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A COMPREHENSIVE STUDY OF IRRIGATION INFRASTRUCTURE TRENDS AND SPATIAL VARIABILITY IN HARYANA: INSIGHTS FROM NET IRRIGATED AREA SOURCES (1970-71 TO 2014-15)

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Article Info

Keywords: irrigation sources, agricultural productivity, canal systems, water distribution, lift canals.

Abstract

Irrigation plays a pivotal role in sustaining global agriculture and ensuring food security. The significance of irrigated agriculture is particularly evident in India, where it has significantly contributed to food production. This paper delves into the intricate challenges associated with irrigated agriculture, highlighting the diverse sources of irrigation that are essential for sustaining agricultural productivity. The reliability and flexibility of these irrigation sources are influenced by various limiting factors. The study draws insights from previous research, which underscores the dynamic nature of irrigation systems and their profound impact on agricultural production. Focusing on the context of Haryana, a northern Indian state, the research sheds light on the unique irrigation modes prevalent in the region. The two primary modes of irrigation, namely tubewells and canals, account for the entire irrigation spectrum. The West Yamuna and Bhakra canals take center stage as the major irrigation networks, each encompassing an intricate web of canals, distributaries, minors, sub-minors, watercourses, water drains, and nullahs. These canal systems, with origins dating back to the British colonial era, have been pivotal in shaping the agricultural landscape of Haryana. A critical aspect of the water distribution system in these canal networks is the "Warabandi" mechanism, which allocates water usage across the Culturable Command Area (CCA) of each outlet. Furthermore, the study highlights the role of lift canals in the region's water distribution. These canals, catering to elevated sandy upland areas, ingeniously employ pump houses to elevate water from the Western Yamuna Canal system. The research emphasizes the importance of understanding the historical, topographical, and technological underpinnings of these irrigation systems to effectively manage water resources and enhance agricultural productivity. In conclusion, this study underscores the intricate relationship between irrigation systems and agricultural productivity, particularly in the context of Haryana, India. The historical evolution of canal systems, coupled with the innovative utilization of lift canals, showcases the region's resilience in optimizing water distribution for sustainable

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agricultural growth. This research contributes to a deeper comprehension of the factors shaping irrigated agriculture, offering valuable insights for policymakers, researchers, and practitioners engaged in water resource management and food security enhancement.

Introduction:

Irrigation is a critical aspect of agriculture and is essential for ensuring food security in many countries. In India, irrigated agriculture has contributed significantly to the country's food production (Kumar et al., 2012). However, there are several challenges to developing irrigated agriculture using various sources of irrigation. Different irrigation sources are constrained by one limiting factor that gives the source various degrees of reliability and flexibility in terms of effectiveness (Dhawan, 1988; Koli & Bodhale, 2006). Moreover, the changing structure of irrigation systems in terms of area under different sources of irrigation in a region to a great extent influences agricultural production through changing cropping patterns and increasing crop yields (Gautam, 2021).

In Haryana, a state in northern India, there are only two basic irrigation modes, the tubewells and the canals, which contribute a total of 100 percent of irrigation (Gautam & Sangwan, 2021a). The West Yamuna and Bhakra canals are the two major canal irrigation networks in Haryana (Jeet, 1998). These canal systems comprise several necessary canals, distributaries, minors, sub-minors, watercourses, water drains, and nullahs such as the WJC system, Gurgaon Canal System, Jui Canal System, Loharu Canal System, Sewani Canal System, JLN Canal System, Naggal Canal System, and Agra Canal Channels. These canal systems were built during British times and later on (Khullar, 2017). The topography of the region allows gravity flow in about 88 percent of the Culturable Command Area (CCA) of these canal systems (Singh, 1976). The water distribution system is "Warabandi," in which the total time in a week is divided by the entire Culturable Command Area on a particular outlet (Ajmera, 2013). The lift canals, covering the South Western sandy upland high altitude areas, receive water from the Western Yamuna Canal system. Water is lifted at various locations through a chain of pump houses (Khullar, 2017).

However, water supplies in this region are generally erratic and highly inadequate because of the non-completion of the Satluj Yamuna Link (SYL) canal (Singh, 1976). Irrigation Intensity is around 50 percent in Western Yamuna Command, 62 percent in Bhakra command, and 4 to 38 percent in the lift irrigation command areas (Khullar, 2017). The Bhakra Canal System with a CCA of about 1.17 million hectares provides water mainly to Hissar, Sirsa, Fatehabad, and parts of Kurukshetra, Jind, and Kaithal districts (Khullar, 2017). On the other hand, the West Jamuna Canal (WJC) system, with a CCA of about 1.7 million hectares, provides water to Sonipat, Panipat, Rohtak, Jhajjar, and parts of Jind and Bhiwani districts through gravity and to parts of Bhiwani, Mohindergarh, and Rewari districts through lift canals (Kumar et al., 2012; Khullar, 2017).

Groundwater pumped throughout a battery of about 6.2 lakhs (620,000) tubewells provides irrigation to about 1.44 million hectares of land in Haryana (Kumar et al., 2012). However, overexploitation of groundwater has led to the exhaustion of groundwater reserves, so much so that the groundwater table has gone down by five to ten meters. Irrigation plays a crucial role in ensuring food security and increasing agricultural productivity. In Haryana, irrigation is mainly dependent on canal and tubewell systems, with the former being the primary source of surface water for irrigation. However, due to various constraints such as the noncompletion of the Satluj Yamuna Link (SYL) canal and overexploitation of groundwater resources, the current irrigation systems face significant challenges. The changing structure of irrigation systems also affects agricultural production through shifting cropping patterns and altering crop yields. Therefore, it is imperative to assess the effectiveness of

different irrigation sources and explore alternative irrigation methods to address the challenges faced by the current systems. This study aims to evaluate the irrigation performance of different sources and provide recommendations for sustainable irrigation practices in Haryana.

Objectives:

The main objectives of the present study are: -

1. To present the changing irrigation structure (source-wise) in the state of Haryana.
2. To show the regional variations in share under different sources of net irrigated area with respect to Haryana state.

Database and Research Methodology:

The present study has been conducted in Haryana at the districts level. The study covers the period from 1970-71 to 2014-15 to show source-wise irrigation structure trends. To display the district-wise area under irrigation, five-time points have been selected, i.e., 1980-81, 1990-91, 2000-01, 2010-11 and 2014-15, a period of 35 years. The related data and associated information used in the study have been obtained from various issues of statistical abstracts of Haryana. To show the growth rate of area under canal and tubewell irrigation, the annual compound growth rate has been computed with the help of the following formula: -

$R = \text{Antilog}\,(\text{Log}X_2 - \text{Log}X_1) - 1/N$

Where, R is an annual compound growth rate of a chosen variable;

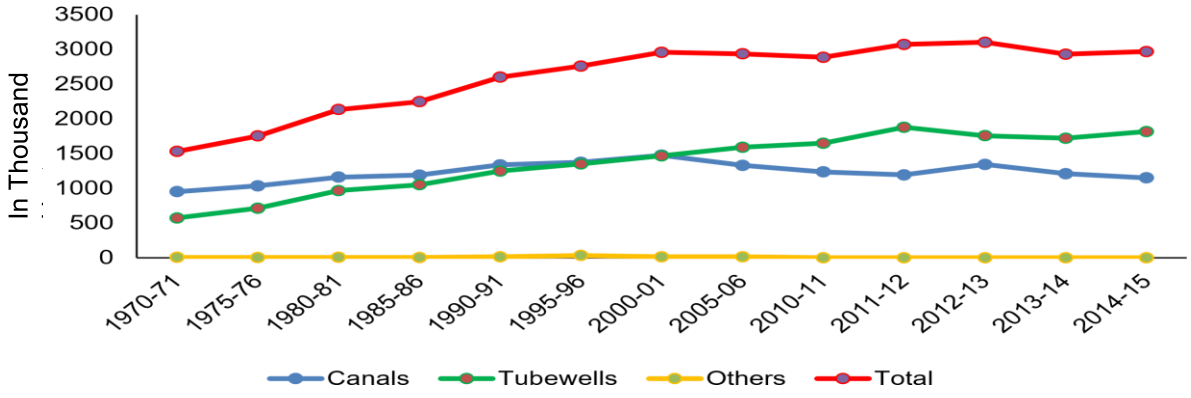
X_1 is the value of the variable during an earlier period; X_2 is the value of the variable during the later period; N is the interval between two periods.

