



Regional Disparities in Groundwater Structures in Odisha (1986-87 to 2017-18)

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Abstract: The paper is based on data from the 6th rounds of minor irrigation censuses conducted by the Directorate of Economics and Statistics, Planning & Convergence Department, Odisha on behalf of the Ministry of Jal Shakti (formerly MoWR) between 1986-87(1st census) and 2017-18 (6th census). The analysis reveals regional disparities in growth rates, utilization challenges, and increasing reliance on groundwater for agriculture. It also reveals that although groundwater structures have consistently dominated MI schemes, their growth rate has slowed down over time, with significant regional disparities in Odisha. The Central region, initially leading in growth, now faces stagnation, while Northern and Southern regions show modest gains. The study also highlights disparities in irrigation potential utilization (IPU), with some districts achieving high efficiency while others lag behind. It points out that the annual growth rate of ground water structures is increasing from 1986-87(1st census) to 2017-18(6th census) in all regions of Odisha. Despite a rise in irrigation potential, the utilization remains inconsistent across districts, emphasizing the need for sustainable water management practices and targeted interventions to enhance irrigation efficiency in underperforming regions. Accordingly, management strategies need to be chalked out.

Keywords: Culturable Command Area, Groundwater Irrigation, Irrigation Potential Created, Irrigation Potential Utilized, Minor Irrigation Census, Regional Disparities

Introduction

India's emphasis on groundwater management in minor irrigation (MI) reflects broader global trends seen in many developing nations, which face significant challenges in sustainable water management and regional equity.

Agriculture sector continues to be the main source of livelihood for a large section of the population in Odisha. The availability of water at the right time is

indispensable for agriculture, especially in Odisha, where the uncertainties of the monsoon and shifting cropping patterns present constant challenges.

According to the 6th MI Census, Uttar Pradesh leads in minor irrigation schemes (17.2%), with Maharashtra, Madhya Pradesh, and Tamil Nadu following. For groundwater schemes, top states are Uttar Pradesh, Maharashtra, Madhya Pradesh, Tamil Nadu, and Telangana. For surface water schemes, Maharashtra, Karnataka, Telangana, Odisha, and Jharkhand have the highest shares. Odisha significantly depends on groundwater for minor irrigation, contributing over 80% of its structures. Despite growth, it faces challenges like regional disparities and underutilization, similar to broader trends across India.

The analysis of minor irrigation schemes in Odisha aligns with Sustainable Development Goal 6 (Clean Water and Sanitation) and SDG, emphasizing sustainable water management, groundwater conservation, and efficient irrigation for agricultural development and food security. Food security relies on efficient irrigation to boost crop yields, stabilize food supply, and ensure consistent access to nutritious food, especially in agriculture-dependent regions. As agriculture remains the backbone of the state's economy and the primary source of livelihood for millions, irrigation emerges as a critical component in the pursuit of enhanced productivity and sustainable growth. The effectiveness of crop production in Odisha hinges not only on the quality of seeds, fertilizers, and pesticides but also, crucially, on irrigation. The irrigation facilities are meticulously classified into major, medium and minor systems, based on the cultivable command area. These systems are the lifeblood of the state's agricultural output, ensuring that water reaches fields precisely when needed, thereby enabling farmers to thrive amid changing environmental conditions.

A minor irrigation (M.I.) structure is defined as one with a cultivable command area less than 2000 hectares. The Ministry of Jal Shakti, (formerly MoWR) Government of India conducts a Census of all Minor Irrigation structures to build up a realistic data base in the minor irrigation sector. The first M.I. Census was conducted in 1986-87, followed by the second, third, fourth, fifth and sixth in the year 1993-94, 2000-01, 2006-07, 2013-14 and 2017-18 respectively. All the minor irrigation structures are broadly classified into two types i.e. (i) Ground Water Structures and (ii) Surface Water Structures. The ground water structures include Dug well, Shallow Tube well, Medium Tube well and Deep Tube well whereas surface water structures include Surface Flow and Surface Lift systems. The ground water structures have accounted for more than 80% of the Minor Irrigation structures in Odisha, the ground water

has rapidly emerged to occupy a dominant place in country's agricultural production. Odisha has substantial untapped potential in major, medium, and minor irrigation projects besides the untapped groundwater potential.

