat.

Field trials and performance evaluations conducted under the NITI Aayog and ICAR-NIAP micro-irrigation study (2023), along with state-led assessments of PINS (Pressurised Irrigation Network Systems) in Gujarat, show that micro-irrigation systems can reduce water use by 30–50% and increase yields by 20–30% in horticultural and commercial crops. These benefits arise from precise water delivery, minimized runoff and evaporation, and improved nutrient uptake efficiency, particularly for shallow-rooted crops.

As a result, farmers—particularly those in canal command areas of Gujarat and western Madhya Pradesh—have increasingly leveraged these technologies not only to reduce input costs but also to restructure their cropping choices. The saved water is often reallocated to diversify into high-value crops such as banana, papaya, chili, tomato, and even floriculture, which offer better market returns and support year-round income streams. This has also contributed to a rise in on-farm employment demand, especially for harvesting, sorting, and irrigation management.

In Bharuch, Drip irrigation adoption spans ~35,000 ha, mainly for banana and papaya. Water savings reach 50%, with 25–30% yield gains. Supported by PINS and Sardar Sarovar canal access. In Dhar, Micro-irrigation covers ~18,000 ha in tomato and cotton areas. Reports indicate 35–40% water savings. Adoption driven by tribal outreach, but rocky terrain limits recharge. In Khargone, drip systems are widespread in cotton and chili zones. Yield gains of 15–18% and water savings of 30–40% reported. Flat-rate electricity supports expansion, though groundwater drawdown is rising. In Narsinghpur, early adoption of drip systems in vegetables shows 20–25% yield gains. Lift-irrigation dominance and limited PMKSY access constrain wider use.

7.3 Adoption of Micro-Irrigation Systems (Drip & Sprinkler)

Since the launch of the Pradhan Mantri Krishi Sinchayee Yojana – Per Drop More Crop (PMKSY–PDMC) in 2015–16, micro-irrigation has emerged as a key strategy in the Narmada basin to tackle groundwater stress, improve water-use efficiency (WUE), and diversify into high-value crops.

As of February 2024, Gujarat has achieved 1.08 million hectares (Mha) under micro-irrigation—13% of India’s total coverage—thanks to systematic investments in canal-command drip systems and strong state support through the PINS (Pressurised Irrigation Network Systems) program. Madhya Pradesh follows with 0.36 M ha, primarily under sprinkler irrigation, suitable for large semi-arid tracts and field crops like wheat, soybean, and gram.

7.3.1 District-Wise and Crop-Wise Highlights

Bharuch (Gujarat): One of the largest adopters of drip irrigation, covering over 35,000 ha, especially in banana and papaya farms. The district benefits from both canal connectivity (Sardar Sarovar) and contract farming infrastructure.

Vadodara (Gujarat): Extensive sprinkler use in wheat and gram, especially among tail-end users in command areas. Micro-irrigation adoption exceeds 20,000 ha in these districts.

Khargone (Madhya Pradesh): Over 30,000 ha has shifted to drip irrigation for cotton and chili, supported by flat electricity tariffs and borewell access. This region also sees strong NGO and private sector involvement in irrigation kit deployment.

Dhar and Barwani (MP): Focus on tribal belt micro-irrigation, largely through sprinkler kits for soybean and maize, covering ~15,000–18,000 ha each. The hilly terrain favors pressurized irrigation due to gravitational inefficiencies in flood systems.

Narsinghpur and Hoshangabad (MP): Though known for lift irrigation, recent years have seen the expansion of drip kits in vegetables (tomato, brinjal, green chili) under PMKSY. Total coverage exceeds 12,000 ha combined.

Impact on Cropping Patterns

- In Gujarat, water savings have enabled diversification into floriculture, spices, and horticulture in canal areas.
- In Madhya Pradesh, sprinklers for rabi crops have become standard in many blocks, with wheat and gram yields increasing by 8–12%.
- In high-performing areas like Khargone and Bharuch, per-hectare incomes have increased by ₹20,000–₹40,000 through higher-value output and reduced water costs.

Table 15: State-wise micro-irrigation uptake relevant to the Narmada Basin (2015-24)

State (basin share)	Cumulative area under micro-irrigation (ha)	% of national total	Predominant technology	Key programmes / remarks
Gujarat (11 % basin)	1,087,039	13.0 %	Drip > Sprinkler	Narmada canal PINS, UGPL, state top-up subsidy (pib.gov.in)
Madhya Pradesh (87 %)	356,091	4.3 %	Sprinkler > Drip	MP Micro-Irrigation Mission; focus on soybean + wheat belts (pib.gov.in)
Maharashtra (2 %)	938,089	11.2 %	Drip(cotton, horticulture)	State drip mandate in cotton zones

Source: Department of Agriculture & Farmers Welfare (DA&FW), Government of India. (2024). PMKSY – Per Drop More Crop: State-wise Progress under Micro-Irrigation (2015–2024).

8 Chemical Fertilizer and Plant Protectant Use

8.1 Trends in fertilizer and pesticide use

The Green Revolution led to the widespread adoption of chemical fertilizers and pesticides in India. Although the Narmada River Basin was not the epicenter of this transformation, its agriculture has since seen significant growth in agrochemical use, particularly in Madhya Pradesh and Gujarat sections of the basin.

National fertilizer consumption rose from 2.9 million tonnes (1970–71) to 27 million tonnes (2018–19), while pesticide usage increased from ~45,000 tonnes (2001–04) to ~60,000 tonnes (2019–20). The Narmada Basin has followed this trend, particularly in irrigated districts using water from the Narmada canal and tributaries.

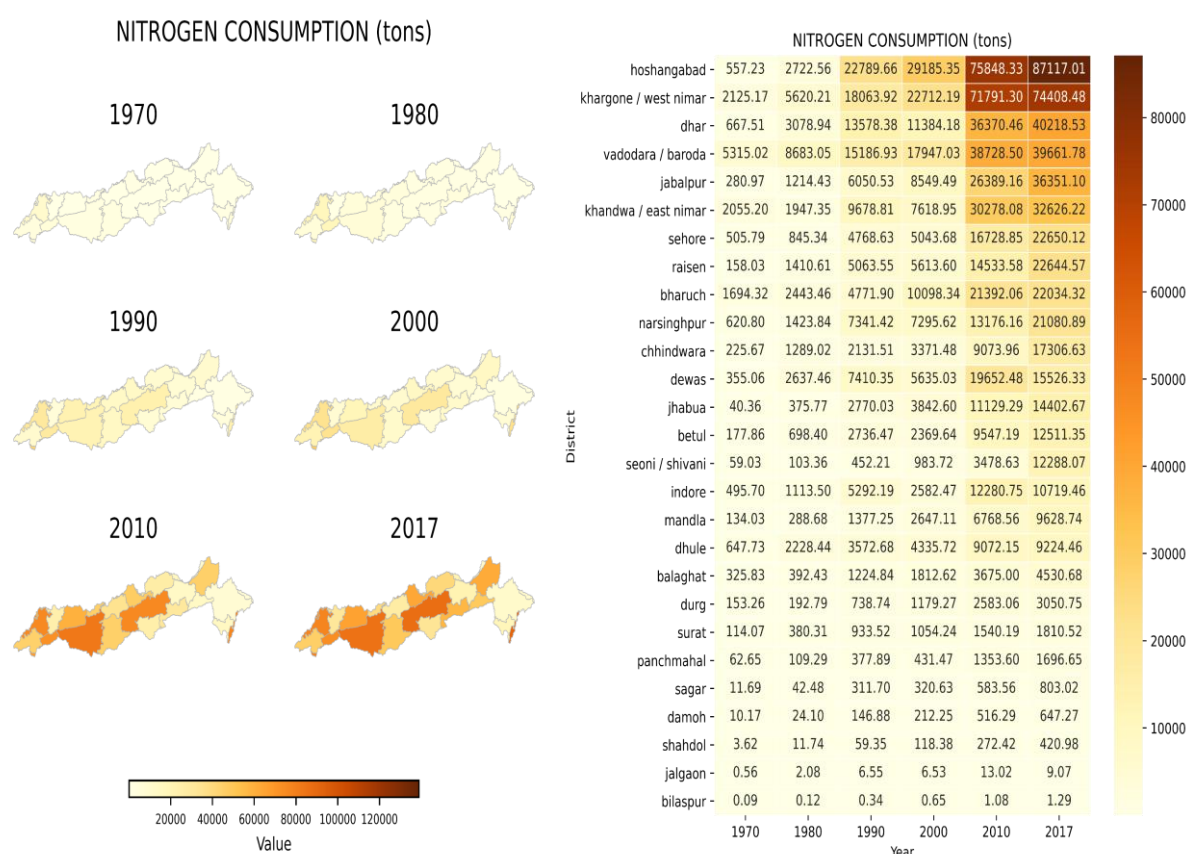


Figure 23: District wise nitrogen fertilizer consumption in Narmada basin

The majority of districts demonstrate a clear upward trend in nitrogen consumption over the observed periods. This reflects the broader pattern of agricultural intensification in the region, potentially driven by higher cropping intensity, improved access to fertilizers, and policy

incentives promoting input use. Districts such as Hoshangabad and Khargone (West Nimar) consistently report the highest levels of nitrogen use, surpassing 80,000 tons in the most recent time period. This indicates significant agricultural activity and fertilizer demand in these areas. Several districts including Bharuch, Narsinghpur, and Dhar fall in the mid-range of the consumption spectrum. On the other end, districts such as Jalgaon, Shahdol, and Damoh report minimal usage, often below 100 tons, suggesting either lower fertilizer reliance or limited agricultural extent.

