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A Study on Groundwater Irrigation Expansion in Bihar, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Water use has increased by more than twice the rate of population growth over the past century. Although, there is worldwide water scarcity, an increasing number of areas are chronically short of water. There has been a substantial increase in irrigated areas in the last thirty -five years. The Net Irrigated Area (NIA) in Bihar has increased from 2808 thousand hectares in 1985 to 3083 thousand hectares in 2021. The total annual replenishable groundwater potential of Bihar has been estimated as 33.15 billion cubic meters (bcm) with an annual extraction of 13.50 bcm. The share of surface water is declining while groundwater is increasingly being used in crop production. A total of 11754 thousand hectares have been estimated as the ultimate irrigation potential in the state, including major, medium and minor irrigation schemes, utilizing both surface and groundwater. If the available potential is fully exploited, it can cover more than the total cultivated area of the state. Considering the interests of both present and future generations attention needs to be directed towards the sustainable use of groundwater and promoting various sources of surface water.

Keywords: Bihar; groundwater; irrigation; potential; surface water.

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1. INTRODUCTION

Groundwater is an important natural resource used for home, agricultural and industrial purposes and which is typically found in fresh water [1,2]. Many cities rely on groundwater for their daily water needs [3]. Many nations that rely heavily on agriculture also rely on groundwater for irrigation. Recently, approximately 60 per cent of irrigated agriculture depends on groundwater [4]. Given India's growing population, achieving food security would be extremely difficult, and water shortages would make it much more difficult. Agricultural production in India was stabilized by system canal irrigation; however, it was unable to supply all the water demand for irrigation. It was necessary to develop groundwater resources and gradually use them to meet the irrigation requirements of intensive agriculture. Since the start of the Green Revolution in 1967, groundwater has replaced surface water as the main source of irrigation in India. Modern drilling methods, inexpensive or free power, electric-operated pumping systems and the absence of effective groundwater laws have encouraged the unrestrained use of groundwater in the country [5]. Farmers also prefer groundwater because they have more control over the quantity and duration of water delivery [6].

In India, the green revolution was able to combat food shortages due to groundwater irrigation. However, at present, the effects of overdoses such as premature failure of resources, decreased groundwater discharge and depletion of water tables are evident [7,8]. Since independence, the area irrigated by government canals has decreased by 2.4 percent, while that irrigated by wells has increased by 3.9 percent [9]. Over the past three decades, it has become the main source of growth in irrigated areas. The primary source of irrigated crop production in the country is groundwater. Groundwater is widely used for crop production. Undoubtedly, agricultural productivity of irrigated land is higher than that of unirrigated land. The present study was conducted with the main objectives of determining the growth of irrigated areas under groundwater in Bihar (Fig. 1).

Fig. 1. Location of the study area

2. METHODOLOGY

To fulfil the objectives of the study secondary data were collected from Central Ground Water Board, Directorate of Economics and Statistics, Economic Survey and Department of Water Resources. The tabular method of analysis was used extensively in this study. In addition, Compound Annual Growth Rate (CAGR) of the area under surface water and groundwater irrigation was estimated in this study.

2.1 Compound Annual Growth Rate

Growth rates are measures of the past performance of economic variables and are commonly used as summaries of trends. Growth rates were estimated to study the percentage increase or decrease in the selected variable per unit of time. The growth rate was estimated using the exponential growth function of the form

$$Y_t = ab^t e^u$$

Log transformation of the above function is

$$\ln Yt = \ln a + t (\ln b) + u$$
$$\ln b = \ln (1+r)$$
where, $b = 1+r$
$$r = b - 1$$
$$r = [\text{Antilog } (\ln b) - 1]$$

The compound growth rates were calculated using the formula

$$CGR (\%) = r \times 100$$

Where, Yt = area/production/yield/export of major spices for the year 't'

t = Time variable
a = Constant
ln b = Regression coefficient of time
u = Error term, and
r = CGR

3. RESULTS AND DISCUSSION

3.1 Water Resources of the Bihar

The state of Bihar possesses abundant groundwater and surface water resources. In addition to rainfall, the state's internal rivers provide a large amount of water. These rivers contribute to the state's hydrothermal energy production and provide water for irrigation. In addition, they influence the Bihar Plain and serve as a medium for the transportation of water, supply fish for the fishing industry and enrich the natural resources of the state in many other ways. Bihar also has non-exhaustible supply of groundwater which is in use for drinking, irrigation and industries.