The ground water source is regarded as the primary source of irrigation in the context to Odisha. Although a number of major and medium irrigation projects have been constructed in the state to increase irrigation facilities which constitutes a major chunk of small and marginal farmers depend on minor irrigation structures fit for their purpose. Odisha's groundwater scenario shows a relatively stable situation compared to other severely over-exploited states like Punjab or Rajasthan. According to a 2020 assessment by the **Central Ground Water Board (CGWB)**, 98% of Odisha's groundwater blocks are classified as "safe" for use. Only a small fraction (around 2%) falls under the "over-exploited" or "semi-critical" category. Keeping in view the importance of the precious natural resources, all out efforts are being taken for restoration of ground water through water shed development, ground water recharge, aquifer mapping and a ground water law to tackle ground water related problems. In order to meet the demand of the crop, the farmers are gradually shifting towards deeper source of irrigation. The purpose of this paper is to insight the changes in ground water sector since 1986-87 to 2017-18 and to draw some policy recommendation for effective management of ground water irrigation in development of farm sector. This is the first analysis of its kind using six rounds of MI census data. Dhawan (1979) had looked at trends in tube well irrigation from 1951-78 using data from different sources. According to Mukherji et al. (2013), India's ground water sector has slowed down since 2000-01, mostly in eastern India.

Main Objective

- (i) **Analyse the Regional Disparity /Growth:** Evaluate changes in the number of groundwater structures across different regions of Odisha over time.
- (ii) **Measure Irrigation Efficiency:** Assess the improvements in irrigation efficiency, defined as the ratio of net irrigated area to net sown area, across various regions.
- (iii) **Analysis the Historical Trend;** The historical trends in the groundwater sector from 1986-87 to 2017-18,

- (iv) **Examine Ownership Trends:** Examine the shifts in ownership of groundwater structures among different farmer categories and social groups.
- (v) **Impact of minor irrigation on the yield rate, net area sown, and groundwater structure:** To evaluate how these irrigation systems enhance agricultural productivity, expand cultivable land, and maintain sustainable water use.
- (v) **Compare Public and Private Ownership:** To analyse trends in public versus private ownership of groundwater structures and their impacts.

Methodology and Data source

This study used secondary data from the MI censuses spanning results of 1986-87 (1st census) to 2017-18 (6th census) of Odisha, GoI. reports and Agriculture Census Reports, 2015. The parameters used for analysis of groundwater structure are mentioned below.

IPC: Irrigation Potential Created,

IPU: Irrigation Potential Utilised,

NIA: Net Irrigated Area,

NSA: Net Sown Area,

CAGR: Compound Annual Growth Rate

These parameters were used to evaluate trends, growth rates and Karl Pearson's correlation coefficient was also used to know the impact of IPU to yield rate, net sown area and groundwater structure development across three regions of Odisha i.e Central, Northern, and Southern regions Odisha. The study also assessed irrigation efficiency and sustainability by examining the impact of groundwater structures on irrigation performance.

Data

Data for this paper has been obtained from six rounds of Minor Irrigation Census (1st to 6th) and two rounds of Agricultural Census. (9th &10th) The paper has only -compared those parameters for which the data is available for more than one census period. A regional analysis has also been made to observe the divergence of M.I. structures across the regions of Odisha. The three different regions of Odisha have been taken into considered for analysis. The region wise distribution of districts in Odisha is given in Table 1

Table 1: Zone-wise Division of Districts in Odisha

<i>Northern</i>	<i>Southern</i>	<i>Central</i>
Dhenkanal, Angul, Keonjhar, Sambulpur, Deogarh, Jharsuguda, Baragarh, Sundargarh, Bolangir, Sonepur	Ganjam, Gajapati, Kadhamal, Boudh, Koraput, Malkanagiri, Nawarangpur, Rayagada, Kalahandi, Nauapada	Balasore, Bhadrak, Cuttack, Jagatsingpur, Kendrapada, Jajpur, Maurbhanj, Puri, Khurdha, Nayagarh

Findings

(a) Status of Ground Water Structures in Odisha

It is revealed that right from 1986-87, the ground water structures have constituted more than 80% of all M. I. structures in Odisha (Table 2). The share of ground water structures has gone down from 91.58% in 1986-87 to 81.47% in 2017-18, while the surface water schemes are moving upward by raising its share from 8.42% in 1986-87 to 18.53% in 2017-18. Thus, ground water structures continue to dominate M.I schemes in the State. As such the rest of this paper deals with only ground water structures.