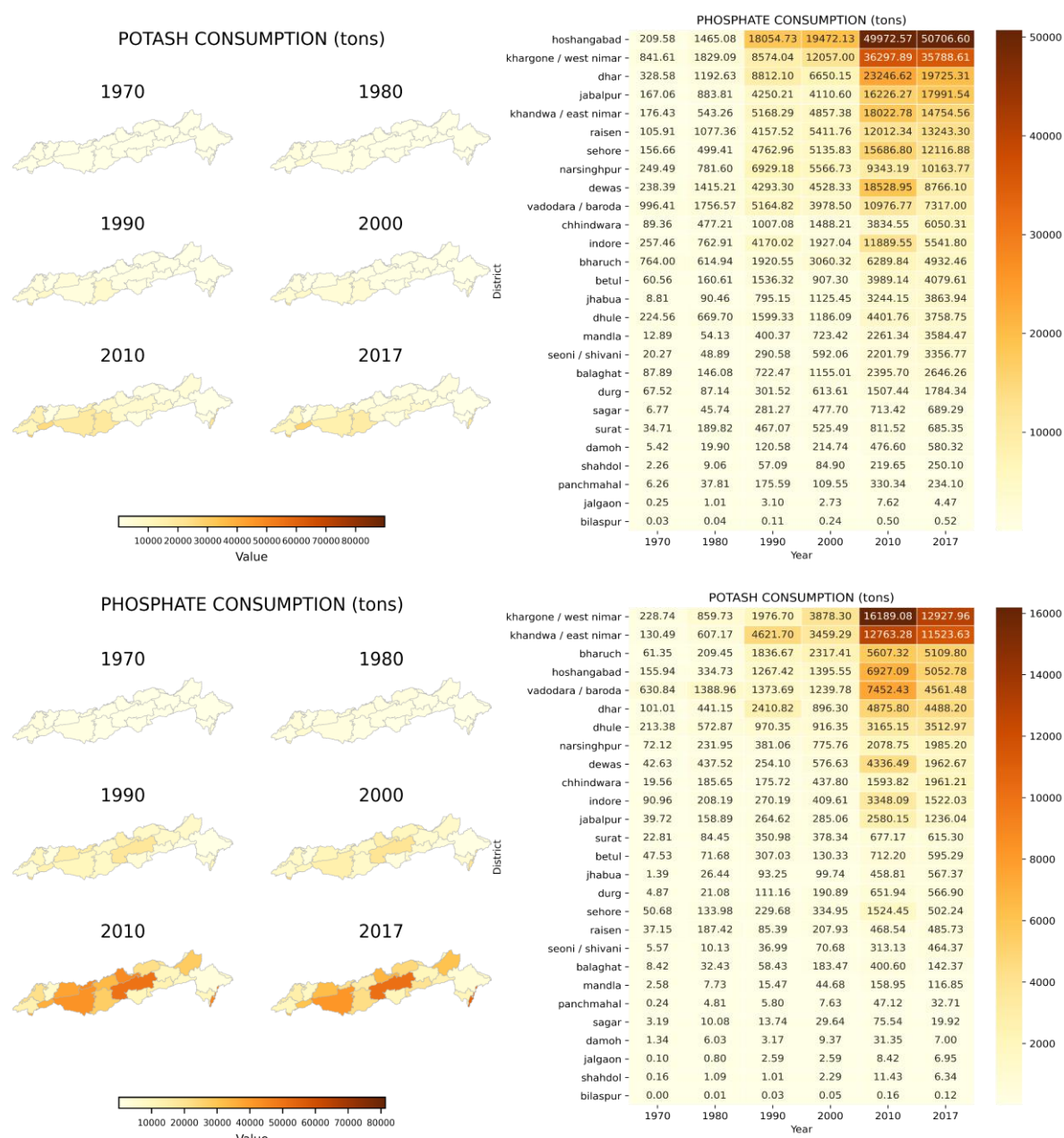


Figure 24: District wise phosphate and potash fertilizer consumption in Narmada basin

This visualization underscores the growing reliance on nitrogen-based fertilizers in the Narmada Basin and signals potential environmental risks in high-use zones due to excessive nutrient loading. Conversely, low-use regions may require targeted support to enhance productivity through balanced fertilization strategies. These insights can inform agronomic planning, nutrient budgeting, and regional sustainability frameworks aimed at optimizing fertilizer use efficiency.

For phosphate, districts such as Hoshangabad, Khargone (West Nimar), Dhar, Khandwa (East Nimar), Dewas, and Jabalpur show a consistent increase in consumption over time, with Hoshangabad reaching the highest recorded value of over 50,000 tons by 2017. Districts like Sehore, Raisen, Narsinghpur, and Indore also show mid-to-high phosphate use, whereas districts such as Jalgaon, Bilaspur, Shahdol, and Damoh reflect minimal usage throughout the decades. Similarly, for potash, the highest consumption is concentrated in districts like Khargone (West Nimar), Khandwa (East Nimar), Hoshangabad, Vadodara (Baroda), and Dhar, with Khargone peaking at over 16,000 tons in 2010. Districts including Jhabua, Mandla, Sagar, Panchmahal, Jalgaon, and Bilaspur exhibit extremely low levels of potash consumption across all periods. Both heatmaps clearly highlight regional disparities in fertilizer use intensity, reflecting varying agricultural practices, cropping patterns, and access to inputs across districts in the basin.

8.2 Regional Disparities and Over/Underutilization

The Narmada River Basin demonstrates significant spatial disparities in agrochemical application, shaped by differences in irrigation access, socio-economic development, and soil-climatic conditions. Fertilizer use is notably high in the western and central districts such as Indore, Bharuch, Khargone (West Nimar), Vadodara (Baroda), and Hoshangabad, where total nitrogen consumption in 2017 exceeded 87,000 tons in Hoshangabad, and phosphate and potash consumption in Khargone surpassed 50,000 tons and 16,000 tons respectively (Fertilizer Statistics, 2018-19). These regions benefit from strong canal and groundwater irrigation infrastructure, supported by Narmada river projects, and exhibit cropping intensities above 150%, as recorded in the Agricultural Census 2015–16 (Ministry of Agriculture, 2019).