Result and Discussion:

Changing Irrigation Structure in Haryana: Temporal Analysis

Figures 1 and 2 reveal that the Haryana state has transformed irrigation using different irrigation sources. While the percentage of canals irrigated area has declined over the years, the percentage of tubewell irrigated area is distinctively rising. In the initial years of the green revolution, the canal irrigation system was the primary source of irrigation (Kumar, 2014). It provided irrigation to about 952 thousand hectares of land in 1970-71, while canals irrigated 1151 thousand hectares during 2014-15. There has been a reduction of over 23.14 per cent in the canal irrigated area from 1970-71 to 2014-15. Canals' net irrigated area shows an increasing trend until 2000-01 with the highest increase at 1476 thousand hectares in 2000-01. Nevertheless, over the last four years, the area under canals irrigation has been declining, and it has reduced from 1476 thousand hectares in 2000-01 to 1193 thousand hectares in 2011-12. It also decreased from 1345 thousand hectares in 2012-13 to 1151 thousand hectares in 2014-15 (Figure 1).

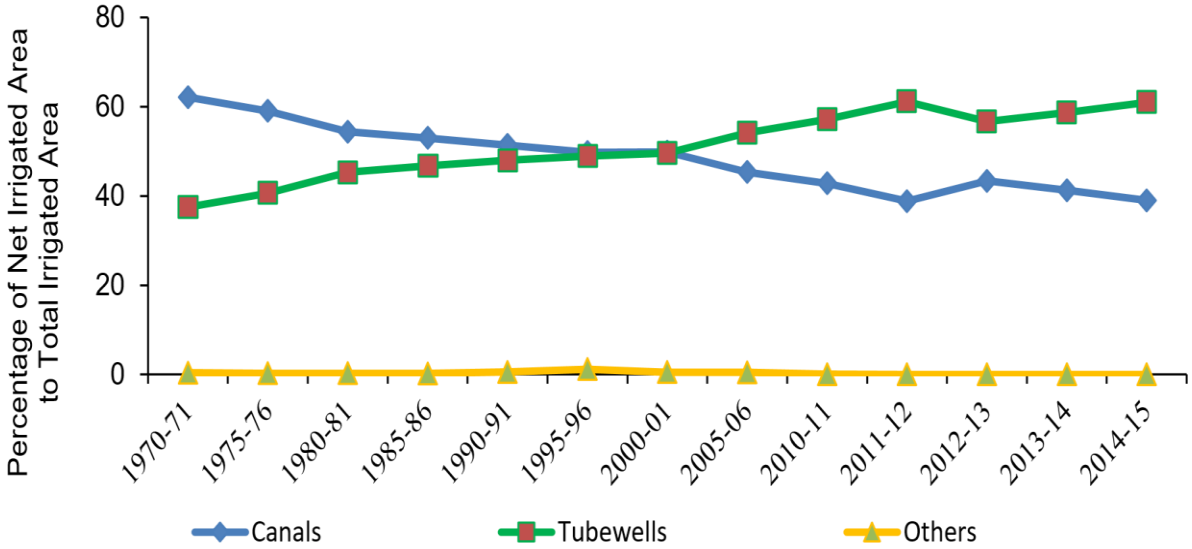
Net Irrigated Area in Haryana by Sources
(1970-71 to 2014-15)



Source: Statistical Abstract of Haryana (Various Issues) 1970-71 to 2014-15

Fig. 1

Percentage of Net Irrigated Area in Haryana by Sources (1970-71 to 2014-15)



Source: Statistical Abstract of Haryana (Various Issues) 1970-71 to 2014-15

Fig. 2

In contrast, the percentage of canals irrigation shows a downward trend from 62.14 per cent in 1970-71 to 38.83 per cent in 2011-12, with the highest decline in 2011-12 (Figure 2). The tubewell net irrigated area and the percentage of tubewell net irrigated area both have been rising consistently from 574 thousand hectares and 37.46 per cent in 1970-71 to 1879 thousand hectares and 61.16 per cent in 2011-12, after that there has been a decline in the last two years where it has declined from 1757 thousand hectares (56.64 per cent) in 2012-13 to 1721 thousand hectares (58.71 per cent) in 2013-14 and after that, it slowly increased to 1818 thousand hectares (61 per cent) in 2014-15 (Figure 1 and 2).

Thus, from the analysis of the area under irrigation under different sources of irrigation in Haryana, two important observations can be noted here. First is the shift in the tubewell irrigation from canal irrigation, and second, the percentage of canals irrigated area has declined over the years. The percentage of tubewells irrigated area is distinctively on the rise. The main reason for the sharp increase in tubewell irrigation during 1970-71 to 2014-15 is groundwater overutilisation through tubewells because the tubewells are a more reliable, self-controlled, and flexible source of irrigation than canal irrigation is mainly adopted by the farmers (Gautam, 2021).

Changing Irrigation Structure in Haryana: District Level Analysis

Net Irrigated Area by sources has been studied at the district level (Table 1). There are only two sources of irrigation in all the districts, as discussed earlier. The area under irrigation by other sources is very negligible in all districts. It is seen that tubewell irrigation is more prominent in

Panchkula, Kurukshetra, Faridabad, Yamunanagar, Ambala, Gurugram, Rewari, and Mahendragarh district where more than 90 per cent of the Net Irrigated Area are under tubewell irrigation. In three districts, Kurukshetra, Panchkula, and Faridabad recorded 100 per cent of the Net Irrigated Area under tubewell irrigation. The lowest net irrigated area under tubewell irrigation is recorded in Cotton belt districts in Bhiwani (23.9 per cent), followed by Hissar (24.3 per cent), Sirsa (24.3 per cent), and Jind (26.8 per cent) district. The tubewell irrigation,

understandably, shows the reverse of the area under canal irrigation. Most of the agricultural districts show a mixed irrigation system in the state. **Table: 1 Net Irrigated Area in Haryana by Sources (1980-81 to 2014-15)**

(Area in 000' Hectares)

Districts/ Agro Climatic Zone	Canals					Tubewells				
	1980-81	1990-91	2000-01	2010-11	2014-15	1980-81	1990-91	2000-01	2010-11	2014-15
Ambala	6 (6)	1 (1)	14 (12)	4 (4)	3 (3)	89 (88)	77 (93)	97 (86)	90 (96)	102 (94)
Kurukshetra	74 (31)	19 (14)	27 (18)	28 (19)	0 (0)	160 (67)	114 (85)	122 (82)	123 (82)	147 (100)
Karnal	77 (27)	27 (18)	70 (37)	35 (18)	38 (20)	207 (71)	126 (82)	117 (63)	165 (83)	155 (80)
Yamunanagar	-	3 (3)	3 (3)	3 (3)	4 (3)	-	88 (97)	106 (97)	112 (97)	120 (97)
Panipat	-	46 (31)	28 (30)	28 (29)	31 (33)	-	105 (69)	64 (70)	68 (71)	63 (67)
Panchkula	-	-	0 (0)	1 (8)	0 (0)	-	-	13 (87)	11 (92)	22 (100)
Northern Zone	**157 (25)**	**96 (16)**	**142 (21)**	**99 (15)**	**76 (11)**	**456 (72)**	**510 (83)**	**519 (78)**	**569 (85)**	**609 (89)**
Sonipat	73 (58)	53 (51)	83 (47)	75 (52)	24 (16)	48 (38)	52 (50)	92 (53)	70 (49)	128 (84)
Rohtak	117 (62)	184 (71)	101 (80)	74 (66)	74 (54)	66 (35)	75 (29)	25 (20)	38 (34)	63 (46)
Jind	146 (80)	125 (61)	133 (56)	193 (90)	175 (73)	37 (20)	80 (39)	103 (44)	22 (10)	64 (27)
Kaithal	-	99 (47)	99 (51)	9 (5)	77 (38)	-	103 (49)	86 (44)	191 (96)	126 (62)
Jhajjar	-	-	71 (59)	60 (48)	49 (37)	-	-	49 (41)	64 (52)	83 (63)
Central Zone	**336 (67)**	**461 (59)**	**487 (57)**	**411 (52)**	**399 (46)**	**151 (30)**	**310 (40)**	**355 (42)**	**385 (48)**	**464 (54)**
Faridabad	18 (23)	39 (49)	25 (21)	0 (0)	0 (0)	61 (76)	40 (51)	97 (80)	33 (97)	29 (100)
Gurugram	7 (11)	12 (13)	16 (20)	2 (3)	1 (1)	54 (87)	82 (87)	64 (80)	56 (97)	77 (99)
Mahendragarh	2 (2)	3 (4)	3 (3)	2 (4)	1 (2)	80 (98)	72 (96)	117 (98)	47 (96)	65 (97)
Rewari	-	3 (3)	2 (2)	2 (2)	3 (2)	-	90 (97)	100 (98)	95 (98)	123 (98)
Palwal	-	-	-	27 (26)	27 (25)	-	-	-	77 (73)	80 (75)
Nuh	-	-	-	14 (45)	7 (20)	-	-	-	17 (55)	28 (80)
Southern Zone	**27 (12)**	**57 (17)**	**46 (11)**	**47 (13)**	**39 (9)**	**195 (87)**	**284 (83)**	**378 (89)**	**325 (87)**	**402 (92)**