Table 2: Ground water and Surface water Scheme in Odisha

<i>Year</i>	<i>Ground Water Scheme (%to Total MI schemes)</i>	<i>Surface Water Scheme (%to total MI schemes)</i>	<i>Total MI schemes</i>
(1)	(2)	(3)	(4)
Till 1986-87	91.58	8.42	258294
Till 1993-94	88.50	11.50	388810
Till 2000-01	86.91	13.09	467289
Till 2006-07	84.19	15.81	561153
Till 2013-14	83.24	16.76	491394
Till 2017-18	81.47	18.53	510581

Source: 1st MI Census Report of T - 1.1,2.1,3.1,4.1,5.1, 4th & 5th MI Census State Report & 6th MI Census Report.

(b) Declining Rate of CAGR of Ground water Structures

The analysis of M.I. Census data shows that the number of ground water schemes in Odisha is increasing, but at a slower rate over time. Odisha added 1 lakh wells

and tube wells with a 6.45% annual growth rate from 1986-87 to 1993-94. However, from 1993-94 to 2000-01, the state added only 0.62 lakh groundwater structures. During the period from 2000-01 to 2006-07, only 0.66 lakh groundwater structures were commissioned. The highest CAGR of 6.45% was observed between 1986-87 and 1993-94, with a notable decline to 0.42 between 2013-14 and 2017-18. Figure 1 consistent decline in the compound annual growth rate (CAGR) of groundwater structures in Odisha, dropping from 6.45% in 1986-87 to -2.37 in 2013-14 and 0.42% in 2017-18.

(c) Regional Variation in CAGRs of Ground water Structures

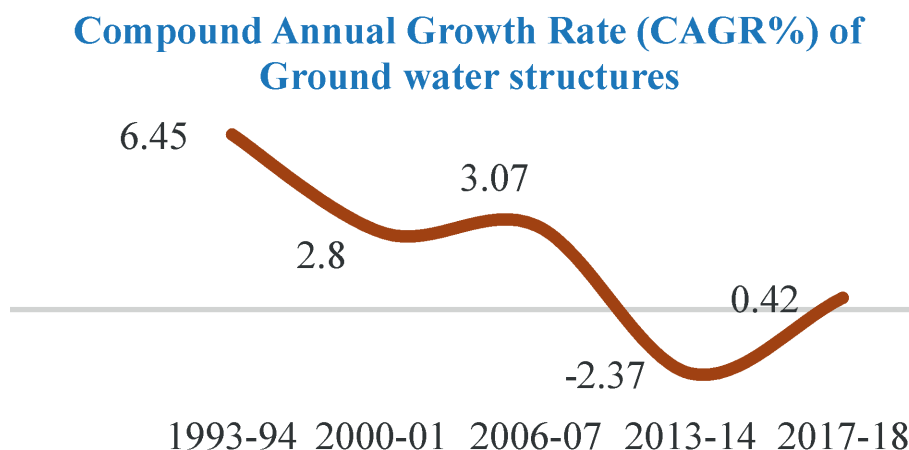


Figure 1: CAGR of Ground water structures

Table 3 exhibits the distribution of ground water structures among these different regions (Northern, Southern and Central) and their compound annual growth rates (CAGR). The northern region showed initial robust growth (6.4% CAGR from 1986-87 to 1993-94) but experienced a slowdown, with recent years seeing minimal growth (0.75%). The southern region had varied growth, with significant early gains (4.38% CAGR) and subsequent fluctuations, ending with the modest growth (1.50%). The central region initially led with high growth rates (9.76% CAGR) but faced declines in later years, culminating in a negative CAGR (-0.72%). Overall, while all regions saw early expansion, they struggled with growth sustainability and faced challenges in recent years.