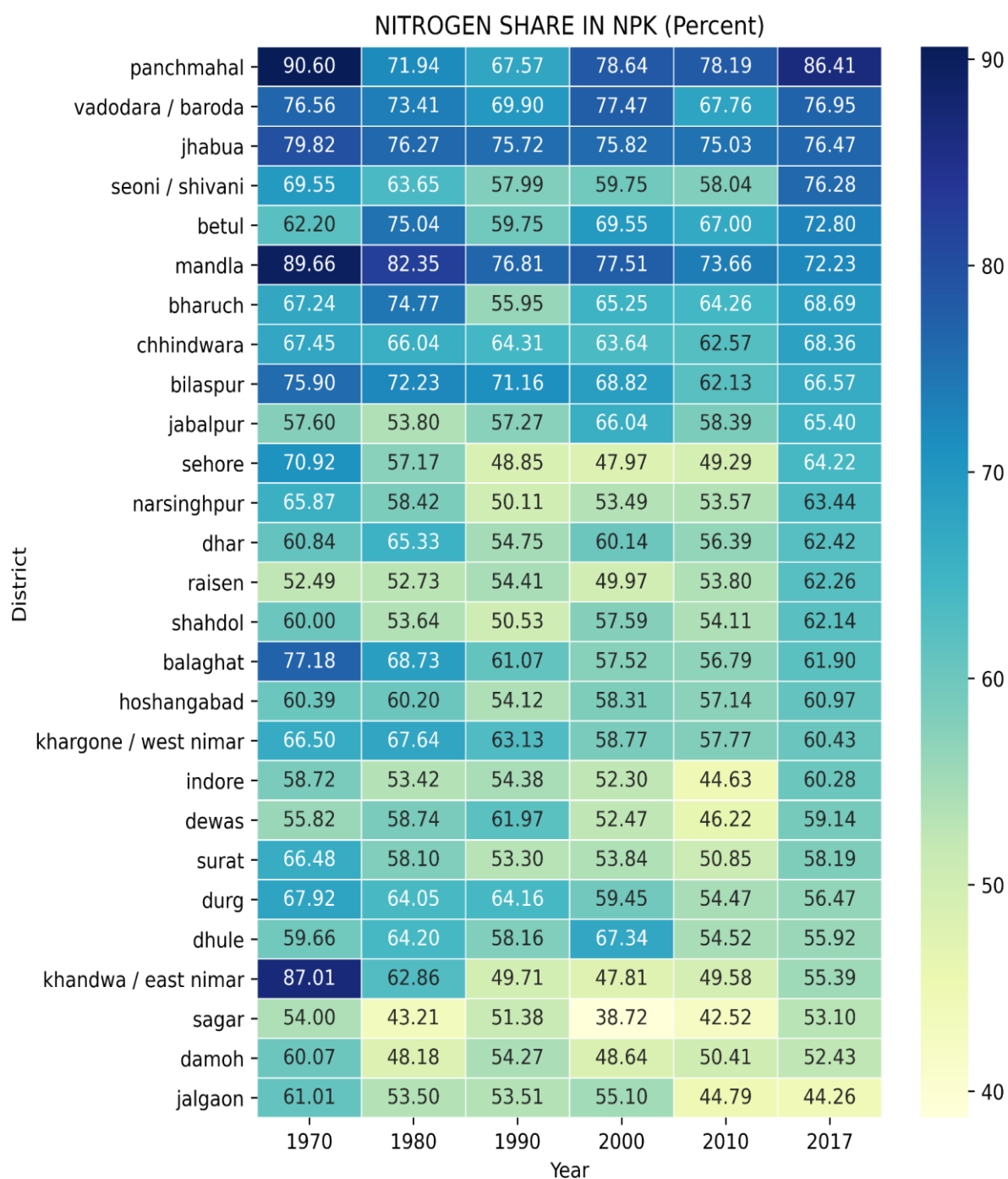


Figure 25: District wise fertilizer share of Nitrogen in Narmada basin

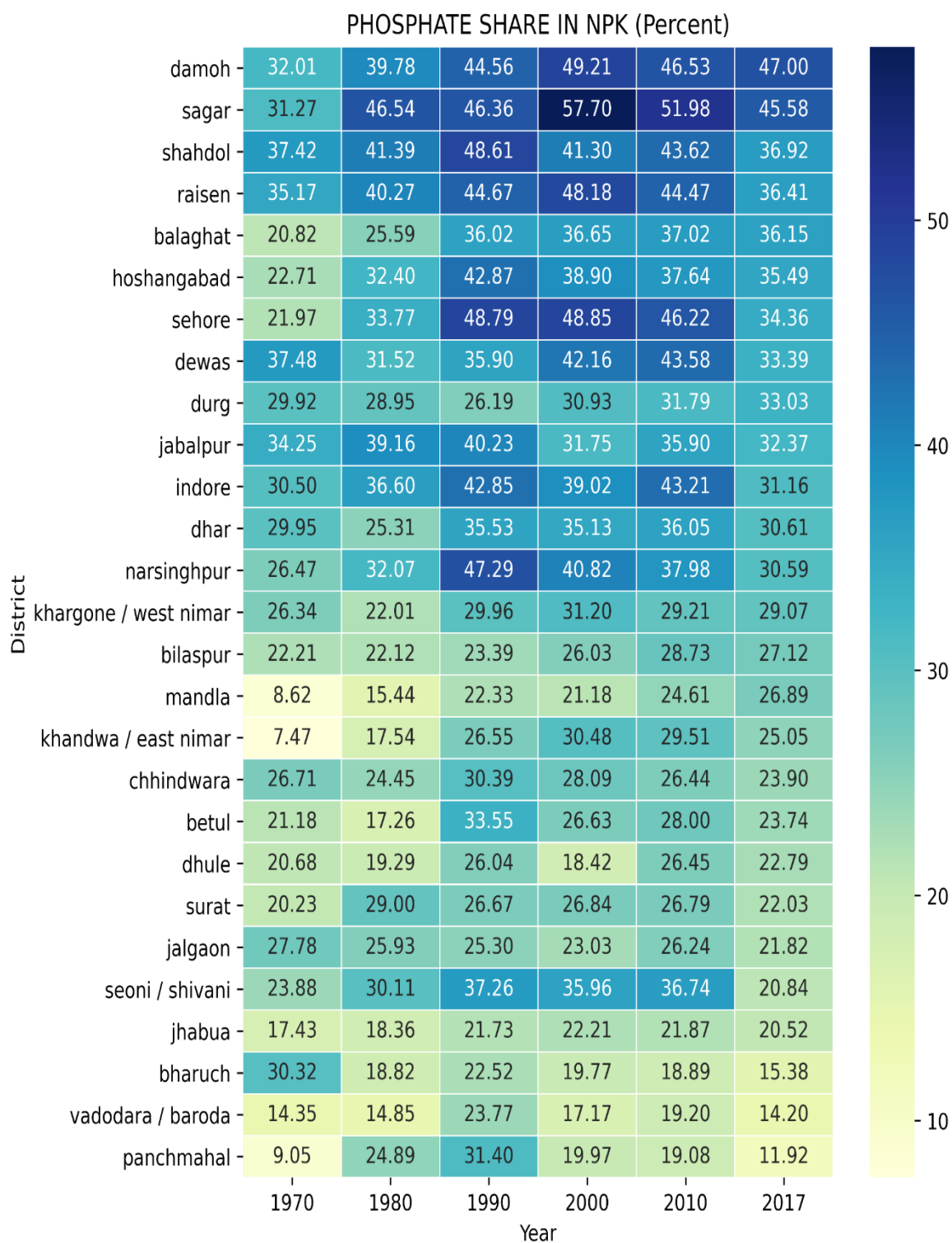


Figure 26: District wise fertilizer share of Phosphate in Narmada basin

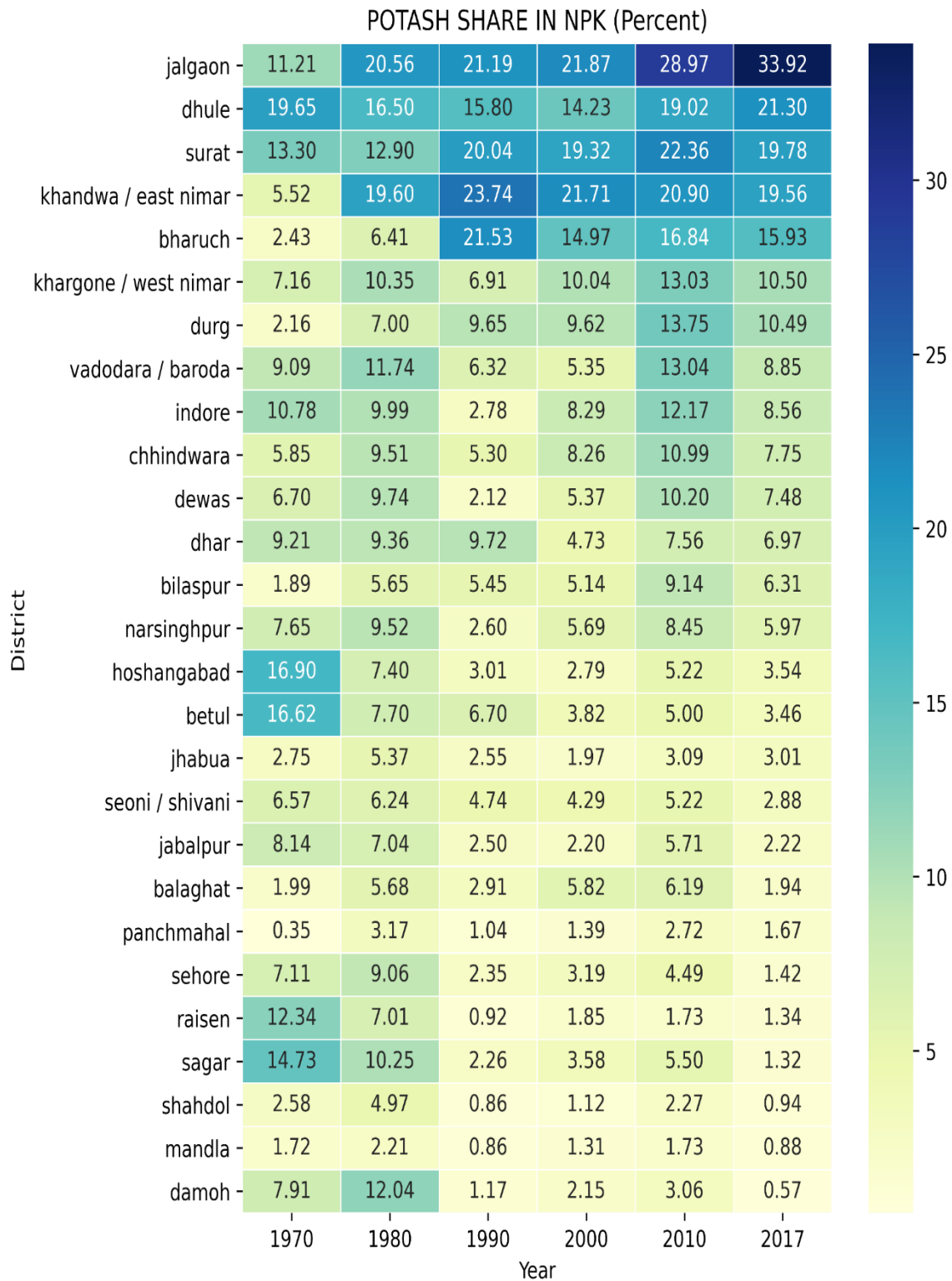


Figure 27: District wise fertilizer share of Potash in Narmada basin

The NPK share patterns across districts in the Narmada Basin reveal substantial imbalances and shifts in fertilizer usage over the decades.

Panchmahal consistently exhibits a highly skewed NPK ratio, with nitrogen accounting for over 90% in 1970 and remaining dominant at 86.4% in 2017, indicating chronic overuse. Phosphate share peaked briefly in 1990 at 31.4%, then declined to just 11.9%, while potash remained negligible throughout (below 2%), suggesting acute potassium deficiency. Vadodara (Baroda) displays slightly better balance; nitrogen share hovered around 70–77%, phosphate around 14–23%, and potash fluctuated between 5–13%, though still below ideal.

Jhabua, a tribal district, shows nitrogen dominance in the range of 75–79%, with minimal phosphate (17–22%) and potash (2–5%), implying limited diversification in fertilizer application. Seoni/Shivani follows a similar trajectory, with nitrogen at 58–76%, phosphate increasing slightly over time but potash remaining below 7%, highlighting a persistent nutrient gap.

In Hoshangabad, nitrogen share started around 60% and stabilized slightly above 60% by 2017. Phosphate showed improvement (from 22% in 1970 to 35%), but potash declined to a mere 3.5%, reinforcing an N-P dominance. Khargone (West Nimar) showed a decline in nitrogen from 67.6% (1970) to 60.4% (2017), and while phosphate increased to 29%, potash remained static (~10.5%).

Khandwa (East Nimar) saw nitrogen reduce from 87% to 55%, with phosphate rising from 7.5% to 25%, and potash improving from 5.5% to 19.8%, suggesting the most balanced trend among all districts. Balaghat maintained nitrogen above 60%, phosphate around 20–36%, and potash below 7%, indicating moderate imbalance.

Indore and Dewas showed gradual shifts from nitrogen dominance (around 58–60%) to a more moderate NPK distribution. Phosphate increased modestly in both (to ~30–40%), while potash remained between 6–12%, still below optimal. Narsinghpur, Sehore, and Chhindwara consistently used over 60% nitrogen, with declining potash shares (often under 6%), and phosphate peaking at around 40%, suggesting partial awareness of balanced application but with potassium being neglected.

Shahdol, Mandla, Damoh, and Sagar—largely tribal and upland districts—had erratic usage. For instance, Damoh showed the highest phosphate share in 1980 (~40%) and a potash share over 12%, but nitrogen declined sharply. Sagar had phosphate peaking at 57.7% in 2000, while nitrogen was just 38.7%, indicating an inverted imbalance. Jalgaon, however, showed consistent nitrogen dominance (around 60%), with phosphate and potash showing modest improvements, reaching 33.9% potash in 2017—the highest in the region.

Districts like Raisen, Durg, and Bharuch maintained nitrogen shares between 60–70%, but had persistently low potash inputs (<10%), which can negatively affect yield resilience and crop quality. Raisen and Shahdol, despite occasional rises in phosphate share, failed to improve potash application, leading to a nutrient void in root zone balance.

This reveals a persistent imbalance in fertilizer use across Narmada Basin districts, with nitrogen consistently dominating the NPK ratio. In 2017, most districts applied over 60% nitrogen, with several exceeding 70%, reflecting a strong dependence on urea. Phosphate usage, while slightly improving in some areas like Indore and Damoh, remained uneven, and potash is severely underapplied; falling below 10% in nearly all districts. Notably, Jalgaon and Khandwa (East Nimar) show some progress toward a more balanced ratio, with potash shares rising to ~20–34%, suggesting either better awareness or crop diversification. Conversely, Panchmahal and Vadodara remain extremely nitrogen-heavy, with minimal uptake of phosphate or potash, pointing to gaps in extension services or subsidy-driven distortion. This pattern of over-reliance on nitrogen, coupled with chronic underuse of potash, poses long-term risks to soil health and crop productivity across the basin.