Bhiwani	92 (71)	104 (66)	135 (61)	84 (42)	86 (76)	37 (29)	54 (34)	85 (39)	116 (58)	27 (24)
Hissar	324 (90)	385 (87)	244 (96)	209 (77)	206 (76)	37 (10)	58 (13)	9 (4)	63 (23)	66 (24)
Sirsa	225 (78)	234 (88)	286 (86)	251 (71)	283 (76)	64 (22)	32 (12)	47 (14)	104 (29)	91 (24)
Fatehabad	-	-	136 (65)	135 (61)	62 (28)	-	-	74 (35)	88 (40)	159 (72)
Western Zone	**641 (82)**	**723 (83)**	**801 (79)**	**679 (65)**	**637 (65)**	**138 (18)**	**144 (17)**	**215 (21)**	**371 (35)**	**343 (35)**
Haryana	**1161 (54)**	**1337 (52)**	**1476 (50)**	**1236 (43)**	**1151 (39)**	**940 (44)**	**1248 (48)**	**1467 (50)**	**1650 (57)**	**1818 (61)**

Note: Figures in parentheses show the percentage of the net irrigated area by sources

(-) Data not available

Canal Irrigation

To have a more accurate analysis of irrigation development in Haryana, district-wise growth patterns must be studied; that is why district-wise decennial canal irrigation statistics from 198081 to 2014-15 are examined. During 1980-81, Canals' net irrigated area was about 1161 thousand hectares for the state, which was 54 per cent of the net irrigated area. However, it varied from district to district.

It is evident from table 1 and figures 3 that the Western zone was highly dependent on canal irrigation, where 82 per cent area was registered under canal irrigation. It is followed by the central and northern zones, where 67 per cent and 25 per cent area were registered under canal irrigation. The minimum canal irrigated area was registered in the southern zone, where 12 per cent area was registered under canal irrigation. Haryana state has observed a positive growth rate of 1.42 per cent in canal irrigated areas from 1980-81 to 1990-91. Nevertheless, it is noticed that the growth rate of canal irrigated areas consistently decline from 1980-81 to 2014-15. Haryana state was a comparatively low performer in terms of canal irrigation. The southern zone was performing the highest positive growth rate of 7.76 per cent (Table 2). The central zone was performing better performance with a positive growth rate of 3.21 per cent. The western zone showed a steady performance with a slightly positive growth rate of 1.21 per cent. The northern zone was performing the highest negative growth rate of 4.80 per cent (table 2). The highest proportion of canal irrigated area was recorded in the Hissar district (90 per cent) in the western zone. Hissar district is highly dependent on canal irrigation. The minimum proportion of canal irrigation was recorded in the Mahendragarh district (2 per cent) in the southern zone.

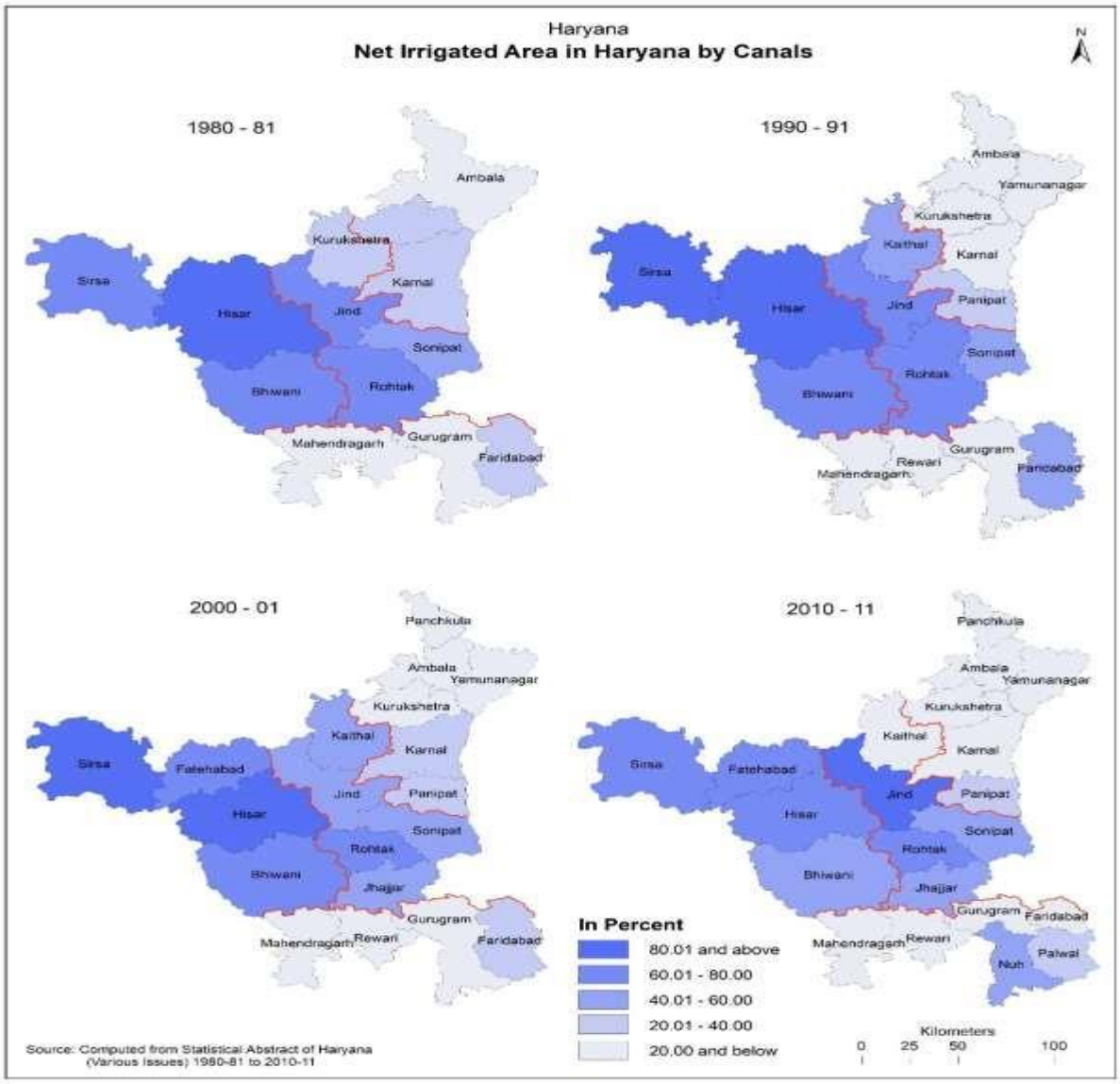


Fig. 3

Figure 3 revealed that, in 1980-81, out of 12 districts, three districts were in the category of very low (20 and below), three districts were in the category of low (21 to 40), one district was in the category of moderate (41 to 60), four districts were in the category of high (61 to 80), and one district was in the very high (81 and above) category of canal irrigated areas. The very low category (20 and below) of canal irrigated area was recorded in Mahendragarh district (2 per cent) in the southern zone. It is followed by Ambala district (6 per cent) in the northern zone and Gurugram district (11 per cent) in the southern zone. The low category (21 to 40) of canal irrigated area was recorded in Faridabad district (23 per cent) in the southern zone. It is followed by Karnal (27 per cent) and Kurukshetra district (31 per cent) in the northern zone. The moderate category (41 to 60) of canal irrigated area was recorded in only Sonipat district (58 per cent) in the central zone. The high category (61 to 80) of canal irrigated area was recorded in the Jind district (80 per cent) in the central zone. It is followed by Sirsa (78 per cent) and Bhiwani district (71 per cent) in the western zone and Rohtak district (62 per cent) in the central zone. The very high category (81 and above) of canal irrigated area was recorded in Hissar district (90 per cent) in the western zone.