3.2 Surface Water Availability

Surface water availability plays a major role in agriculture and water resources in a given area. The river system in Bihar is the main source of surface water, apart from rainfall, which has multiple minor sources and is inconsistent. One of the most significant features of the river system in the state is the principal role of Ganga, which provides water for daily use by habitants for drinking, industry, irrigation, other commercial applications and recharges underground water. The Ganga, which is a major river, is joined by tributaries that originate in the Himalayas. Other rivers originate in the plateau region and flow northward to join the Ganges or other associated rivers. There are numerous rivers in Bihar that contribute significantly to its population.

3.3 Groundwater Availability

The state of Bihar is blessed with a substantial replenishable groundwater resource in the unconsolidated aquifers in the Gangetic alluvial plains, which covers more than two-thirds of its geographical area. The total annual replenishable groundwater potential of Bihar has been estimated as 33.15 billion cubic meters (bcm) with an annual extraction of 13.50 bcm (Table 1). The annual extractable groundwater in the state is 30.04 bcm, which is 7.55 per cent of the total groundwater resources of the country. After leaving aside nearly 44.21 per cent for domestic and industrial uses, a total of 16.76 bcm (55.79 per cent of the total available) is available for irrigation [10]. The stage of groundwater extraction is 44.94 per cent. This is below the country's overall stage of groundwater extraction of 60.08 per cent. Only 1.5 per cent of the state blocks are over exploited. As the groundwater development in Bihar is in the safe zone, it can be harnessed to a great magnitude to boost irrigation facilities in the state.

3.4 Ultimate Irrigation Potential

In Bihar, agriculture is still highly dependent on rainfall. Owing to recent climate change, the average annual rainfall is around 1000 mm,

varying across the state. The agricultural economy of the state depends on the extent of irrigation infrastructure. The irrigation system is broadly divided into three categories: (i) major irrigation scheme that covers a Culturable Command Area (CCA) of more than 10,000 ha; (ii) medium irrigation scheme that covers CCA between 2000 and 10,000 ha; and (iii) minor irrigation scheme that covers up to 2000 ha of CCA.

The results, in Table 2 shows the details of the ultimate irrigation potential and current utilization in Bihar for the last five years i.e. from 2017 to 2021. A total of 11754 thousand hectares have been estimated as the ultimate irrigation potential in the state, including major, medium and minor irrigation schemes, utilizing both surface and groundwater. While major and medium irrigation schemes have an ultimate potential of 5353 thousand hectares, minor irrigation schemes have a potential of 6401 thousand hectares. If this potential is fully exploited, it can more than cover the total cultivated area in the state (under all three schemes). A decrease was observed in the utilized potential of major and medium irrigation from 90 per cent in 207-18 to 75.8 per cent in 2021-22. Out of the total potential created through the major and medium schemes, only 75.8 per cent has been utilized till 2021-22 and an irrigation potential of 24.2 per cent is lost. In the minor irrigation sector, although 90 per cent of the created potential is utilized, a substantial portion of the ultimate potential remains to be exploited.

The advantages of investing in irrigation are realized only when there is an efficient utilization of the created irrigation potential (Fig. 2). The water use efficiency of major and medium irrigation projects in Bihar during the period 2017-18 to 2021-22 is presented in Table 2. The ratio of actual irrigation to created irrigation potential is known as the utilization efficiency. The overall utilization efficiency in 2017-18 was 65.10 per cent which increased to 75.80 per cent in the year 2021-22. Among the agricultural seasons, the utilization efficiency was highest during the hot weather season (96.6 %) followed by the rabi (92.7 %) and kharif (87.7 %) seasons in the year 2017-18. The utilization efficiency was the highest during the kharif season (97.5 %), followed by the rabi season (96.2 %) and hot weather season (85.2 %) in 2021-22. As only 75 per cent of the created potential has been utilized, there is still potential to exploit it further.