8.3 Environmental and Health Concern

8.3.1 Water Pollution

Excessive use of nitrogen and phosphate-based fertilizers has led to serious water quality issues in the Narmada Basin. Groundwater sampling in agricultural hotspots such as Omkareshwar (Khandwa district) and Hoshangabad has recorded nitrate concentrations exceeding 50–60 mg/L, which is well above the World Health Organization’s safe drinking water limit of 45 mg/L (CGWB, 2020). Surface water bodies adjacent to intensively cultivated fields show elevated levels of phosphate (0.5–1.2 mg/L), which contributes to eutrophication and algal blooms. Additionally, riverbed sediment samples collected from stretches downstream of agricultural zones (e.g., Barwani and Sehore) have shown high concentrations of zinc (Zn: 150–220 mg/kg), chromium (Cr: 40–60 mg/kg), and nickel (Ni: 30–45 mg/kg)—all traceable to phosphate fertilizer residues and persistent pesticide runoff (CPCB, 2019).

8.3.2 Soil Degradation

Prolonged and imbalanced fertilizer application, especially urea, has led to soil acidification in multiple districts of the Narmada Basin. In regions like Dhar and Dewas, long-term monitoring has shown a pH drop from 6.5 to below 5.5 over the last two decades (ICAR-IISS, 2021). Excess nitrogen also accelerates leaching of essential micronutrients such as zinc (Zn) and iron

(Fe), with over 40% of cultivated soils in Madhya Pradesh now zinc-deficient (NBSS&LUP, 2018). This degradation reduces soil productivity and increases dependence on synthetic nutrient supplements.

8.3.3 Health Risks

Groundwater contamination due to agrochemicals poses direct health risks. Elevated nitrate levels above 50 mg/L are linked to methemoglobinemia, or "blue baby syndrome", in infants. Case studies from Harda and Hoshangabad districts have reported rising incidences of water-related illnesses in villages sourcing drinking water from shallow handpumps (MoHFW, 2020). Chronic exposure to pesticide residues—notably organophosphates and chlorpyrifos—has been associated with increased risks of non-Hodgkin lymphoma and neurological disorders in rural agricultural workers (ICMR, 2017). Biomonitoring surveys have found detectable pesticide residues in 30–40% of groundwater samples in intensively farmed areas of the basin.

Table 16: Environmental Risks from Agrochemical Use

Parameter	Observed Level	Permissible Limit (WHO/IS)	Risk Zone (Basin)	Key Impacts
Nitrate (NO ₃ ⁻)	45–90 mg/L	<45 mg/L	Omkareshwar, Bharuch	Drinking water contamination
Phosphate (PO ₄ ³⁻)	1.5–3.0 mg/L	<1 mg/L	Hoshangabad, Barwani	Eutrophication, aquatic toxicity
Pesticide Residues	Detected (2–4 compounds)	NA	Agricultural belts	Chronic exposure, health risks
Heavy Metals	Zn, Ni, Cr above limits	Varied	River sediments in MP/Guj	Aquatic ecosystem impact

Source: CPCB Water Quality Reports (2022), Singh et al. (2021), Groundwater Board (2020)

9 Agricultural Management Practices and Sustainable Agricultural Practices

The Narmada River Basin's agricultural management combines local innovations, government-driven technology dissemination, and traditional knowledge systems. Different approaches to tillage, nutrient use, crop planning, and livestock integration have resulted from the basin's diversity, which includes upland tribal farming and irrigated canal command zones. Climate variability, soil fatigue, and increasing resource pressure, however, highlight the necessity of bolstering sustainable management in every zone.

i. Methods of Tillage

By agro-ecological zone, tillage techniques differ throughout the basin. Conventional tillage using tractor-mounted ploughs is common in Madhya Pradesh's alluvial plains (such as Sehore, Harda, and Hoshangabad), particularly for wheat and soybean. Manual or animal-drawn tillage is still common in rainfed and tribal areas (such as Mandla, Dindori, and Kabirdham). In order to lessen erosion and preserve moisture, conservation tillage techniques like contour bunding and reduced tillage have been encouraged under Watershed Development Programs (WDC). KVKs and MGNREGA-based schemes have demonstrated success in introducing ridge-furrow methods and zero tillage for selected crops, particularly in pilot projects under climate-resilient agriculture (CRA) programs.

ii. Crop Rotation and Diversification

Crop diversification is one important practice to raise farm income and soil health in the basin. Although irrigated regions of central and western Madhya Pradesh (such as Narsinghpur and Sehore) are dominated by traditional wheat–soybean and wheat–gram rotations, horticultural crops, pulses, and oilseeds are receiving more and more attention. For example, banana cultivation has increased in Nandurbar and Bharuch, while cotton-based rotations have expanded to include vegetables, onions, and garlic in Khargone and Barwani. Lack of irrigation and market access limits diversification in upland tribal areas; however, government initiatives under RKVY and NFSM are encouraging intercropping with short-duration legumes, pulses, and millets to increase soil nitrogen content and food security. Additionally supported are seasonal rotations such as paddy-lathyrus, sorghum-pigeon pea, and maize-black gram.

iii. Precision Farming and Better Methods (like SRI in Paddy)

Though on a smaller scale, precision agriculture methods are being progressively implemented in a few districts. In eastern Madhya Pradesh and Chhattisgarh, where smallholder rice growers face water stress, agricultural universities and KVKs have advocated for the System of Rice Intensification (SRI). In districts like Kabirdham and Mandla, SRI trials have demonstrated a 15–25% increase in yields with a 40% reduction in water use; however, labor requirements and low awareness continue to limit adoption. To increase irrigation efficiency, RKVY and PMKSY-PDMC are promoting technologies like soil moisture sensors, GPS-based sowing, and laser land leveling in the western and central districts. In Gujarat and Madhya Pradesh, mobile-based advisory platforms and digital soil health cards are also being utilized, which helps precision farming.

- **Case Study of SRI (from KVK Mandla)**

Premlal Sangour, a farmer from Boriya village in Mandla district, Madhya Pradesh, has emerged as a leading example of agricultural innovation through the adoption of integrated farming systems and the System of Rice Intensification (SRI). Despite facing early hardships and limited formal education, Premlal took responsibility for his family at the age of 35 and began cultivating his 3.2 hectares of irrigated land.

His transformation began in 2007–08, when he connected with the Krishi Vigyan Kendra (KVK) Mandla, seeking low-cost techniques to improve paddy yields. Encouraged by the KVK scientists, he organized fellow farmers for training in SRI. Despite resistance from his own family and villagers rooted in traditional rice cultivation methods, he became the first farmer in the district to adopt SRI practices. These included using 10-day-old seedlings, raised nursery beds, vermicompost, wider spacing (25 cm x 25 cm), and timely irrigation and weeding.

His efforts paid off significantly—he achieved a record paddy yield of 75 quintals/ha (variety PS-5), compared to just 20 quintals/ha through traditional methods. His success inspired others in the district to follow suit.

Over time, Premlal expanded into integrated farming, establishing a biogas plant, NADEP compost pit, and engaging in horticulture (mango, banana, guava, aonla), livestock rearing (cows, goats, poultry), and kitchen gardening. He earns additional income through lac production and banana cultivation, and uses the biogas plant for lighting and cooking at home.

Today, Premlal is recognized as the Best Progressive Farmer of Mandla District, cultivating improved varieties of paddy (MTU-1010, PS-3) and wheat (JW-3211), and exemplifying the benefits of sustainable, integrated, and technology-driven farming on small landholdings.

10 Agricultural Manpower, Land, and Livestock Holdings

10.1 Labour availability and workforce characteristics.

Hoshangabad stands out with the highest increase in both male and female wages, peaking at ₹103.23 for males and ₹104.53 for females in 2009. This parity suggests a relatively progressive wage structure. In Narsinghpur, male wages rose from ₹1.46 in 1970 to ₹79.25 in 2009, while female wages followed closely, reaching ₹71.83, highlighting consistent wage growth. Khargone (West Nimar) also showed notable growth, with male wages reaching ₹75.68 and female wages at ₹65.77 by 2009—though a slight gender gap persists.

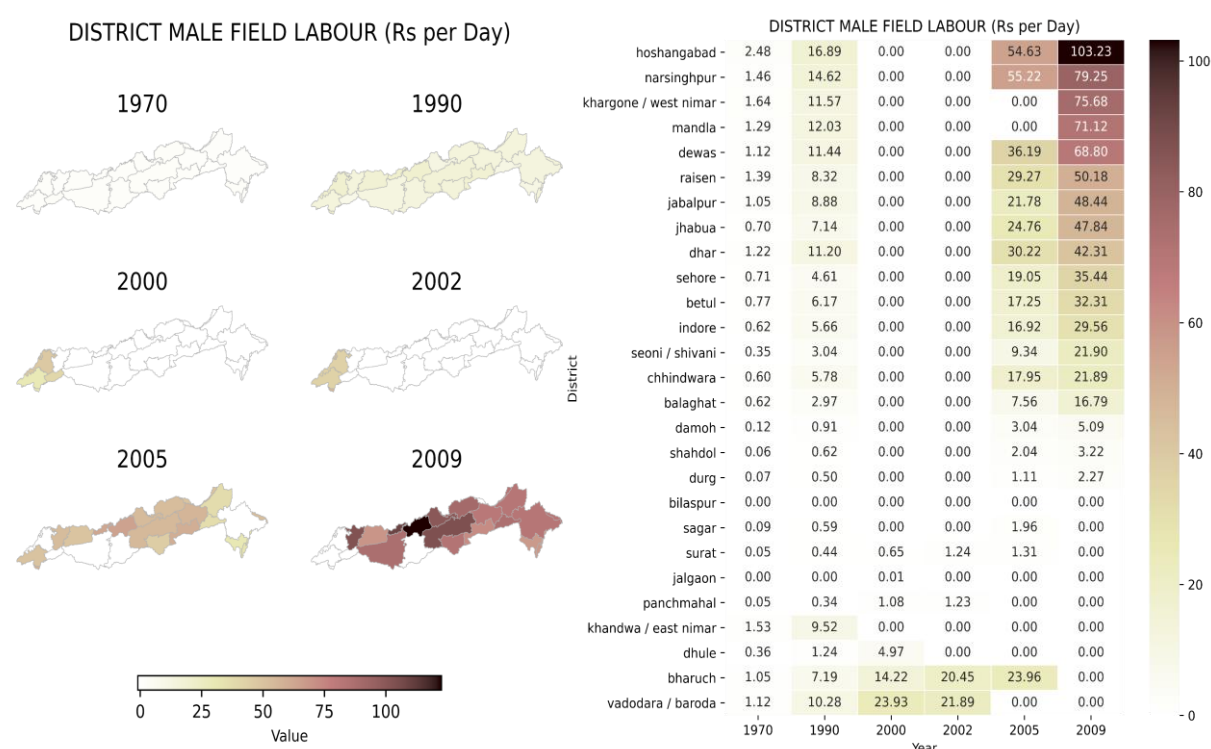


Figure 28: District wise male and male labour availability

Mandla, a tribal-dominated district, showed moderate increases with male wages reaching ₹71.12 and female wages at ₹58.71, indicating some gender disparity. Dewas recorded growth to ₹68.8 (male) and ₹56.09 (female), with a slight narrowing wage gap over time. Raisen showed wages increasing to ₹50.18 (male) and ₹57.91 (female), reflecting an unusual case where female wages briefly surpassed male wages, possibly due to seasonal labour patterns or reporting anomalies.