During 1990-91, Canals' net irrigated area was about 1337 thousand hectares for the state, which was 52 per cent of the net irrigated area. However, it varied from district to district. It is evident from table 1 that the Western zone was highly dependent on canal irrigation, where 83 per cent area was registered under canal irrigation. It is followed by the central and southern zones, where 59 per cent and 17 per cent area were registered under canal irrigation. The minimum canal irrigated area was registered in the northern zone, where 16 per cent area was registered under canal irrigation. Haryana state has observed a slightly positive growth rate of 0.99 per cent in canal irrigated area from 1990-91 to 2000-01. Haryana state was a comparatively low performer in terms of canal irrigation. The northern zone was performing the highest positive growth rate of 3.99 per cent. The western zone was performing better performance with a positive growth rate of 1.03 per cent. The central zone showed a steady performance with a slightly positive growth rate of 0.55 per cent. The southern zone was performing a negative growth rate of 2.12 per cent (table 2). The highest proportion of canal irrigated area was recorded in Sirsa district (88 per cent) in the western zone. Sirsa district is highly dependent on canal irrigation. The minimum proportion of canal irrigation was recorded in the Ambala district (1 per cent) in the northern zone.

Figure 3 revealed that, in 1990-91, out of 16 districts, seven districts were in the category of very low (20 and below), one district was in the category of low (21 to 40), three districts were in the category of moderate (41 to 60), three districts were in the category of high (61 to 80), and two districts were in the very high (81 and above) category of canal irrigated areas. The very low category (20 and below) of canal irrigated area was recorded in Ambala district (1 per cent) in the northern zone. It is followed by Rewari district (3 per cent) in the southern zone, Yamunanagar district (3 per cent) in the northern zone, Mahendragarh (4 per cent) and Gurugram district (13 per cent) in the southern zone, Kurukshetra (14 per cent) and Karnal district (18 per cent) in the northern zone. The low category (21 to 40) of canal irrigated area was recorded in the Panipat district (31 per cent) in the northern zone. The moderate category (41 to 60) of canal irrigated area was recorded in Kaithal district (47 per cent) in the central zone. It is followed by Faridabad district (49 per cent) in the southern zone and Sonipat district (51 per cent) in the central zone. The high category (61 to 80) of canal irrigated area was recorded in Rohtak district (71 per cent) in the central zone, Bhiwani district (66 per cent) in the western zone, and Jind district (61 per cent) in the central zone. The very high category (81 and above) of canal irrigated areas was recorded in Sirsa (88 per cent) and Hissar district (87 per cent) in the western zone.

During 2000-01, Canals' net irrigated area was about 1476 thousand hectares for the state as a whole, which was 50 per cent of the net irrigated area. In 2000-01 both the major sources of irrigation, i.e., canal and tubewell, became almost equal contributors in irrigational development, contributing 49.9 per cent and 49.6 per cent irrigated area respectively. However, it varied from district to district. It is evident from table 1 that the Western zone was highly dependent on canal irrigation, where 79 per cent area was registered under canal irrigation. It is followed by the central and northern zones, where 57 per cent and 21 per cent area were registered under canal irrigation. The minimum canal irrigated area was registered in the southern zone, where 11 per cent area was registered under canal irrigation. Haryana state has observed a negative growth rate of 1.76 per cent in canal irrigated areas from 2000-01 to 2010-11. Haryana state was a comparatively low performer in terms of canal irrigation. Only the southern zone was performing a slightly positive growth rate of 0.22 per cent. The other three zones, the western zone, central zone, and northern zone, showed a negative growth rate of 1.64 per cent, 1.68 per cent, and 3.54 per cent. The northern zone performed the highest negative growth rate of 3.54 per cent in canal irrigated areas (Table 2). The highest proportion of canal irrigated area was recorded in the Hissar district (96 per cent) in the western zone. Hissar district is highly dependent on canal irrigation. The minimum proportion of canal irrigation was recorded in the Panchkula district (zero per cent) in the northern zone. Figure 3 revealed that, in 2000-01, out of 19 districts, seven districts were in the category of very low (20 and below), three districts

were in the category of low (21 to 40), four districts were in the category of moderate (41 to 60), three districts were in the category of high (61 to 80), and two districts were in the very high (81 and above) category of canal irrigated areas. The very low category (20 and below) of canal irrigated area was recorded in Panchkula district (zero per cent) in the northern zone. It is followed by Rewari (2 per cent) and Mahendragarh districts (3 per cent) in the southern zone, Yamunanagar (3 per cent), Ambala (12 per cent), and Kurukshetra districts (18 per cent) in the northern zone, and Gurugram district (20 per cent) in the southern zone. The low category (21 to 40) of canal irrigated areas was recorded in the Faridabad district (21 per cent) in the southern zone. It is followed by Panipat (30 per cent) and Karnal districts (37 per cent) in the northern zone. The moderate category (41 to 60) of canal irrigated areas was recorded in Sonipat district (47 per cent) in the central zone. It is followed by Kaithal (51 per cent), Jind (56 per cent), and Jhajjar districts (59 per cent) in the central zone. All central zone districts were registered in the moderate category except Rohtak district, where it is registered in the high category of canal irrigated areas. The high category (61 to 80) of canal irrigated area was recorded in Rohtak district (80 per cent) in the central zone. It is followed by Bhiwani (61 per cent) and Fatehabad districts (65 per cent) in the western zone. The very high category (81 and above) of canal irrigated areas was recorded in Hissar (96 per cent) and Sirsa districts (86 per cent) in the western zone.

During 2010-11, Canals' net irrigated area was about 1236 thousand hectares for the state, which was 43 per cent of the net irrigated area. In 2010-11 net irrigated area declined by 240 thousand hectares. However, it varied from district to district. In 2010-11, the area under tubewell irrigation surpassed the area under canal irrigation. In 2000-01 both the irrigation sources almost came under equal proportion irrigating almost equal parts, but in 2010-11, tubewell irrigation dominated the state's irrigation facilities. It is evident from table 1 that the Western zone was highly dependent on canal irrigation, where 65 per cent area was registered under canal irrigation. It is followed by the central and northern zones, where 52 per cent and 15 per cent area were registered under canal irrigation. Minimum canal irrigation area was registered in the southern zone, where 13 per cent area was registered under canal irrigation. Haryana state has observed a slightly negative growth rate of 0.71 per cent in canal irrigated area from 2010-11 to 2014-15. Haryana state was a comparatively low performer in terms of canal irrigation. All four zones were showed a negative growth rate in terms of canal irrigated area. The central and western zones showed a slightly negative growth rate of 0.30 per cent and 0.64 per cent. The southern zone was performing a negative growth rate of 1.85 per cent. The northern zone performed the highest negative growth rate of 2.61 per cent in canal irrigated areas (Table 2). The highest proportion of canal irrigated area was recorded in the Jind district (90 per cent) in the Central zone. Jind district is highly dependent on canal irrigation. The minimum proportion of canal irrigation was recorded in the Faridabad district (zero per cent) in the southern zone.