Table 3: Region-wise number and growth in ground water structures

Region/year	No of Ground water structures					
	1986-87	1993-94	2000-01	2006-07	2013-14	2017-18
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Northern	116753	169389	199724	226164	198148	202665
Southern	76228	98565	102831	120065	103614	108350
Central	43562	76149	103587	126214	107278	104966
Odisha	236543	344103	406142	472443	409040	415981
		CAGR				
Region/year		1986-87 to 1993-94	1993-94 to 2000-01	2000-01 to 2006-07	2006-07 to 2013-14	2013-14 to 2017-18
		(8)	(9)	(10)	(11)	(12)
Northern		6.4	2.78	2.52	(-)2.18	0.75
Southern		4.38	0.71	3.15	(-)2.43	1.5
Central		9.76	5.26	4.03	(-)2.67	(-)0.72
Odisha		6.45	2.80	2.55	(-)2.37	.28

(d) Distribution of districts according to growth rate: (2013-14 to 2017-18)

The distribution of districts by groundwater growth rates shows varied performance. Ten districts, including Bolangir and Cuttack, had stagnant or negative growth (<0%). Twelve districts, such as Angul and Balasore, saw moderate growth (0-10%). Four districts, including Dhenkanal and Puri, achieved higher growth (10-20%), while another four districts, like Bargarh, Kandhamal, Malkangiri and Rayagada, experienced the highest growth rates (20-30%). This indicates that while some districts made significant progress, others struggled, highlighting areas for focused improvement and successful practices that could be replicated in lower-performing regions.

Table 4: Distribution of districts according to growth rate in Ground Water Structures From 2013-14 to 2017-18

<i>Range of growth rate (%)</i>	<i>Name of the Districts</i>	<i>No of Districts (30)</i>
less than 0	Bolangir, Cuttack, Gajapati, Khordha, Koraput, Mayurbhanj, Nayagarh, Sambalpur, Subernpur and , Sundergarh	10
0 to 10	Angul, Balasore, Bhadrak, Boudh, , Deogarh, Ganjam, Jagatsinghpur, Kalhandi, Kendrapara, Keonjhar, Nawarangpur and Nuapada	12
10 to 20	Dhenkanal, Jharsuguda, Jajpur and Puri	4
20 to 30	Bargarh, Kandhamal, Malkangiri and Rayagda	4

Source: State Report of 2nd ,3rd & ,4th ,5th MI and Central Report of 3rd & 6th MI

(e) Situation of Water Lifting Device

Lifting device for drawing water from wells and tube wells for irrigation purpose is an important indicator to know use of electricity in irrigation. As discussed earlier a lion's share of ground water structures constitute dug wells (depth within 15 mts). As such the farmers used to manual / animal driven practices for irrigation. So, use of electricity / diesel energy was noticed in tube wells. The ground water structures using electricity / diesel energy for lifting device are displayed in Table 5. It is seen that the central zone was the foremost contender in use of electricity energy. As many as 16.19% of the ground water structures utilized electricity as lifting device during 1986-87 in central zone followed by, the share of other zones was 4.83%,1986-87 (southern zone) and 4.18% (northern zone). Use of electricity and diesel was seen in 10.62% of ground water structures in the northern zone, 8.27% in southern zone and 5.13% in central zone during 1993-94. During the period from 2000-01 to 2006-07 the ground water structures in central zone had utilized electricity energy as lifting device in case of 15.83% and 15.40% of the ground water structures respectively. 7.28% ground water structures in the northern zone reported to have utilized electricity energy for lifting device. In the southern zone 4.24% ground water structures during 2000-01 and 3.13% during 2006-07 reported use of electricity lifting device. The trend continued into the later years. In 2013-14, about 21% of groundwater structures in the northern zone used electricity for lifting devices, compared to 10.65% in the southern zone and 41.74% in the central zone. By 2017-18, the figures further increased, with 64.15% of groundwater structures in the northern zone, 27.88% in the southern zone, and 55.03% in the central zone using electricity for lifting devices.

Table 5: Percentage of Electric Water Lifting Devices to all Water Lifting Devices relating to G.W Structures 1986-87 to 2017-18 Odisha by region

Region/ Year	1986-87	1993-94	2000-01
Northern	4.18 (4882)	10.62 (18004)	6.26 (12507)
Southern	4.83 (3688)	8.27 (8153)	4.24 (4359)
Central	16.19 (7053)	5.13 (3913)	15.18(15729)
Odisha	15623	30070	33254
Region/ Year	2006-07	2013-14	2017-18
Northern	7.28(16482)	20.68 (37753)	64.15 (126216)
Southern	3.13 (3766)	10.65 (10143)	27.88 (27993)
Central	15.40 (19441)	41.74 (38384)	55.03 (55643)
Odisha	39689	86280	209852