In Jabalpur, male wages increased from ₹1.05 to ₹48.44, while female wages grew from ₹0.88 to ₹40.24, showing a steady but lagging trend for women. Jhabua, another tribal district, reached ₹47.84 (male) and ₹45.31 (female), showing minimal wage disparity. Dhar followed a similar pattern with male wages at ₹42.31 and female at ₹40.53 in 2009.

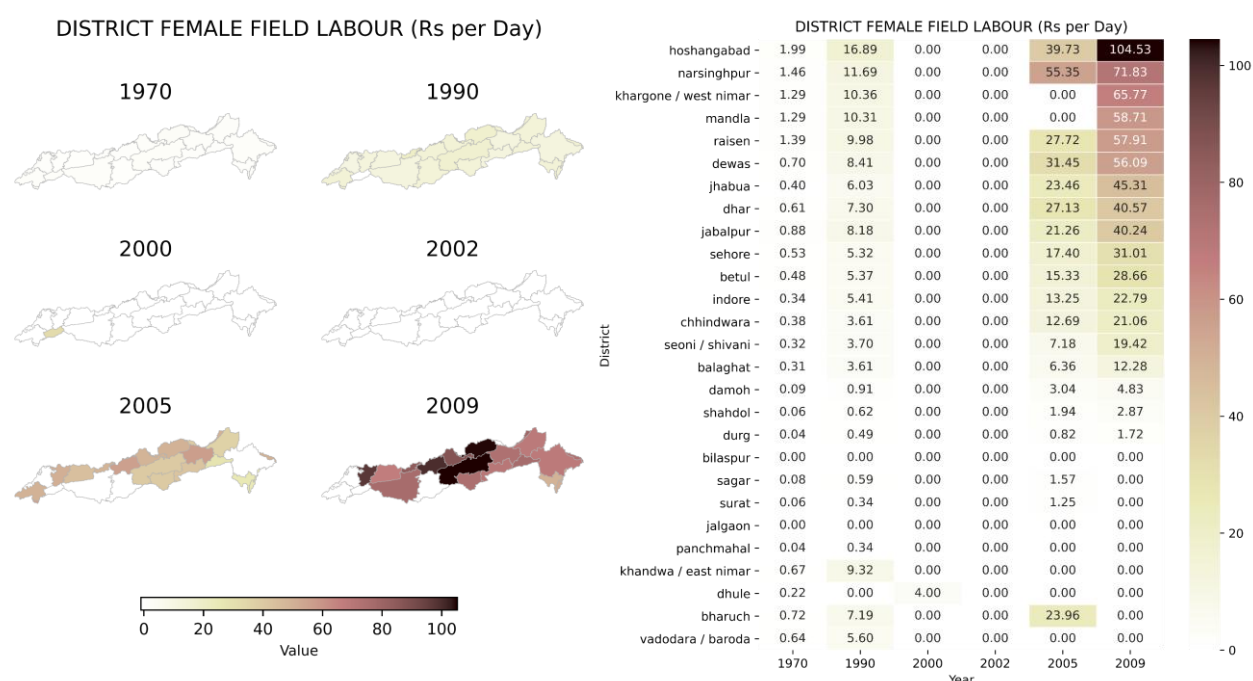


Figure 29: District wise male and female labour availability

Sehore and Narsinghpur both crossed ₹60 for men by 2009, but Sehore maintained a consistent gender gap with females earning ₹31.01 compared to ₹35.44 for men. Betul, Indore, and Chhindwara all followed similar trends, with female wages consistently 15–20% lower than male wages. Seoni/Shivani and Balaghat recorded lower overall wages, with male wages peaking at ₹21.9 and ₹16.8 respectively, and female wages under ₹20.

In Damoh, Shahdol, and Durg, wages for both genders remained under ₹10/day until 2005, and barely crossed ₹5 for females, suggesting minimal market integration and weak demand for wage labour. Bilaspur, Sagar, and Jalgaon consistently reported ₹0 wages for both genders

post-1990, indicating either missing data, non-reporting, or absence of formal wage employment.

Surat and Panchmahal displayed stagnant or negligible wage data, particularly for females, with male wages only marginally rising to ₹1.2 in 2002 and falling again. Khandwa (East Nimar) showed modest growth (₹35.39 male, ₹0 female by 2009), highlighting possible underreporting or systemic gender exclusion in rural wage tracking.

Dhule showed patchy reporting, with some rise to ₹4.9 (male) and ₹0 (female) in 2002. Bharuch had a clearer upward trend, reaching ₹23.96 for males by 2005, and a peak of ₹23.96 for females in 2005 as well—suggesting temporary wage parity.

Vadodara (Baroda) exhibited a relatively consistent increase in male wages (₹23.9 in 2005) and modest female wage improvements, though with gaps in the latter years—pointing to probable data incompleteness post-2005.

10.2 Land ownership patterns and tenancy

Land ownership in the Narmada Basin is highly skewed, with a predominance of marginal and small holdings. According to the Agricultural Census 2015–16 (Ministry of Agriculture & Farmers Welfare, 2019), over 86% of operational land holdings in Madhya Pradesh, 91% in Gujarat, and 80% in Maharashtra fall under the marginal (below 1 ha) and small (1–2 ha) categories. In key Narmada Basin districts like Dhar, Khargone, Sehore, and Vadodara, marginal holdings account for more than 60% of total holdings, contributing to high fragmentation and lower economies of scale in agriculture.

Tenancy, though widespread, remains largely informal and underreported. As per NSS 77th Round (2019) on Land and Livestock Holdings (MOSPI, 2021), only 10–15% of cultivators report leasing in land, but ground surveys in tribal regions such as Mandla reveal a much higher incidence of oral tenancy and sharecropping arrangements. These arrangements are rarely formalized due to fear of losing ownership rights, despite legal protections. The Model Agricultural Land Leasing Act, 2016, proposed by NITI Aayog, was intended to facilitate secure leasing, but its adoption remains limited across basin states.

The issue of landlessness also persists, especially among Scheduled Tribes and Scheduled Castes, who often rely on informal lease or labor arrangements for access to land. For example, the India Land and Livestock Holding Survey 2019 shows that 35% of rural households in MP and 28% in Gujarat do not own any cultivable land. Additionally, women's land ownership

remains critically low, with women owning only 13.96% of operational holdings in MP, 14.9% in Gujarat, and 12.4% in Maharashtra (National Gender Profile of Agriculture, 2021 – ICAR-CIWA).

Overall, the land tenure system in the basin is marked by fragmentation, insecurity for tenants, low women's ownership, and poor formalization of leasing—creating significant barriers to investment, mechanization, and sustainable agricultural planning. Addressing these challenges requires both legal reform and on-ground support systems for tenant recognition, land records digitization, and targeted land access programs for women and landless groups.

10.2.1 Livestock holdings and mixed farming practices

Livestock composition across Narmada Basin districts reveals varied trends in species dominance and regional specialization. Khargone (West Nimar) led in both cattle and buffalo numbers, with cattle rising from 528.6 thousand in 1966 to 799.3 thousand in 2012, and buffalo increasing from 146.3 to 271.0 thousand.

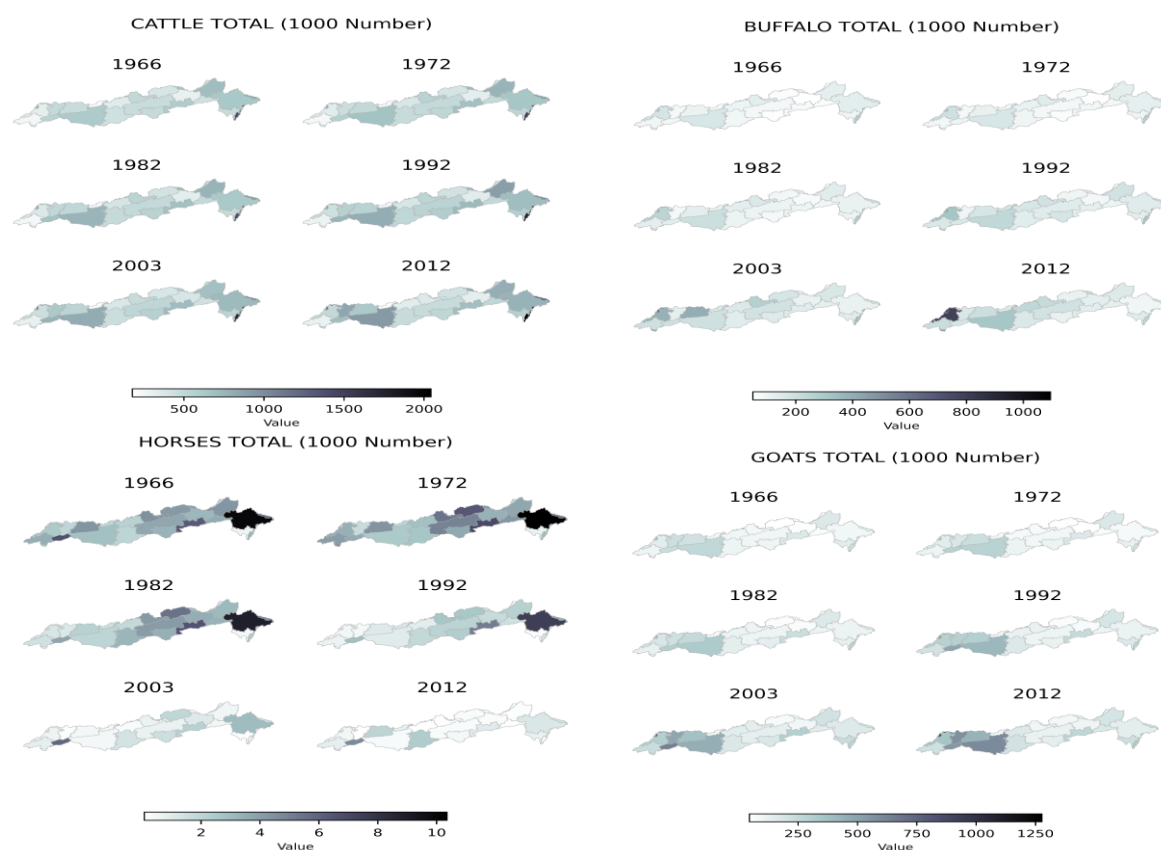


Figure 30. District wise temporal livestock holdings statistics

Mandla, with its tribal-majority population, maintained high cattle holdings—660.9 thousand in 2012—while also showing a notable increase in goats (from 81.7 to 123.2 thousand). Hoshangabad recorded substantial buffalo growth (86.4 to 184.1 thousand) and consistently high cattle (471.9 to 478.5 thousand), but sheep numbers declined dramatically, from 38.6 to just 1.4 thousand by 2012.