Figure 3 revealed that, in 2010-11, out of 21 districts, ten districts were in the category of very low (20 and below), two districts were in the category of low (21 to 40), four districts were in the category of moderate (41 to 60), four districts were in the category of high (61 to 80), and only one district was in the very high (81 and above) category of canal irrigated areas. The very low category (20 and below) of canal irrigated area was recorded in Faridabad (zero per cent), Rewari (2 per cent), and Gurugram districts (3 per cent) in the southern zone. It is followed by Yamunanagar district (3 per cent) in the northern zone, Mahendragarh district (4 per cent) in the southern zone, Ambala district (4 per cent) in the northern zone, Kaithal district (5 per cent) in the central zone, Panchkula (8 per cent), Karnal (18 per cent) and Kurukshetra districts (19 per cent) in the northern zone. The low category (21 to 40) of canal irrigated areas was recorded in Palwal district (26 per cent) in the southern zone. It is followed by the Panipat district (29 per cent) in the northern zone. All districts of the northern and southern zone were registered in the very low and low category of canal irrigated area, except Nuh district, where it is registered in the moderate category. The moderate category (41 to 60) of canal irrigated areas was recorded in the Bhiwani district (42 per cent) in the western zone. It is followed by the Nuh district (45 per cent) in the southern zone, Jhajjar (48 per cent), and Sonipat districts (52 per cent) in the central zone. The high category (61 to 80) of canal irrigated areas was recorded in Hissar (77 per cent) and Sirsa districts (71 per cent) in the western zone. It is followed by Rohtak district (66 per cent) in the central zone and Fatehabad district (61 per cent) in the western zone. The very high category (81 and above) of canal irrigated area was recorded in only one district, Jind (90 per cent) in the central zone. In the southern zone, district Palwal and Nuh were the newly formed districts carved out of district Faridabad and district Gurugram, respectively that is why both the old districts showed declined figures for the net irrigated area by canals in comparison to 2000-01. During 2014-15, Canals's net irrigated area was about 1151 thousand hectares for the state as a whole, which was 39 per cent of the net irrigated area. However, it varied from district to district. It is evident from table 1 that the Western zone was highly dependent on canal irrigation, where 65 per cent area was registered under canal irrigation. It is followed by the central and northern zones, where 46 per cent and 11 per cent area were registered under canal irrigation. The minimum canal irrigated area was registered in the southern zone, where 9 per cent area was registered under canal irrigation. Haryana state has observed a very slightly negative growth rate of 0.02 per cent in canal irrigated areas from 198081 to 2014-15. Haryana state was a comparatively low performer in terms of canal irrigation. The western zone was performing a very slightly negative growth rate of 0.02 per cent. The central zone was performing a very slightly positive growth rate of 0.49 per cent. The southern zone was performing a better positive growth rate of 1.06 per cent. The northern zone performed the highest negative growth rate of 2.05 per cent in canal irrigated areas (Table 2). The highest proportion of canal irrigated area was recorded in Bhiwani, Hissar, and Sirsa districts (76 per cent) in the western zone. These districts are highly dependent on canal irrigation. The minimum proportion of canal irrigation was recorded in Kurukshetra (zero per cent) and Panchkula districts (zero per cent) in the northern zone and Faridabad district (zero per cent) in the

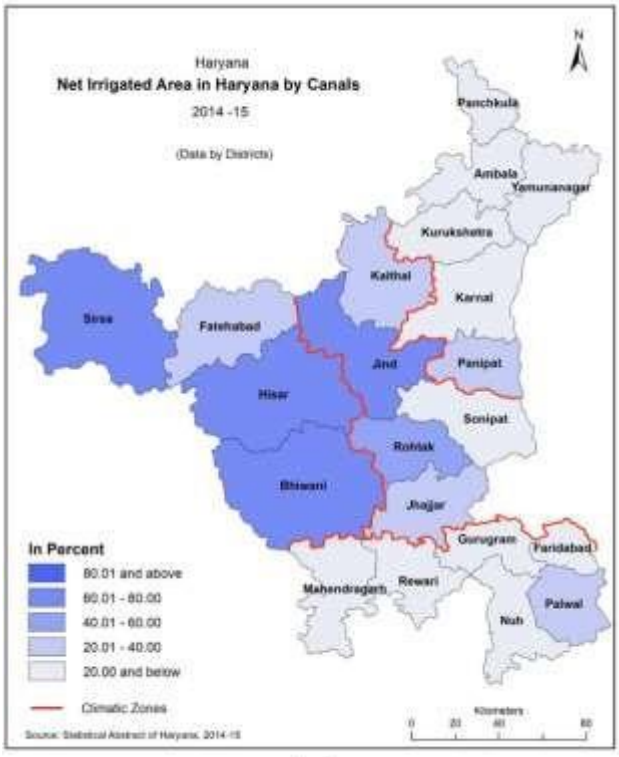


Fig. 4

southern zone. In the Kurukshetra district, groundwater is a reliable source for all farmers (Gautam & Singh, 2019). In Panchkula and Faridabad districts, it is because of urban and industrial development that more agricultural land has been brought under construction works and human settlements (Singh, 1976).

Figure 4 revealed that, in 2014-15, out of 21 districts, 11 about 50 per cent districts were in the category of very low (20 and below), five districts were in the category of low (21 to 40), only one district was in the moderate category (41 to 60), four districts were in the high category (61 to 80), and there is no district fell in the very high category (81 and above) of canal irrigated area. The very low category (20 and below) of canal irrigated area was recorded in Kurukshetra (zero per cent) and Panchkula district (zero per cent) in the northern zone and Faridabad district (zero per cent) in the southern zone. There has no (zero per cent) canal irrigated area registered in this study period in these three districts. It is followed by Gurugram (1 per cent), Mahendragarh (2 per cent) and Rewari districts (2 per cent) in the southern zone, Ambala (3 per cent) and Yamunanagar district (3 per cent) in the northern zone, Sonipat district (16 per cent) in the central zone, Karnal district (20 per cent) in the northern zone and Nuh district (20 per cent) in the southern zone. The low category (21 to 40) of canal irrigated areas was recorded in Palwal district (25 per cent) in the southern zone. It is followed by Fatehabad district (28 per cent) in the western zone, Panipat (33 per cent) in the northern zone and Jhajjar (37 per cent), and Kaithal district (38 per cent) in the central zone. The moderate category (41 to 60) of canal irrigated area was recorded in only one district, Rohtak (54 per cent) in the central zone. The high category (61 to 80) of canal irrigated area was recorded in Bhiwani (76 per cent), Hissar (76 per cent), and Sirsa district (76 per cent) in the western zone. It is followed by the Jind district (73 per cent) in the central zone. Furthermore, no district fell in the very high category (81 and above) of canal irrigated area. The net irrigated area by canals has decreased 54 per cent to 39 per cent from 1980-81 to 2014-15 (table 1). This situation was showing that canal irrigated area has decreased because tubewell irrigation has increased year by year. The reason is lack of maintenance of canals because of which there are siltation and less water in canals (Kumar, 2014). In an extensive field visit of Haryana, it was noticed that the channels existed, but there was no water in them, and farmers have resorted to groundwater irrigation. While the area irrigated under canals is declining, the dependence on groundwater has increased enormously. Government and private banks were provided easy bank loans to install tubewell or pumping sets and other irrigation facilities to farmers (Gautam & Sangwan, 2021a, b). The area under tubewell irrigation grew at a much faster pace than the area under canal irrigation. Canal irrigation accounted for more than three-fourths of the net irrigated area when the state came into existence. This decline may be attributed to a more rapid expansion in groundwater exploitation. It can be interpreted that canal irrigation is dominant in the Western zone districts (Bhiwani, Hissar, and Sirsa) and Central zone districts (Rohtak and Jind). Whereas, least canal irrigated area is recorded in northern zone districts (Ambala, Kurukshetra, Karnal, Yamunanagar, Panipat, and Panchkula) and southern zone (Faridabad, Gurugram, Mahendragarh, Rewari, Palwal, and Nuh) districts.