Source: State Report of 1st, 2nd, 3rd, 4th, 5th & 6th MI Census

(f) Culturable Command Area (CCA), Irrigation Potential Created (IPC) and Irrigation Potential Utilized (IPU)

The Minor Irrigation Censuses also provide three key sets of data related to irrigation i.e : Culturable Command Area (CCA), Irrigation Potential Created (IPC), and Irrigation Potential Utilized (IPU). These data sets are crucial for understanding the extent and effectiveness of irrigation infrastructure. The data provided IPC as a share of the CCA reflects gross area irrigated under different crops. The higher the ratio of IPC to CCA, the higher is the chance that the irrigated area is utilizing that potential. The ratio of IPU to IPC shows the extent of utilization of irrigation potential. The higher ratio reflects better utilization status. Table 6 gives these three irrigation related data for ground water structures during six M.I. Censuses. The total gross area under minor irrigation has increased from 2.33 lakh ha during 1986-87 to 5.53 lakh ha during 2006-07. But utilization of the potential has not been up to the mark. During 1986-87, 47.99% of the potential created was utilized. This has further come down to 38.16% during 1993-94. A further decline in utilization of the potential was also noticed during 2000-01 (26.25%). However, a sign of relief may be observed from the utilization of the potential up to 35.22% during 2006-07. From 2013-14 to 2017-18, CCA and IPC have increased significantly, with IPU reaching its highest at 65.93%, showing improved utilization. Overall, CCA and IPC increased significantly from 1986-87 to 2017-18, with IPU showing fluctuating but ultimately improving utilization rates.

Table 6: Typology of districts based on percentage of IPU to IPC (2013-14 and 2017-18)

<i>Percentage of IPU to IPC</i>	<i>2013-14</i>	<i>2017-18</i>
Up to 40	Bhadrak (40), Nuapada (30) & Jagatsingpur (36)	Jagatsingpur (30)
40 to 50	Kandahmal (50), Kalahandi (41), Sambalpur (42) & Kendrapara (46)	Bhadrak (43), Kalahandi (50), Nuapada (41) & Nayagarh (45)
50 to 60	Dhenkanal (52), Angul (51), Balasore (53), Boudh (55), Deogarh (57) & Jharsuguda (51)	Angul (58), Bolangir (55), Balasore (54), Boudh (59), Jajpur (59), Kandahmal (58) and Mayurbhanj (57)
60 and above	Cuttack (59), Bolangir (88), Gajapati (80), Bargarh (98), Rayagada (79), Khordha (66), Nayagarh (65), Nawarangpur (90), Mayurbhanj (65), Ganjam (80), Jajpur (70), Subernpur (91), Malkangiri (75), Puri (67), Koraput (69), Keonjhar (62) and Sundergarh (63)	Bargarh (79), Cuttack (71), Deogarh (69), Dhenkanal (66), Gajapati (79), Ganjam (74), Rayagada (79) (Jharsuguda (71), Kendrapada (74), Keonjhar (65), Khordha (65), Koraput (86), Malkangiri (69), Mayurbhanj (57), Nawarangpur (80), Subernpur (83) and Sundergarh(67)

Source: State Report of 5th & 6th MI census Central Report,

(g) Percentage of IPU to IPC

Basing on the utilization of the potential a class wise analysis among the districts of the State has been prepared. Table 8 transpires the utilization of the potential as a percentage to IPC during the last two censuses. It is seen that 3 districts across the State reported low utilization of minor irrigation up to 40% of the potential and were regarded as low-utilized districts during 2013-14, decreasing to only 1 district in 2017-18. In 40% to 50% utilization range, 4 districts were reported during 2013-14, further increasing to 4 districts in 2017-18. For 50% to 60% utilization, 6 districts were noted during 2013-14, increasing to 7 districts in 2017-18. More than 60% utilization was seen in 17 districts during 2013-14, decreasing to 16 districts in 2017-18. From 2013-14 to 2017-18, irrigation potential utilization in Odisha showed mixed progress. Low utilization (up to 40%) decreased, with only Jagatsinghpur district remaining in this category by 2017-18. Medium utilization (40-50%) saw shifts, with districts like Bhadrak and Nayagarh showing moderate improvement. High utilization (50-60%) expanded significantly, reflecting better irrigation practices in districts such as Bolangir and Jajpur. Very high utilization

(60% and above) saw substantial gains, with strong performances from districts like Cuttack and Bargarh. While overall utilization improved, disparities persist, highlighting the need for targeted interventions to enhance irrigation in underperforming districts.