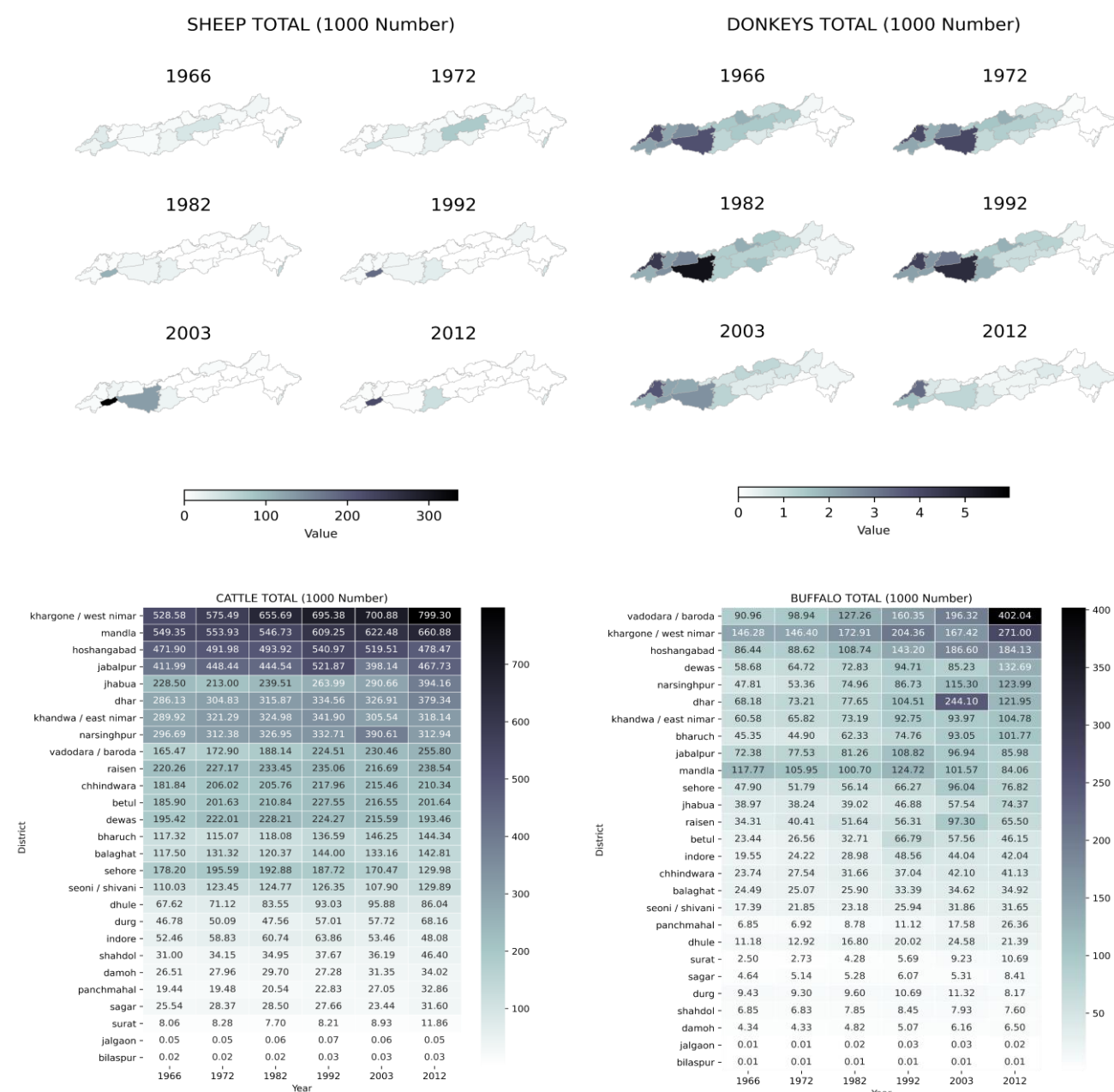


Figure 31: District wise temporal livestock holdings statistics

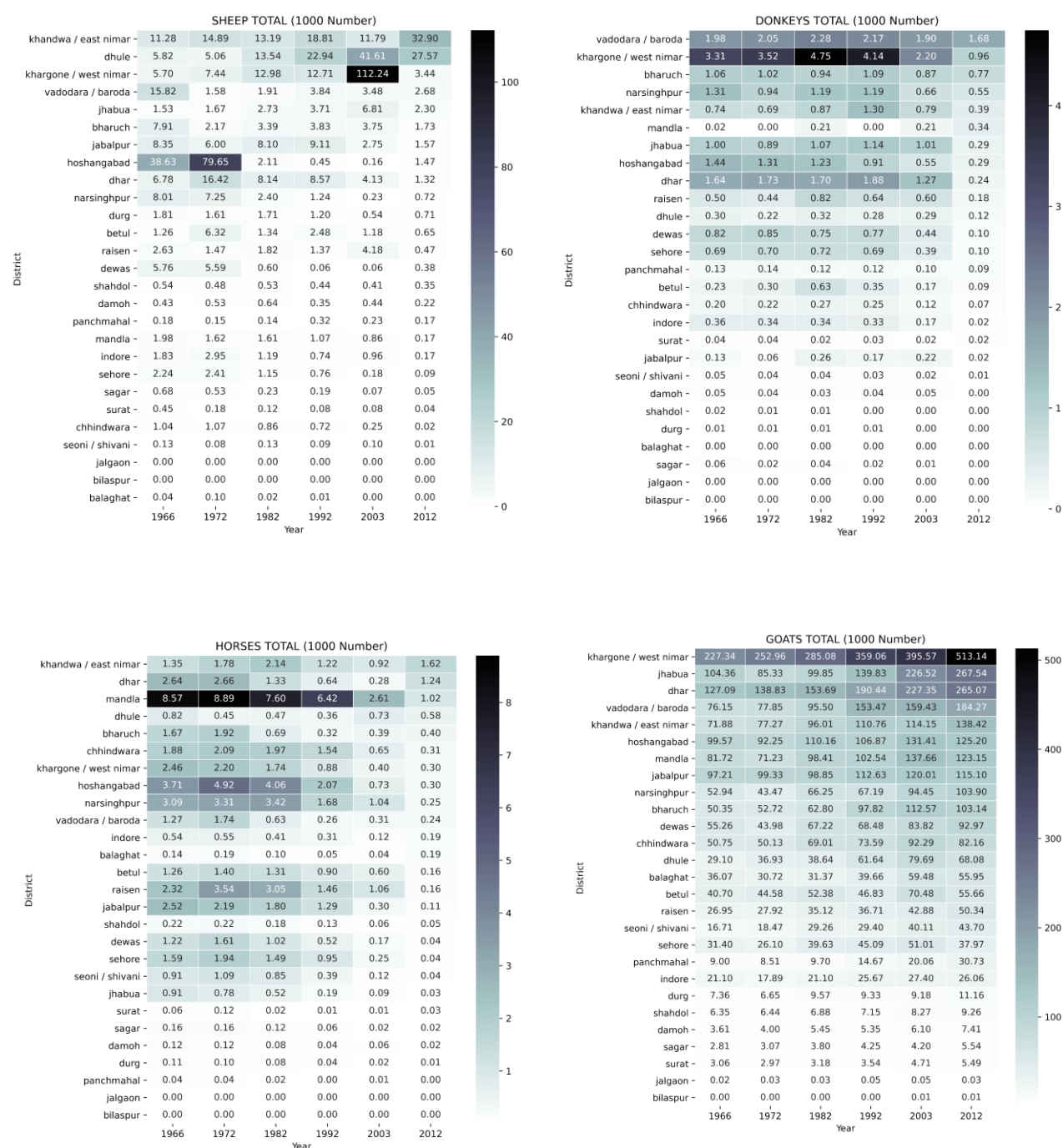


Figure 32: District wise temporal livestock holdings statistics

Jabalpur showed growth in buffaloes (72.4 to 84.1 thousand) and goats (97.2 to 115.1 thousand), while Dhar also saw buffalo rise from 73.2 to 121.9 thousand. Khandwa (East Nimar) had balanced livestock distribution—cattle grew to 318.1 thousand and buffalo to 104.8 thousand by 2012. Jhabua, a tribal belt, significantly increased goat holdings (from 85.3 to 267.5 thousand), though cattle peaked at 394.2 thousand. Narsinghpur retained high cattle (312.9 thousand) and goats (103.9 thousand), while buffaloes reached 123.9 thousand in 2012.

In Sehore, cattle numbers fell (from 178.2 to 129.9 thousand), yet buffalo and goats held stable at 76.8 and 37.9 thousand respectively. Betul had moderate growth across goats (from 44.6 to 56.7 thousand) and buffalo (46.2 thousand), with cattle peaking at 201.6 thousand. Chhindwara maintained 210.3 thousand cattle and 82.2 thousand goats, while buffalo numbers stayed below 42 thousand.

Dewas had 193.5 thousand cattle in 2012, but buffaloes decreased slightly, and goat holdings rose to 92.9 thousand. In Gujarat, Vadodara (Baroda) showed notable buffalo growth from 90.9 to 402.0 thousand and goats increasing from 76.2 to 184.2 thousand, while cattle reached 255.8 thousand. Bharuch followed similar trends with buffalo at 101.8 thousand and goats at 103.1 thousand. Raisen and Balaghat maintained goat holdings over 50 thousand, while cattle remained under 250 thousand.