Table: 2 Compound Growth Rates of Irrigated Area in Haryana by Canals (1980-81 to 2014-15)

(In Per cent)

Districts/Agro Climatic Zone	Canals				
	1980-81 to 1990-91	1990-91 to 2000-01	2000-01 to 2010-11	2010-11 to 2014-15	1980-81 to 2014-15
Northern Zone	-4.80	3.99	-3.54	-2.61	-2.05

Central Zone	3.21	0.55	-1.68	-0.30	0.49
Southern Zone	7.76	-2.12	0.22	-1.85	1.06
Western Zone	1.21	1.03	-1.64	-0.64	-0.02
Haryana	**1.42**	**0.99**	**-1.76**	**-0.71**	**-0.02**

Source: Computed from Table: 1

Tubewell Irrigation

Concomitant with an expansion of area under irrigation, the modes of irrigation have also been changing in favor of tubewells. The tubewell irrigation, understandably, shows the reverse of the area under canal irrigation. To have a more accurate analysis of irrigation development in

Haryana, a separate and detailed analysis for tubewell irrigation is required under the study. Irrigation from groundwater in the form of Tubewell is substantial during the past four decades when Haryana became an independent state. There is an immense increase in groundwater abstraction structures' growth due to the augmentation of tubewells and villages' electrification. During 1980-81, the net irrigated area by Tubewells was about 940 thousand hectares for the state as whole, which was 44 per cent of the net irrigated area.

However, it varied from district to district. It is evident from the table 1 that the Southern and Northern zones were highly dependent on tubewell irrigation, where 87 per cent and 72 per cent area were registered under tubewell irrigation. It is followed by central zone, where 30 per cent area was registered under tubewell irrigation. Minimum tubewell irrigated area was registered in western zone, where 18 per cent area was registered under tubewell irrigation. Haryana state has observed a positive growth rate of 2.87 per cent in tubewell irrigated area from 1980-81 to 199091. It is noticed that the area under tubewell irrigation is a consistent increase from 940 thousand hectares (44 per cent) to 1818 thousand hectares (61 per cent) from 1980-81 to 2014-15, But the growth rate of tubewell irrigated area is a consistent decline from 2.87 per cent to 0.97 per cent in the corresponding period. Haryana state was a comparatively high performer in terms of tubewell irrigation. The central zone was performing better performance with a positive growth rate of 7.46 per cent. The southern zone was performing better performance with a positive growth rate of 3.83 per cent. The northern and western zone showed a steady performance with a slightly positive growth rate of 1.13 per cent and 0.43 per cent (table 3). The highest proportion of tubewell irrigation was recorded in the Mahendragarh district (98 per cent) in the southern zone. Mahendragarh district is highly dependent on tubewell irrigation. Tubewell has been successfully commissioned primarily in the southern part of Haryana. The minimum proportion of tubewell irrigation was recorded in the Hissar district (10 per cent) in the western zone. Tubewell irrigation is not widespread in the Hissar district because canal irrigation was very much developed in Hissar district in 1980-81.

Figure 5 revealed that, in 1980-81, out of 12 districts, two districts were in the very low category (20 and below), four districts were in the low category (21 to 40), no district fell in the moderate category (41 to 60), three districts were in the high category (61 to 80) and three districts were in the very high (81 and above) category of tubewell irrigation. The very low category (20 and below) of tubewell irrigation was recorded in Hissar district (10 per cent) in the western zone and Jind district (20 per cent) in the central zone. The low category (21 to 40) of tubewell irrigation was recorded in Sirsa (22 per cent) and Bhiwani district (29 per cent) in the western zone. It is followed by Rohtak (35 per cent) and Sonipat district (38 per cent) in the central zone. No district fell in the moderate (41 to 60) category of tubewell irrigation. The high category (61 to 80) of tubewell irrigation was recorded in the Faridabad district (76 per cent) in the southern zone. It is followed by Karnal (71 per cent) and Kurukshetra district (67 per cent) in the northern zone. The very high category (81 and above) of tubewell irrigation was recorded in

the Mahendragarh district (98 per cent) in the southern zone. It is followed by Ambala district (88 per cent) in the northern zone and Gurugram district (87 per cent) in the southern zone.

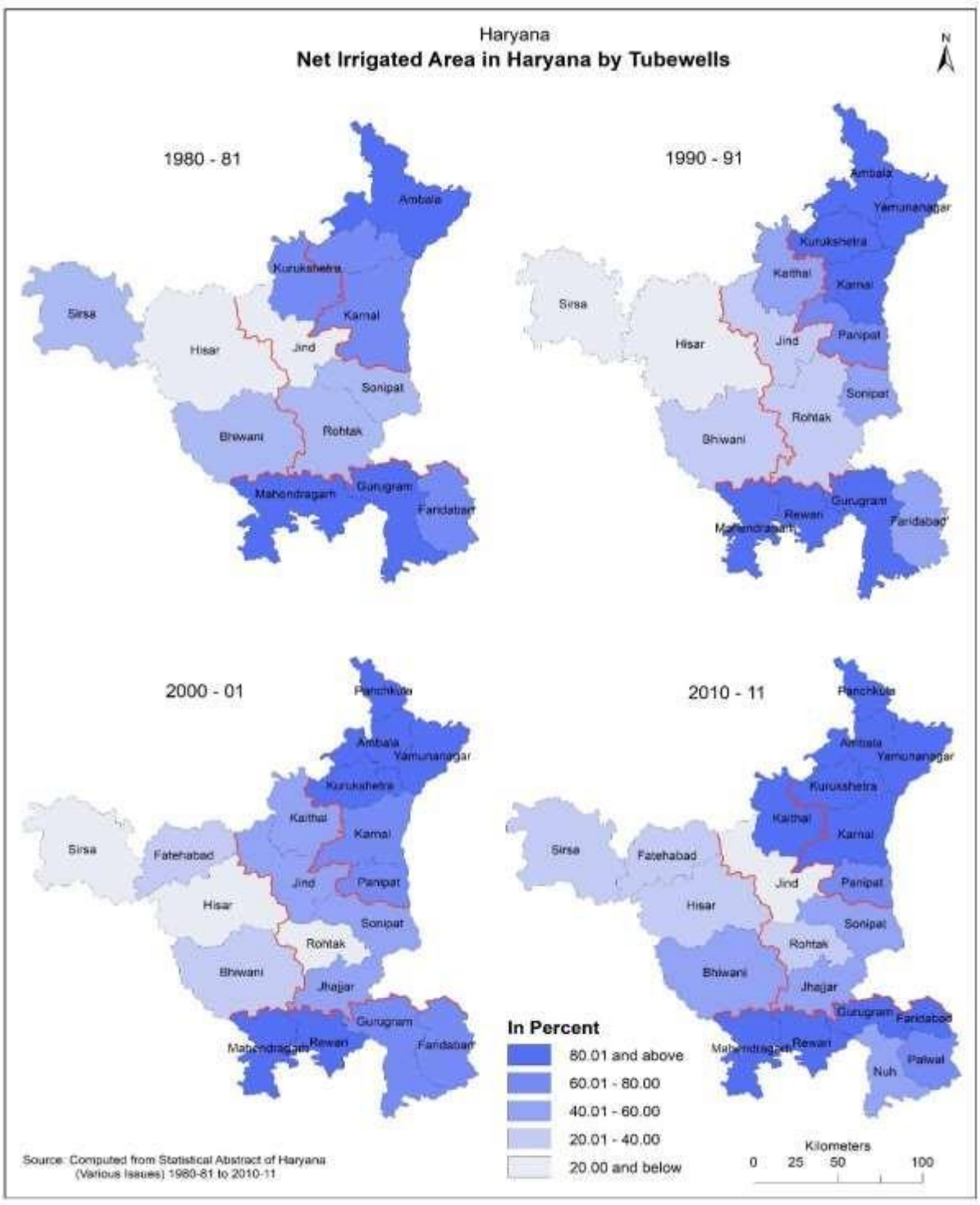


Fig. 5

During 1990-91, the net irrigated area by Tubewells was about 1248 thousand hectares for the state as a whole, which was 48 per cent of the net irrigated area. In 1990-91, the net irrigated area increased by 308 thousand hectares. However, it varied from district to district. It is evident from table 1 that the Northern and Southern zone was highly dependent on tubewell irrigation, where both zones were showed 83 per cent area under tubewell irrigation. It is followed by the central zone, where 40 per cent area was registered under tubewell irrigation.