The total area irrigated during 2019-20 to 2021-22 through various minor irrigation sources is presented in Table 3. In 2019-20, only 42.80 per cent of the area was irrigated through tanks (including Ahars and Pyne) which increased to 84.80 per cent by 2021-22. Ahars and Pyne (Fig. 3) are traditional irrigation systems of Bihar. Ahars, with earthen bund on three sides, collects water from natural drainage or through pynes (local name of the diversion channel), which diverts water from the river. Pynes are artificial channels built to utilize river water for irrigation. In South Bihar, the Ahar-Pyne irrigation system was overwhelmingly more significant, irrigating over 35 per cent of 2.5 million hectares of cropped land during the first two decades of 20th century [11]. The area irrigated by private and state tubewells under the minor irrigation scheme was 56.80 per cent in 2019-20 which was drastically reduced to 14.60 per cent in 2021-22.

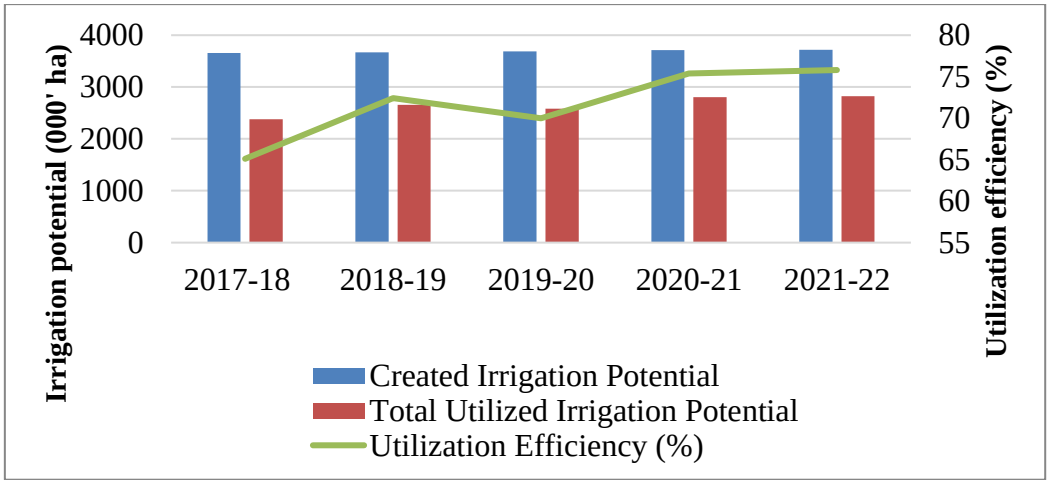

Fig. 2. Water utilization pattern of major and medium irrigation schemes (2017-18 to 2021-22)

Table 1. Groundwater availability and utilization in Bihar and Bhagalpur, 2022

Particulars	Bihar
Annual replenishable GW resources (bcm)	33.15
Net groundwater availability (bcm)	16.76
Annual extractable groundwater resource (bcm)	30.04
Current annual groundwater extraction (bcm)	13.50
Stage of groundwater development (per cent)	44.94
Safe blocks (%)	87.66
Semi-critical blocks (%)	8.60
Critical blocks (%)	2.24
Over-exploited blocks (%)	1.50

Source: Central groundwater board, 2022

Table 2. Source-wise irrigation potential created under government schemes (in 000' ha), 2017-2021

Type of Irrigation Potential	Ultimate Potential	2017		2019		2021	
		Created	Utilized	Created	Utilized	Created	Utilized
(a) Major & Medium Irrigation	5353	2969	2672(90.0)	3689	2582(70.0)	3722	2822(75.8)
(b) Minor Irrigation	6401	4079	367(90.0)	4358	3922(90.0)	4527	4074(90.0)
(i) Surface Irrigation	1544	814	732(90.0)	937	843(90.0)	1072	964(90.0)
(ii) Ground Water	4857	3265	2938(90.0)	3421	3079(90.0)	3455	3109(90.0)
Total	11754	7048	6342(90.0)	8047	6504(80.8)	8249	6896(83.6)