Dhule and Indore showed modest buffalo increases but had low goat and sheep populations. Seoni (Shivani) and Durg saw gradual goat growth but remained under 100 thousand. In sheep, Khargone experienced a sharp increase to 112.2 thousand by 2003, followed by a steep decline. Khandwa, Dhule, and Mandla also had peaks, but most districts showed declining sheep and donkey numbers over time. For example, Khargone had 3.3 thousand donkeys in 1966 but only 0.9 thousand by 2012, while Vadodara retained around 1.7 thousand donkeys. Other districts such as Jalgaon, Bilaspur, and Sagar showed negligible livestock data, indicating either low populations or missing records.

Mixed farming—the integration of crop cultivation with livestock rearing—is emerging as a resilient pathway for sustainable agriculture in the Narmada Basin. Given the basin's dominance of marginal and smallholders (over 85% of farmers owning <2 ha), mixed farming offers both risk diversification and income stabilization. Districts such as Khargone (West Nimar), Mandla, Jhabua, and Betul already have high livestock density (with cattle populations exceeding 300,000 and goats over 100,000 in 2012), providing a strong foundation for integrating livestock with cropping systems. In tribal uplands like Mandla and Dindori, rainfed millet and maize cultivation can be efficiently paired with small ruminants like goats and poultry for nutrient recycling, while crop residues serve as fodder.

Implementation strategies include promoting backyard poultry and goats for landless households, composting and integrated nutrient management using dung and crop waste, and developing fodder banks and silage pits at village levels. Agro-climatically, the basin supports dual-season cropping, enabling interspersed fodder cultivation (e.g., Napier grass, lucerne) on

bunds and field margins. Schemes like Rashtriya Gokul Mission and National Livestock Mission, when converged with MGNREGA fodder and shed infrastructure, can further institutionalize mixed farming. Ensuring veterinary outreach, decentralized feed supply, and marketing support through FPOs and cooperatives will be key to scaling this model. Overall, a basin-wide transition to mixed farming can enhance nutrient cycling, drought resilience, women's income share, and long-term ecological stability.

11 Government Schemes and Institutional Support in the Narmada River Basin

11.1 Overview of Major agriculture related Government Schemes

The Government of India has implemented with the cooperation of states, multiple flagship schemes to support sustainable agriculture, many of which have been operational across the Narmada River Basin in varying degrees. Since these portals related to these schemes do not provide basin wise data, this report discusses the major government schemes with respect to states in which Narmada River Basin falls.

I. PM-KISAN (Pradhan Mantri Kisan Samman Nidhi)

- **Objective:** Provides income support of ₹6,000 per year to all landholding farmer families.
- **Scope in the Basin:** All districts in the Narmada Basin are covered under this scheme.

Table 17: M-KISAN Beneficiaries (State-wise) – 2023–2024

Sl. No.	State/UT	Dec 2023 – Mar 2024 No. of Beneficiaries	Apr – Jul 2024 No. of Beneficiaries	Aug – Nov 2024 No. of Beneficiaries
1	Chhattisgarh	2,320,526	2,431,795	2,496,294
2	Gujarat	4,640,941	4,845,930	4,912,111
3	Madhya Pradesh	7,987,390	8,080,376	8,136,105
4	Maharashtra	8,961,525	9,143,017	9,141,983

Source: data.gov.in, pmkisan.gov.in/

Table 17 shows that between December 2023 and November 2024, the PM-KISAN scheme recorded a consistent increase in the number of beneficiaries across the Narmada River Basin states, highlighting expanding coverage and improved implementation. In Chhattisgarh, farmer enrolment rose from 2.32 million to 2.49 million, indicating gradual outreach in tribal and semi-

rural districts. Gujarat saw an increase from 4.64 million to 4.91 million, reflecting strong digital integration and administrative efficiency. Madhya Pradesh, covering the largest share of the basin, reported a steady rise from 7.98 million to 8.13 million farmers. Maharashtra maintained the highest number of beneficiaries, remaining around 9.14 million across all three quarters. These trends suggest that PM-KISAN is playing a critical role in supporting farmers across the basin, particularly in resource-stressed and agriculturally dependent districts.

II. PMKSY (Pradhan Mantri Krishi Sinchayee Yojana)

- **Objective:** To expand irrigated areas, improve on-farm water use efficiency, and promote micro-irrigation.
- **Key components relevant to the basin:**
 - **Har Khet Ko Pani (HKKP)** – improving canal and groundwater irrigation.
 - **Per Drop More Crop (PDMC)** – promoting drip and sprinkler irrigation.
- **Implementation in the Basin:**
 - **Gujarat:** High adoption of micro-irrigation in **Bharuch, Vadodara, and Narmada** districts.
 - **Madhya Pradesh:** Targeted micro-irrigation programs in **Khargone, Dhar, and Barwani**. Over **1.08 lakh hectares** covered under drip/sprinkler as of 2022.
 - **Maharashtra:** Adoption in **Nandurbar and Jalgaon** for banana and grape cultivation.

Table 18: Central Assistance Released PMKSY in Narmada Basin States (₹ in Crore)

Sl. No.	State/UT	Accelerated Irrigation Benefits Programme (AIBP)	Har Khet Ko Pani (HKKP)	Watershed Development Component (WDC)	Per Drop More Crop (PDMC)
1	Chhattisgarh	67.76	32.77	255.81	240.64
2	Gujarat	6220.55	83.41	609.43	1685.34
3	Madhya Pradesh	1072.24	NA	1215.52	792.40
4	Maharashtra	2514.73	NA	1141.12	1960.46

Source: <https://pmksy.gov.in>, data.gov.in

III. Krishi Vigyan Kendras (KVKs) in the Narmada Basin

Krishi Vigyan Kendras (KVKs) are district-level agricultural knowledge and training institutions under the Indian Council of Agricultural Research (ICAR). In the Narmada Basin, they play an essential role in facilitating scheme outreach, technology dissemination, and

farmer education. Table 19 shows extension programmes and number of participants in the basin states of the Narmada River Basin.

Table 19: Extension Programmes and No. of Participants in the Basin States (2021-22)

State	No. of Extension Programmes Organized	Total No. of Participants	No. of KVKs
Chhattisgarh	22,927	657,301	28
Gujarat	25,932	589,521	30
Madhya Pradesh	39,138	3,062,011	54
Maharashtra	18,869	1,110,768	50

Source: ICAR, data.gov.in

IV. The Soil Health Card (SHC) Scheme

The scheme aims to assess the nutrient status of soils and provide farmers with customized recommendations for balanced fertilizer application. This initiative is particularly important for basin regions where agricultural intensification has led to overuse of chemical fertilizers, declining Across the four basin states—Madhya Pradesh, Gujarat, Maharashtra, and Chhattisgarh—the implementation of the SHC scheme has been substantial. Maharashtra leads with over 26.24 million soil health cards issued to farmers between 2015 and 2021, followed by Madhya Pradesh with 18.04 million, Gujarat with 13.84 million, and Chhattisgarh with 9.47 million cards (Table 20). These cards provide farmers with essential information on soil pH, organic carbon, nitrogen, phosphorus, potassium, and micro-nutrients such as zinc and boron. The goal is to enable data-driven decisions at the farm level, reducing the over-reliance on nitrogen-based fertilizers, improving productivity, and protecting long-term soil fertility. soil health, and reduced input efficiency.

Table 20: Number of Soil Health Cards Issued to Farmers in Narmada Basin States

Sl. No.	State/UT	Cycle-I (2015–17)	Cycle-II (2017–19)	Model Village Programme (2019–20)	2020–21	Total SHCs Issued
1	Chhattisgarh	3,890,709	5,514,508	65,341	387	9,470,945
2	Gujarat	5,108,923	8,671,152	63,591	NA	13,843,666

3	Madhya Pradesh	8,872,377	8,907,385	127,585	133,000	18,040,347
4	Maharashtra	12,977,232	13,067,735	201,837	NA	26,246,804

Source: <https://soilhealth.dac.gov.in>, data.gov.in

12 Conclusion and Policy Recommendations

The Narmada River Basin Agricultural Profile Report presents a district-level, analysis of agricultural patterns, transformations and challenges across the Narmada River Basin. Drawing from longitudinal data between 1966 and 2017, the report presents agro-climatic conditions, cropping trends, irrigation pattern, fertilizer use, landholding structures, and socio-economic characteristics that define the basin's agricultural profile.

12.1 Agrarian Core and Cropping Intensity and Irrigation

In terms of agricultural core zone, Harda, Sehore, Hoshangabad, and Narsinghpur consistently dominate the production of wheat and soybeans. For example, Harda increased its soybean production from about 102 to 184 thousand hectares, and yields reached over 4500 kg/ha, which is significantly higher than the state average. Similar to this, Hoshangabad and Sehore continued to grow wheat on 200–350 thousand hectares thanks to robust irrigation supported by groundwater and canals. With areas exceeding 100,000 hectares after 1990, Khargone (West Nimar) and Barwani became cotton strongholds on the western flank. This change was made possible by Bt cotton, black soils, and better micro-irrigation. Thanks to the Sardar Sarovar canal command, cotton, groundnut, and pulse cultivation also increased in Gujarat's Vadodara and Bharuch. However, due to limited irrigation resources and hilly terrain, tribal-dominated upland districts like Mandla, Dindori, and Shahdol exhibit lower cropping intensities and smaller cropped areas.

When talking about cropping intensity, over the past 50 years, in the basin has dramatically increased. The majority of districts used single cropping in 1966, with intensity close to 100%. Cropping intensities of 160–180% were reported by districts like Balaghat, Betul, Khandwa, and Khargone by 2017, indicating an extensive use of double cropping aided by chemical and irrigation inputs. In central Madhya Pradesh, where institutional, technological, and infrastructure support allowed for sustained agricultural intensification, this trend is most apparent. However, due to agro-ecological limitations and infrastructure deficiencies, the eastern and peripheral districts kept showing lower intensity.

The transition from conventional surface irrigation to pressurized, micro-irrigation systems has been one of the basin's most significant changes. Historically, seepage losses, low water-use efficiency (35–45%), and inadequate water delivery to tail-end farmers characterized canal systems like those in Khargone, Raisen, and Barwani. Madhya Pradesh and Gujarat implemented the PMKSY-PDMC (Per Drop More Crop), PINS (Pressurized Irrigation Network Systems), and UGPL (Underground Pipeline) programs to address these inefficiencies. More than 2.5 lakh hectares in Gujarat and 1.2 lakh hectares in Madhya Pradesh had switched to micro-irrigation by 2022. Other examples can be stated such as in Bharuch, Drip irrigation increased banana yields by 25–30% while saving 45–55% of water. Dhar districts shows water savings of 35–40% and yield gains of 20–25% were achieved by tomatoes grown under drip. However, upfront expenses, a lack of technical expertise, and dispersed landholdings continue to be barriers for smallholders and tribal communities.