Table 7: Ultimate Irrigation Potential, Irrigation Potential Created and Irrigation Potential Utilised by G.W structures in Odisha (1986-87 to 2017-18)

Year	CCA	IPC	%CCA out of IPC	IPU	% to IPC out of IPU
1986-87	165263	233354	141.20	111995	47.99
1993-94	260419	419669	161.15	160159	38.16
2000-01	329462	588865	178.74	154581	26.25
2006-07	257789	553027	214.53	194787	35.22
2013-14	429102	550152	128.21	269931	49.06
2017-18	668351	936235	140.08	617213	65.93

Source: State Report of 2nd, 3rd, 4th & 5th MI and Central Report of 3rd & 6th MI Census

(h) Net Area Sown vs Net Irrigated Area

An attempt has been made to assess number of ground water structures per 100 hectares of net area sown among different regions of the State. Increase in number of structures irrespective of the regions has given rise to higher share of ground water structures per 100 hectares of net area sown. Table 8 assesses the number of groundwater structures per 100 hectares of net area sown across different regions of Odisha. The increase in groundwater structures has led to a higher share per 100 hectares of net area sown in all regions. The northern region saw the most significant rise, from 6.30 in 1986-87 to 13.73 in 2006-07 and further to 14.54 in 2017-18. The southern region's share grew from 4.60 to 7.57 during the 1986-87 to 2006-07. In the central region, the share increased from 2.49 in 1986-87 to 8.02 in 2006-07, stabilizing around 7% in 2017-18. Overall, the state witnessed an increase in groundwater structures per 100 hectares of net sown area, from 4.50 in 1986-87 to 9.83 in 2006-07 and 9.61 in 2017-18. This data also highlights the growing dependence on groundwater resources for agriculture, emphasizing the need for sustainable water management practices to ensure long-term viability in future Table 9 highlights the changes in irrigation efficiency, measured as the percentage of net irrigated area to net sown area, from 1986-87 to 2017-18. The Central Zone shows a consistent rise in this ratio, increasing from 19.86% to 35.07%, reflecting improved

irrigation infrastructure. The North Zone fluctuates, with a peak of 20.34% in 1993-94 and a decline to 17.93% by 2017-18, indicating variable irrigation effectiveness. The South Zone demonstrates significant growth, from 16.92% to 36.65%, suggesting substantial improvements in irrigation practices. Overall, the total percentage of net irrigated area relative to net sown area rose from 16.83% to 30.07%, indicating enhanced irrigation coverage over the period.

Table 8: Number of Ground Water Structure per 100 Ha of Net Sown Area

Zone	1986-87			1993-94			2000-01		
	Net area sown	Ground Water Structure	%	Net area sown	Ground Water Structure	%	Net area sown	Ground Water Structure	%
Central	1751196	43562	2.49	1729747	76149	4.4	1587893	103587	6.52
North	1853845	116753	6.3	1633292	169389	10.37	1693444	199724	11.8
South	1655646	76228	4.6	1566237	98565	6.29	1554869	102831	6.61
Total	5260687	236543	4.5	4929276	344103	6.98	4836206	406142	8.4
Zone	2006-07			2013-14			2017-18		
	Net area sown	Ground Water Structure	%	*Net area sown (in Ha)	Ground Water Structure	%	**Net area sown	Ground Water Structure	%
Central	1574543	126214	8.02	1567018	104966	6.7	1500022	104966	7
North	1647077	226164	13.7	1550055	202665	13.07	1394039	202665	14.5
South	1586470	120065	7.57	1525195	108350	7.1	1435497	108350	7.55
Total	4808090	472443	9.83	4642268	415981	8.96	4329558	415981	9.61

Source: 1st, 2nd, 3rd, 4th, 5th and 6th MI and Agrl. Census report, *2010-11 & **2015-16