Again the minimum tubewell irrigated area was registered in the Western zone, where 17 per cent area was registered under tubewell irrigation. Haryana state has observed a positive growth rate of 1.63 per cent in tubewell irrigated area from 1990-91 to 2000-01. Haryana state was a comparatively high performer in terms of tubewell irrigation. The western zone registered the very least irrigated area by tubewell under this study period, but the western zone performed the highest positive growth rate of 4.09 per cent under tubewell irrigation. The southern and central zones performed better with a positive growth rate of 2.90 per cent and 1.36 per cent. The northern zone showed a steady performance with a slightly positive growth rate of 0.18 per cent (table 3). The highest proportion of tubewell irrigation was recorded in the Yamunanagar district (97 per cent) in the northern and Rewari district (97 per cent) in the southern zone. These districts are highly dependent on tubewell irrigation. The minimum proportion of tubewell irrigation was recorded in Sirsa (12 per cent) and Hissar district (13 per cent) in the western zone. Figure 5 revealed that, in 1990-91, out of 16 districts, two districts were in the category of very low (20 and below), three districts were in the category of low (21 to 40), three districts were in the category of moderate (41 to 60), only one district was in the category of high (61 to 80) and seven districts were in the very high (81 and above) category of tubewell irrigation. The very low category (20 and below) of tubewell irrigation was recorded in Sirsa (12 per cent) and Hissar district (13 per cent) in the western zone. The low category (21 to 40) of tubewell irrigation was recorded in Rohtak district (29 per cent) in the central zone. It is followed by Bhiwani district (34 per cent) in the western zone and Jind district (39 per cent) in the central zone. The moderate category (41 to 60) of tubewell irrigation was recorded in Kaithal (49 per cent) and Sonipat district (50 per cent) in the central zone. It is followed by the Faridabad district (51 per cent) in the southern zone. The high category (61 to 80) of tubewell irrigation was recorded in only one district, Panipat (70 per cent) in the northern zone. The very high category (81 and above) of tubewell irrigation was recorded in Yamunanagar district (97 per cent) in the northern zone and Rewari district (97 per cent) in the southern zone. It is followed by Mahendragarh district (96 per cent) in the southern zone, Ambala (93 per cent) in the northern zone, Gurugram (87 per cent) in the southern zone, Kurukshetra (85 per cent), and Karnal district (82 per cent) in the northern zone.

During 2000-01, the net irrigated area by Tubewells was about 1467 thousand hectares for the state as a whole, which was 50 per cent of the net irrigated area. In 2000-01, the net irrigated area increased by 219 thousand hectares. In 2000-01 both the major sources of irrigation, i.e., canal and tubewell, became almost equal contributors in irrigation development, contributing 49.9 per cent and 49.6 per cent irrigated area respectively. However, it varied from district to district. It is evident from table 1 that the Southern and Northern zones were highly dependent on tubewell irrigation, where 89 per cent and 78 per cent area was registered under tubewell irrigation. It is followed by the central zone, where 42 per cent area was registered under tubewell irrigation. Again the minimum tubewell irrigation was registered in the western zone, where 21 per cent area was registered under tubewell irrigation. Haryana state has observed a positive growth rate of 1.18 per cent in tubewell irrigation from 2000-01 to 2010-11. Haryana state was a comparatively high performer in terms of tubewell irrigation. The western zone registered the very least irrigated area by tubewell under this study period, but the western zone performed the highest positive growth rate of 5.61 per cent under tubewell irrigation. The northern and central zones were showed a steady performance with a slightly positive growth rate of 0.92 per cent and 0.81 per cent. The southern zone registered a very huge irrigated area by tubewell, but the southern zone performed a negative growth rate of 1.50 per cent in tubewell irrigation (table 3). The highest proportion of tubewell irrigation was recorded in Mahendragarh (98 per cent) and Rewari district (98 per cent) in the southern zone, and Yamunanagar district (97 per cent) in the northern zone. These districts are highly dependent on tubewell irrigation. The minimum proportion of tubewell irrigation was recorded in Hissar (4 per cent) and Sirsa district (14 per cent) in the western zone.

Figure 5 revealed that, in 2000-01, out of 19 districts, three districts were in the very low category (20 and below), two districts were in the low category (21 to 40), four districts were in the moderate category (41 to 60), four districts were in the high category (61 to 80) and six districts were in the very high (81 and above) category of tubewell irrigation. The very low category (20 and below) of tubewell irrigation was recorded in Hissar (4 per cent) and Sirsa district (14 per cent) in the western zone. It is followed by Rohtak district (20 per cent) in the central zone. The low category (21 to 40) of tubewell irrigation was recorded in Fatehabad (35 per cent) and Bhiwani district (39 per cent) in the western zone. The moderate category (41 to 60) of tubewell irrigation was recorded in Jhajjar (41 per cent), Kaithal (44 per cent), Jind (44 per cent), and Sonipat district (53 per cent) in the central zone. Mostly central zone districts were registered in the moderate category of tubewell irrigation except for Rohtak district, where it is registered in the very low category of tubewell irrigation. The high category (61 to 80) of tubewell irrigation was recorded in Gurugram (80 per cent) and Faridabad district (80 per cent) in the southern zone. It is followed by Panipat (70 per cent) and Karnal district (63 per cent) in the northern zone. The very high category (81 and above) of tubewell irrigation was recorded in Mahendragarh (98 per cent) and Rewari district (98 per cent) in the southern zone. It is followed by Yamunanagar (97 per cent), Panchkula (87 per cent), Ambala (86 per cent), and Kurukshetra district (82 per cent) in the northern zone.

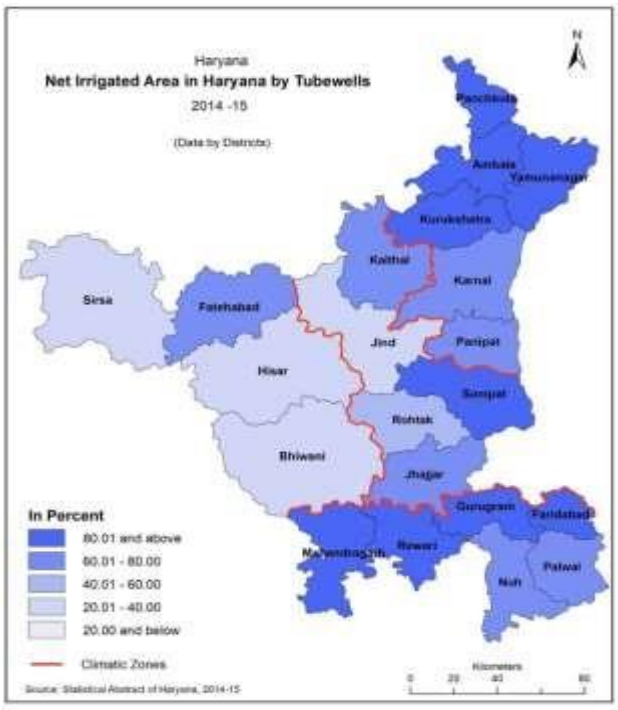


Fig. 6

During 2010-11, the net irrigated area by Tubewells was about 1650 thousand hectares for the state as a whole, which was 57 per cent of the net irrigated area. In 2010-11, the net irrigated area increased by 183 thousand hectares. However, it varied from district to district. In 2010-11, the area under tubewell irrigation surpassed the area under canal irrigation. In 2000-01 both the irrigation sources almost came under equal proportion, irrigating almost equal parts, but in 201011, tubewell irrigation dominated the state's irrigation facilities. This change clearly indicates that the tubewells irrigated area is increasing day by day. It is evident from table 1 that the Southern and northern zones were highly dependent on tubewell irrigation, where 87 per cent and 85 per cent area was registered under tubewell irrigation. It is followed by the central zone, where 48 per cent area was registered under tubewell irrigation. The minimum tubewell irrigation was registered in the western zone, where 35 per cent area was registered under tubewell irrigation. Haryana state has observed a slightly positive growth rate of 0.97 per cent in tubewell irrigation from 2010-11 to 2014-15. The southern and central zones were performing a better positive growth rate of 2.15 per cent and 1.88 per cent. The northern zone was performing a very slightly positive growth rate of 0.68 per cent. The western zone performed a very slightly negative growth rate of 0.78 per cent in terms of tubewell irrigation (table 3). The highest proportion of tubewell irrigation was recorded in the Rewari district (98 per cent) in the southern zone. Rewari district is highly dependent on tubewell irrigation under this study period. The minimum proportion of tubewell irrigation was recorded in the Jind district (10 per cent) in the central zone. Figure 5 revealed that, in 2010-11, out of 21 districts, one district was in the very low category (20 and below), four districts were in the low category (21 to 40), four districts were in the moderate category (41 to 60), two districts were in the high category (61 to 80) and ten districts were in the very high (81 and above) category of tubewell irrigation. The very low category (20 and below) of tubewell irrigation was