12.2 Fertilizer and Pesticide Use and Agricultural Manpower

The use of chemical inputs has sharply increased in tandem with the intensification of the basin. The use of nitrogen fertilizer increased significantly, particularly in Khargone, Dhar, and Hoshangabad (87,000+ tons). By 2010, the amount of potash consumed in Khargone had risen to 16,000 tons, while the amount of phosphate used in Hoshangabad had peaked at 50,000 tons.

Despite the fact that these inputs increased yield, the report expresses concerns regarding:

- Unbalanced nutrient levels (high nitrogen versus low potassium/phosphate)
Nitrate contamination of groundwater (found in Omkareshwar and Harda)
Decline in Soil pH in Dhar and Dewas.
- Environmental toxicity in Sehore and Barwani canal commands.
- Organic amendments, balanced nutrient management, and the expansion of Integrated Nutrient Management (INM) are all recommended in the conclusion.

High levels of marginalization and fragmentation define the basin's landholding structure. The Agricultural Census 2015–16 shows that 91% of holdings in Gujarat and more than 86% of holdings in MP are small or marginal. Fragmentation of the landholdings limits:

- Institutional credit availability
- Using mechanization

- Infrastructure investment for irrigation
- Formalization of land leasing

Particularly in tribal areas like Mandla, tenancy is still mostly informal, which reduces productivity and fosters insecurity. The extremely low rates of female land ownership (13.96% in MP and 14.9% in Gujarat) necessitate gender-specific land access reforms.

12.3 Crop Planning, Yield Gaps

The yield performance analysis reveals notable spatial differences throughout the Narmada River Basin. Due in large part to better irrigation infrastructure, agronomic inputs, and extension assistance, districts like Harda, Sehore, and Hoshangabad continuously produced the most soybean and wheat. Nevertheless, significant yield disparities still exist in spite of these success stories, especially in areas that are rainfed and dominated by tribes. Alirajpur, for example, reported an actual maize yield of only 1.48 tonnes per hectare, while the potential yield is over 12 tonnes per hectare. This indicates significant gaps in crop management techniques, irrigation coverage, and technological outreach. At the same time, the basin is seeing a positive trend toward pulses and horticulture, which indicates a move away from conventional, water-intensive crops and toward more resilient and market-oriented cropping systems. By 2017, the area planted to fruits and vegetables had grown significantly to between 10,000 and 25,000 hectares in districts like Indore, Jabalpur, and Bhopal. Meanwhile, in districts like Seoni, Raisen, and Dewas, chickpea cultivation—which makes use of the soil moisture left over after kharif harvests—has expanded significantly, occupying between 5,000 and 17,000 hectares. A greater responsiveness to market demands and climate variability is reflected in these diversification patterns.

The report shows growing importance of mixed farming systems—where crop production and livestock rearing are combined—as a means of achieving ecological balance and livelihood diversification is another noteworthy finding. Strong livestock economies have been shown in districts like Khargone, Betul, Mandla, and Jhabua. In addition to improving income security, this kind of integration also helps to improve nutrient cycling, particularly in upland and tribal areas like Dindori where access to chemical inputs is restricted. By encouraging fodder cultivation on field bunds, setting up silage pits and composting units, and facilitating convergence with government programs like MGNREGA and the Rashtriya Gokul Mission,

the report highlights the necessity of scaling up sustainable livestock practices. Small and marginal farmers can benefit greatly from these programs, which can help them create diversified, resilient farming systems that are more resilient to climatic shocks and economic volatility.

Thus, Narmada River Basin shows both promising and peril future of agriculture. Despite remarkable improvements in cropping intensity, yield, and diversification in the central and western districts, sizable portions of the basin continue to be underserved, ecologically stressed, and socially vulnerable. For interdisciplinary cooperation, regionally sensitive planning, and evidence-based policy, this report is an essential resource. The agricultural trajectory of the basin must be directed by ecological integrity, equity, and long-term resilience in addition to productivity targets. The Narmada Basin has the potential to become a model of climate-resilient, socially just, and sustainable river basin agriculture for the rest of India with the help of inclusive governance and well-informed intervention.

Recommendations

The report suggests the following priority actions for basin-wide agricultural sustainability:

- Encourage zone-specific crop selections through agro-climatic crop zoning to maximize land and water use.
- Water-Energy Reforms: Use smart meters to increase solar irrigation and change flat-rate electricity systems.
- Balanced Fertilizer Use: Encourage organic inputs and increase knowledge and accessibility to micronutrients and potash.
- Irrigation Efficiency: Encourage smallholder capital subsidies and expand pressurized and micro-irrigation systems.
- Climate Adaptation: Encourage short-duration pulses and drought-tolerant cultivars in regions with limited water supplies.
- Models of Community Governance: Form irrigation committees at the Panchayat level, farmer producer groups, and groundwater user associations.

12. 4 Application.

The comprehensive data compiled in the agricultural profile report for the Narmada Basin serves as a vital foundation for integrated planning, decision-making, and sustainable resource management in the region. The detailed geographic and physiographic information, combined with demographic and ecological insights, allows policymakers and researchers to contextualize agricultural trends within the natural and human landscape of the basin. Mapping of agriculturally dominant areas and agro-climatic zones helps in identifying region-specific crop suitability, optimizing land use, and promoting crop diversification based on soil and climate compatibility. By analyzing cropping patterns, seasonal cycles, and cropping intensity indices, stakeholders can better understand food security dynamics and the potential for multi-cropping to enhance productivity. Furthermore, the crop yield statistics and yield gap analyses highlight production bottlenecks and offer clues for targeted intervention to bridge productivity disparities at sub-basin and district levels. Insight into irrigation sources and groundwater status, especially with district-level detail on drawdown patterns, provides critical guidance for water resource allocation, irrigation planning, and drought management strategies. Similarly, evaluation of irrigation techniques and water-use efficiency emphasizes the importance of adopting micro-irrigation systems like drip and sprinkler irrigation, especially in water-stressed pockets. Data on fertilizer and pesticide usage trends, along with their environmental and health implications, support the formulation of region-specific agrochemical management guidelines to prevent soil degradation, water contamination, and health hazards. Equally important is the information on farming systems, land distribution, agricultural manpower, and livestock holdings, which reveals the socio-economic underpinnings of agriculture in the basin and aids in tailoring government schemes and extension services to local needs. This agricultural profile ultimately enables the formulation of evidence-based policies and recommendations that promote sustainable agriculture, enhance productivity, conserve natural resources, and improve the livelihoods of farming communities across the Narmada Basin.

Bibliography

- Central Ground Water Board (CGWB). (2021). Ground Water Quality Atlas – Gujarat State. Ministry of Jal Shakti, Government of India. Retrieved from: <https://cgwb.gov.in>
- Central Ground Water Board (CGWB). (2022). Dynamic Ground Water Resources of India – 2022. Ministry of Jal Shakti, Government of India. Retrieved from: <https://cgwb.gov.in>
- CPCB (Central Pollution Control Board). (2019). River Water Quality Monitoring Report – Narmada Basin. <https://cpcb.nic.in>
- Department of Agriculture, Government of Gujarat. (2019). Annual Report on Agricultural Inputs and Irrigation Sources. Gandhinagar, Gujarat.
- Department of Farmers' Welfare and Agricultural Development, Government of Madhya Pradesh. (2022). District Irrigation Status Reports: Khargone, Dhar, Hoshangabad, Betul, and Sehore.
- Directorate of Economics and Statistics, Ministry of Agriculture, Government of India. <https://eands.dacnet.nic.in/>
- District Agriculture Contingency Plans (CRIDA, Hyderabad). <https://www.crida.in/>
- FAI (Fertilizer Association of India). (2022). Fertilizer Statistics 2021–22. <https://www.faidelhi.org>
- Global Yield Gap Atlas (GYGA data). <https://www.yieldgap.org/web/guest/coverage-and-data-download>
- ICAR-IISS (Indian Institute of Soil Science). (2021). Soil Health Status and Micronutrient Mapping in Central India. <https://iiss.icar.gov.in>
- ICAR-NBSS&LUP Agro-Climatic Zonation Atlas. <https://www.nbsslup.in/>
- ICAR–NIAP & NITI Aayog (2023). Study on Enhancing Water Use Efficiency through Micro-Irrigation in India. New Delhi: National Institute of Agricultural Economics and Policy Research.
- ICMR (Indian Council of Medical Research). (2017). Health Effects of Pesticide Exposure among Agricultural Workers. <https://www.icmr.nic.in>
- ICRISAT (2020). District-Level Database for India (Version 2.0). Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics. <https://data.icrisat.org>
- Indian Council of Agricultural Research – Water Technology Centre (ICAR-WTC). (2019). Water-Energy-Food Nexus Analysis for Groundwater Sustainability in Central India. New Delhi: ICAR-WTC.
- IndiaStat (2023). District-Wise Area under Micro-Irrigation by State and Year. <https://www.indiastat.com>

- Madhya Pradesh Micro Irrigation Project (MPMIP) (2022). Status of Sprinkler Irrigation in Soybean-Wheat Zones. Bhopal: Department of Farmer Welfare and Agriculture Development, GoMP.
- Ministry of New and Renewable Energy (MNRE). (2023). Progress under PM-KUSUM Scheme. Government of India. Retrieved from: <https://mnre.gov.in>
- MoHFW (Ministry of Health and Family Welfare). (2020). National Health Profile – Groundwater Contamination and Health Outcomes. <https://nhp.gov.in>
- National Institute of Hydrology (NIH). (2020). Report on Artificial Recharge Potential in Semi-Arid and Hard Rock Regions. NIH Roorkee, Ministry of Jal Shakti.
- Planning Commission, Government of India. (2011). Report of the Working Group on Minor Irrigation and Watershed Management for the Twelfth Five Year Plan (2012–17).
- Prayas (Energy Group). (2020). Electricity Subsidies for Agriculture: Current Status, Impacts, and Reforms. Pune: Prayas Energy Group. <https://prayaspune.org>
- State Agriculture Department Reports (Madhya Pradesh, Gujarat, Maharashtra)
- State Agriculture Department Reports (Madhya Pradesh, Gujarat, Maharashtra)
- WHO (World Health Organization). (2017). Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First Addendum. <https://www.who.int/publications/i/item/9789241549950>



© cNarmada, cGanga and NRCD, 2025