Table 9: Percentage of net irrigated area to net sown area

Zone	1986-87			1993-94			2000-01		
	Net area sown	Net area irrigated	%	Net area sown	Net area irrigated	%	Net area sown	Net area irrigated	%
Central	1751196	347792	19.86	1729747	486471	28.12	1587893	483105	30.42
North	1853845	257496	13.89	1633292	332161	20.34	1693444	303161	17.9
South	1655646	280178	16.92	1566237	310393	19.82	1554869	383887	24.69
Total	5260687	885466	16.83	4929276	1129025	22.9	4836206	1170153	24.2

Zone	2006-07			*2013-14			**2017-18		
	Net area sown	Net area irrigated	%	Net area sown	Net area irrigated	%	Net area sown	Net area irrigated	%
Central	1574543	524833	33.33	1567018	539946	34.46	1500022	526053	35.07
North	1647077	271428	16.48	1550055	283396	18.28	1394039	249893	17.93
South	1586470	367521	23.17	1525195	447932	29.37	1435497	526053	36.65
Total	4808090	1163782	24.2	4642268	1271274	27.38	4329558	1301999	30.07

Source: 1st,2nd,3rd,4th,5th and 6th MI and Agrl. Census report, *2010-11 & **2015-16

(i) Ownership of Ground Water Structures in Odisha

The farmers friendly minor irrigation especially the ground water structures are widely acceptable to marginal & small farmers ownership of ground water structures during last six Minor Irrigation Censuses as depicted in Table 10 has rightly justifies the theme. It is seen that 57.2% of the ground water structures were under the ownership of marginal and small farmers during 1986-87, 43.03% during 1993-94, 76.46% during 2000-01 & 64.45% during 2006-07. The share of medium and large farmers over the ground water structures during the said period was 42.81%, 56.98%, 23.54% and 35.55% respectively. In Odisha, ownership of ground water structures has increasingly shifted to marginal and small farmers. By 2013-14, their share was 68.75%, and by 2017-18, it remained substantial at 62.31%. In contrast, medium and large farmers' share decreased from 42.81% in 1986-87 to 35.69% in 2017-18, reflecting the growing importance of smaller farmers in ground water management.

Table 10: Ownership of Ground Water Structures by Size of Land Holdings (in %)

Size Class	1986-87	1993-94	2000-01	2006-07	2013-14	2017-18
Marginal (< 1 ha)	62510 (26.82)	111113 (19.54)	156517 (37.28)	137659 (29.73)	139178 (34.69)	134296 (34.54)
Small (1 – 2 ha)	70802 (30.38)	133577 (23.49)	164514 (39.18)	160758 (34.72)	136661 (34.06)	107989 (27.77)
Medium (2 – 10 ha)	2091 (0.90)	164514 (28.93)	91513 (21.80)	157688 (34.06)	121318 (30.24)	144123 (37.08)
Large (> 10 ha)	97685(41.90)	159528 (28.05)	7304 (1.74)	6910 (1.49)	4046 (1.01)	2367 (0.61)
All	233088 (100.00)	568732 (100.00)	419848 (100.00)	463015 (100.00)	401203 (100)	388775 (100)

Source: State report of 1st, 2nd, 3rd, 4th & 5th and 6th MI Census and Central Report of 6th MI Census

Table 11 reveals that 5th and 6th Minor Irrigation Censuses reveal a significant increase in the number of ground water structures in Odisha. Ownership of ground water structures in Odisha has seen notable shifts. The 5th MI Census (2013-14) recorded 7,432 structures under public agencies and 401,608 under private ownership, totalling 409,040. By the 6th MI Census (2017-18), public ownership surged to 22,419, while private ownership, including groups and individual farmers, increased to 393,562, making the grand total 415,981. This growth indicates enhanced investment in public irrigation infrastructure and a consistent reliance on private ownership for managing ground water resources (Dhawan,1990). Nayak (2009) assessed the extent of groundwater depletion and the factors responsible for its consequences and estimated the level of inequity in accessing various types of groundwater and minor surface irrigation sources across the states in India.