Source : Economic survey, government of Bihar

Note: Figures in parantheses represents utilized potential as percentage of created potential

Table 3. Area brought under irrigation through minor irrigation sources (2019-20 to 2021-22)

Source	2019-20	2020-21	2021-22
Tanks (including Ahars and Pyne)	66429(42.80)	91320(77.60)	43016(84.80)
Tubewells (Private and State)	88175(56.80)	26360(22.40)	7400(14.60)
Other Sources (Lift Irrigation)	640(0.40)	80(0.10)	280(0.60)
Total	155244 (100)	117760(100)	50696(100)

Source: Department of minor water resources, government of Bihar

Note : Figures in parentheses indicate percentage share to total number

3.5 Trends and Shifts of Water use Mechanisms in Bihar

There has been a substantial increase in irrigated area in last thirty -five years. The NIA in Bihar increased from 2808 thousand ha in 1985 to 3083 thousand ha in 2021-22. During this period, a structural shift can be observed in the relative share of different sources of irrigation in the NIA over the years (Fig. 4).

An analysis of net area irrigated in Bihar by source of irrigation (Table 4) is indicates that only 34.58 per cent of the total area is irrigated by surface water or canals and the remaining 33.26 per cent of the area is irrigated by tubewells. The dependence on canals and other sources of surface water gradually decreased over the year, whereas; the dependence on groundwater (through tubewells) increased almost twice in the same period. The share of canal irrigated area decreased slightly from 34.58 per cent during 1985-86 to 31.36 per cent during 2020-21. However, the dependence on groundwater has drastically increased from 33.26 per cent in 1985-86 to 62.41 per cent in 2021-22. The share of tanks and other sources of irrigation have declined drastically over the same period. A

drastic decrease in share of other sources was observed from 27.84 per cent to 4.51 per cent during the period 1985 to 2021.

The use of tanks and canals for irrigation has decreased very little in recent years, mostly as a result of the lack of groundwater use regulations and the inability of surface water infrastructure development to keep up with rising water demands [12]. The majority of the regions are producing double crops with a heavy reliance on groundwater irrigation due to the absence of surface water bodies. With an estimated 900,000 shallow and 1700 deep tubewells built throughout the state [13], groundwater irrigation has been the mainstay in Bihar for a relatively short time [14]. It is estimated that these figures have increased recently [15]. In addition, the population growth have increased by 25 per cent between 2001 and 2011. Thus, to meet the demands of both the expanding industry and large population, the groundwater draft has also been rising dramatically [12].

The growth rate of canal, tank and other sources of irrigated areas showed a negative trend during the period 1985-2020 (Table 5). On the other hand, the growth of tubewell irrigation was found to be 1.58 per cent during the same period and was significant at 1 per cent. A high growth rate was observed in the tubewell irrigated area in almost all time periods, more particularly during 1985-90. The growth rate for tubewell irrigated area was 9.23 per cent in 1985-90, 3.81 in 1991-96 and 5.46 in 1997-2002 and was significant in all time periods.

Fig. 3. Ahar-Pynes- traditional irrigation system of Bihar

Table 4. Net irrigated area (in thousand hectares) in Bihar by sources, 1985- 2021

Years	Canal	Tanks	Tubewell	Other Sources	Total
1985-86	9.70(34.58)	1.21(4.31)	9.33(33.26)	7.81(27.84)	28.05(100)
1990-91	10.90(32.57)	1.15(3.44)	13.88(41.47)	7.54(22.53)	33.47(100)
1995-96	10.99(29.86)	1.40(3.80)	17.28(46.95)	7.13(19.38)	36.8(100)
2000-01	9.40(27.41)	1.41(4.11)	21.26(62.00)	2.22(6.47)	34.29(100)
2005-06	8.40(26.57)	1.37(4.33)	20.45(64.69)	1.39(4.39)	31.61(100)
2010-11	8.91(29.41)	0.65(2.14)	19.46(64.22)	1.28(4.22)	30.3(100)
2015-16	9.17(31.00)	0.60(2.03)	18.41(62.24)	1.40(4.73)	29.58(100)
2020-21	9.55(31.37)	0.55(1.81)	18.99(62.38)	1.35(4.43)	30.44(100)
2021-22	9.67(31.36)	0.53(1.72)	19.24(62.41)	1.39(4.51)	30.83(100)