Table 11: Number of ground water structure owned by Social Groups

<i>MI Census</i>	SC	ST	OBC	Others	<i>Total (Col-1 to 5)</i>	<i>Owned by other than individual farmer (including public & group of farmers)</i>	<i>Total (Col -6 + 7)</i>
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
5th MI Census (2013-14)	51494	97011	199658	53040	401203	7837	409040
6th MI Census (2017-18)	50134	86438	177348	74855	388775	27206	415981

Source: State report of 5th & Central Report of 6th census

It is also seen that the 5th MI Census (2013-14) showed 40,203 ground water structures in Odisha owned by individuals across social categories: SC (51,494), ST (97,011), OBC (199,658), and Others (53,040), with a total of 401,203 (Table 13). By the 6th MI Census (2017-18), individual ownership decreased to 38,875 structures, distributed as SC (50,134), ST (86,438), OBC (177,348), and Others (74,855), while the total number of structures rose to 415,981. Ownership by non-individual entities, including public and farmer groups, increased significantly from 7,837 to 27,206, indicating a shift towards collective and public management.

Table 12: Number of ground water structure by tribal & non-tribal villages of 2013-14 (5th census) & 2017-18 (6th census)

MI Census	Dug well			Shallow Tube well			Medium Tube well		
	Tribal	Non-tribal	Total	Tribal	Non-tribal	Total	Tribal	Non-tribal	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2013-14 (5th census)	86948	236286	323234	1974	48004	49978	1473	23203	24676
2017-18 (6th census)	84759	180795	265554	3029	39414	42443	10930	35620	46550

Source: State report of 5th & Central Report of 6th census

Between 2013 and 2017, ground water structures in Odisha showed significant changes. Dugwells in tribal villages decreased slightly, while non-tribal villages saw a larger drop. Shallow tubewells increased in tribal areas but decreased in non-tribal areas. Medium tubewells saw substantial growth in tribal villages, with less change in non-tribal areas. Deep tubewells grew in both regions. Overall, total ground water structures rose from 409,040 to 415,981, with tribal areas experiencing notable improvements in medium and deep tube wells. (Table 12).

The findings on the impact of irrigation reveals several key insights: using Karl Pearson's co-relation coefficient method

- **Paddy Yield ($r = 0.3137$):** The moderate positive correlation indicates that increased irrigation potential (IPU) slightly improves paddy yield. However, the relationship is not strong, suggesting that factors like soil quality and crop management play important roles.
- **Groundwater Use ($r = 0.9043$):** The strong positive correlation highlights a significant reliance on groundwater as IPU increases, raising sustainability concerns. Over-extraction may lead to resource depletion, stressing the need for efficient water management.
- **Net Sown Area ($r = -0.4896$):** The negative correlation suggests that higher IPU could reduce the net sown area, potentially due to waterlogging or land mismanagement. Improved irrigation and land management practices are needed to prevent such adverse effects.

Conclusion

It is evidence from the above analysis that evolution of Odisha's groundwater irrigation sector from 1986 to 2017 reflects significant changes, with groundwater structures maintaining over 80% of minor irrigation schemes despite a slight decline

due to increasing surface water schemes. The Compound Annual Growth Rate (CAGR) for groundwater structures has decreased over the period from 1986 to 2017, revealing a slowdown in their expansion, with regional disparities evident in growth rates. While the use of electric and diesel-powered devices has increased, showing a shift towards efficient irrigation, variability in irrigation potential utilization persists. Ownership among marginal and small farmers is rising, highlighting their reliance on these structures. To ensure sustainable development, targeted strategies are needed to address regional disparities and enhance groundwater resource management. Integrating and efficiently managing minor irrigation structures are crucial for sustainable water use and agricultural development, especially in light of seasonal and irregular rainfall challenges. Proper operation and management are essential to maximize the benefits of these valuable resources.

Suggestions

1. The major problem faced minor irrigation structures is underutilization of the irrigation potential. The gap between the potential created and utilized need be bridged up to augment the area under irrigation.
2. A paradigm shift from the dug wells to deep tube wells rings the alarm bell for deplete of ground water resources. The only alternative is prudent use of ground water to fill up the disappearance the ground water resource. Effective remedial measures like replenishing/ recharging of ground water and rain water harvesting structures are to be ensured.
3. Most of the ground water structures are under the private domain. There is necessity of extension service to cater farmers information and education in appropriate techniques. Besides, this adaptive trials and demonstration at farmer's field.
4. Community participation for development and management of water resources has its own merit. Shah (2009) suggested that change the conduct of water users. From antiquity until the 1960's, agricultural water management in South Asia was predominantly the affair of village communities and/or the state.

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