Source: Directorate of economics & statistics, government of India
Note: Figures in parentheses indicate percentage to the total number

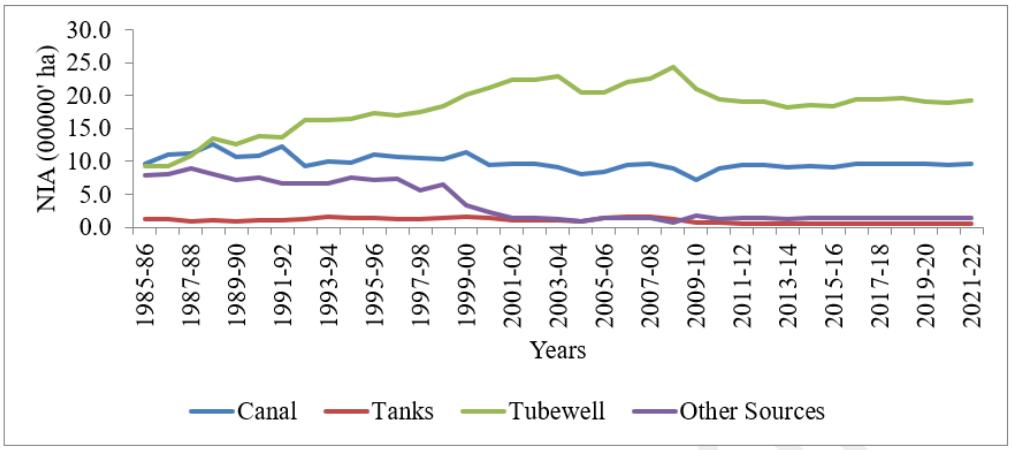

Fig. 4. Trends of different sources of irrigation in Bihar

Table 5. Period-wise compound growth rate of area irrigated by sources, Bihar

Time Period	Canal	Tank	Tubewell	Others
1985-1990	1.61	-2.89	9.23***	-1.65
1991-1996	-0.55	2.43	3.81**	2.48*
1997-2002	-2.43	-4.54	5.46***	-28.15***
2003-2008	1.79	7.90	1.98	-3.45
2009-2014	4.04	-5.63**	-2.20**	-0.58
2015-2021	0.45	-2.12***	0.26	1.43
1985-2021	-0.55***	-2.43***	1.49***	-6.44***

Source: Directorate of economics & statistics, government of India
*Note: *** Significant at 1 per cent, ** Significant at 5 per cent, * Significant at 10 per cent*

There is enormous potential for further groundwater development in the state [12,16,17]. The available net groundwater resource for irrigation is 10.01 bcm. The irrigation intensity of the state can be increased by effectively using this volume. The excess run off due to the water logging condition in the Northern Gangetic Plains can be harnessed by adequately deepening the water level. This can only be achieved by enhancing the groundwater development through sinking tubewells [16].

4. CONCLUSIONS

Agricultural growth remains low in Bihar despite the increased pump density and access to irrigation. Growth fueled by groundwater development has been short-lived and much less significant than that in the neighboring West Bengal, Eastern UP and Bangladesh, with which it shares its history and ecology. The use of surface water is declining and groundwater is increasingly being used in crop production. The share of canal irrigated area decreased while the share of tubewell irrigated area increased. The tubewells are an important component of agricultural development. Tubewells should be planned and maintained properly. Bihar has so far utilized 75.8 per cent of the ultimate irrigation potential of major and medium irrigation projects and 90 per cent of minor irrigation potential. The government must allocate more investments for irrigation to both surface and groundwater. The state must significantly increase the agricultural production to provide a livelihood to the rural population. The state requires more irrigation to increase its agricultural productivity. This is not possible without the use of irrigation water from water bodies or the stock of groundwater. Considering the interest of both present and future generation's attention of academicians, planners need to be directed towards the sustainable use of groundwater. Simultaneously this entails the promotion of various surface water sources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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