recorded in the Jind district (10 per cent) in the central zone. The low category (21 to 40) of tubewell irrigation was recorded in Hissar (23 per cent) and Sirsa district (29 per cent) in the western zone. It is followed by Rohtak district (34 per cent) in the central zone and Fatehabad district (40 per cent) in the western zone. The moderate category (41 to 60) of tubewell irrigation was recorded in Sonipat (49 per cent) and Jhajjar district (52 per cent) in the central zone. It is followed by the Nuh district (55 per cent) in the southern zone and the Bhiwani district (58 per cent) in the western zone. The High category (61 to 80) of tubewell irrigation was recorded in Palwal district (73 per cent) in the southern zone. It is followed by the Panipat district (71 per cent) in the northern zone. The very high category (81 and above) of tubewell irrigation was recorded in Rewari (98 per cent), Faridabad (97 per cent), Gurugram (97 per cent), and Mahendragarh district (96 per cent) in the southern zone. It is followed by Yamunanagar (97 per cent), Ambala (96 per cent), Kaithal (96 per cent), Panchkula (92 per cent), Karnal (83 per cent), and Kurukshetra district (82 per cent) in the northern zone. Most districts of Northern and southern zones were highly dependent on tubewell irrigation and registered in the very high category of tubewell irrigation.

During 2014-15, the net irrigated area by Tubewells was about 1818 thousand hectares for the state as a whole, which was 61 per cent of the net irrigated area. In 2014-15, the net irrigated area increased by 168 thousand hectares. However, it varied from district to district. It is evident from table 1 that the Southern and northern zones were highly dependent on tubewell irrigation, where 92 per cent and 89 per cent area was registered under tubewell irrigation. It is followed by the central zone, where 54 per cent area was registered under tubewell irrigation. The minimum tubewell irrigation was registered in the western zone, where 35 per cent area was registered under tubewell irrigation. Haryana state has observed a positive growth rate of 1.90 per cent in tubewell irrigation from 1980-81 to 2014-15.

The northern zone performed a very slightly positive growth rate of 0.83 per cent in terms of tubewell irrigation (table 3). The highest proportion of tubewell irrigation was recorded in Kurukshetra (100 per cent) and Panchkula district (100 per cent) in the northern zone, and Faridabad district (100 per cent) in the southern zone. These three districts were totally dependent on tubewell irrigation, where these districts were registered 100 per cent irrigation under tubewell. The minimum proportion of tubewell irrigation was recorded in Bhiwani (24 per cent), Hissar (24 per cent), and Sirsa district (24 per cent) in the western zone. Figure 6 revealed that, in 2014-15, out of 21 districts, four districts were in the low category (21 to 40), one district was in the moderate category (41 to 60), seven districts were in the high category (61 to 80), and nine

districts were in the very high (81 and above) category of tubewell irrigation. In 2010-11, only Jind district was registered in the very low category (20 and below) of tubewell irrigation, but in 2014-15 Jind district shifted in low category (21 to 40) of tubewell irrigation. So no district fell in the very low category (20 and below) of tubewell irrigation. The low category (21 to 40) of tubewell irrigation was recorded in Bhiwani (24 per cent), Hissar (24 per cent), and Sirsa district (24 per cent) in the western zone. It is followed by the Jind district (27 per cent) in the central zone. The moderate category (41 to 60) of tubewell irrigation was recorded in only Rohtak district (46 per cent) in the central zone. The high category (61 to 80) of tubewell irrigation was recorded in Karnal district (80 per cent) in the northern zone. It is followed by Nuh (80 per cent) and Palwal district (75 per cent) in the southern zone, Fatehabad district (72 per cent) in the western zone, Panipat district (67 per cent) in the northern zone, Jhajjar (63 per cent), and Kaithal district (62 per cent) in the central zone. The very high category (81 and above) of tubewell irrigation was recorded in Kurukshetra and Panchkula district in the northern and Faridabad districts in the southern zone. These three districts were totally dependent on tubewell irrigation, where these districts were registered 100 per cent irrigation under tubewell. It is followed by Gurugram (99 per cent), Rewari (98 per cent), and Mahendragarh district (97 per cent) in the southern zone, Yamunanagar (97 per cent), and Ambala district (94 per cent) in the northern zone, and Sonipat district (84 per cent) in the central zone. After

analyzing the picture of the last four and half decades, i.e., of 1980-81 to 2014-15, the changing trends can be understood more appropriately. In 1980-81, tubewells net irrigated area was about 940 thousand hectares accounting for 44 per cent of the total irrigated area.

In 2014-15, tube well's irrigated area increased significantly from 940 thousand hectares to 1818 thousand hectares. Although per cent share to the net irrigated area increased significantly (table 1). It can be interpreted that tubewell irrigation is dominant in the Northern zone districts (Ambala, Kurukshetra, Karnal, Yamunanagar, Panipat, and Panchkula) and Southern zone districts (Faridabad, Gurugram, Mahendragarh, Rewari, Palwal, and Nuh). Whereas, least tubewell irrigated area is recorded in western zone districts (Bhiwani, Hissar, Sirsa, and Fatehabad). The moderate tubewell irrigation is recorded in mainly central zone (Sonipat, Rohtak, Jind, Kaithal, and Jhajjar) districts. Haryana state has achieved tremendous growth in tube well irrigation since the onset of the Green Revolution (Kumar, 2014). The area irrigated by Tube well has recorded a remarkable growth during this period. Nevertheless, there has been a secular decline in the share of canals in the state's net irrigated area. This decline may be attributed to a more rapid expansion in groundwater exploitation (Kasana & Singh, 2017).

Table: 3 Compound Growth Rates of Irrigated Area in Haryana by Tubewells (1980-81 to 2014-15) (In Per cent)

Districts/Agro Climatic Zone	Tubewells				
	1980-81 to 1990-91	1990-91 to 2000-01	2000-01 to 2010-11	2010-11 to 2014-15	1980-81 to 2014-15
Northern Zone	1.13	0.18	0.92	0.68	0.83
Central Zone	7.46	1.36	0.81	1.88	3.26
Southern Zone	3.83	2.90	-1.50	2.15	2.09
Western Zone	0.43	4.09	5.61	-0.78	2.64
Haryana	**2.87**	**1.63**	**1.18**	**0.97**	**1.90**

Source: Computed from Table: 1

Percentage of Net Irrigated Area (NIA) to Net Sown Area (NSA) by Source wise

To analyze the extent and trend of irrigation under the two sources of irrigation, the Net Irrigated Area to Net Sown Area is considered for both the sources. The cotton belt districts have the greatest irrigation extent under the canals. It is around 71 per cent in both Jind and Sirsa, which is the highest in 2014-15. It is also noted that the area under canal irrigation has been fluctuating trend in most of the districts. Kurukshetra, Sonipat, Jind, and Fatehabad have shown a major decline in canal irrigation areas after 2010-11. Panchkula, Kurukshetra, and Faridabad districts recorded zero per cent area under canal irrigation in 2014-15. Kaithal and Sirsa districts have shown a significant increase in canal irrigation after 2010-11. The extent of groundwater irrigation is greatest in the districts of Panchkula, Kurukshetra, and Faridabad (100 per cent), followed by Gurugram (98.72 per cent), Rewari (97.62 per cent), and Yamunanagar (96.77 per cent). Sonipat district is a unique district as it shows the equal extent of irrigated area under canals (52.08 per cent) as well as tubewells (48.61 per cent) in 2010-11, but over the next five years, there has been a major shift in 2014-15 it has 15.79 per cent of net irrigated under canals and 84.21 per cent under tubewells.

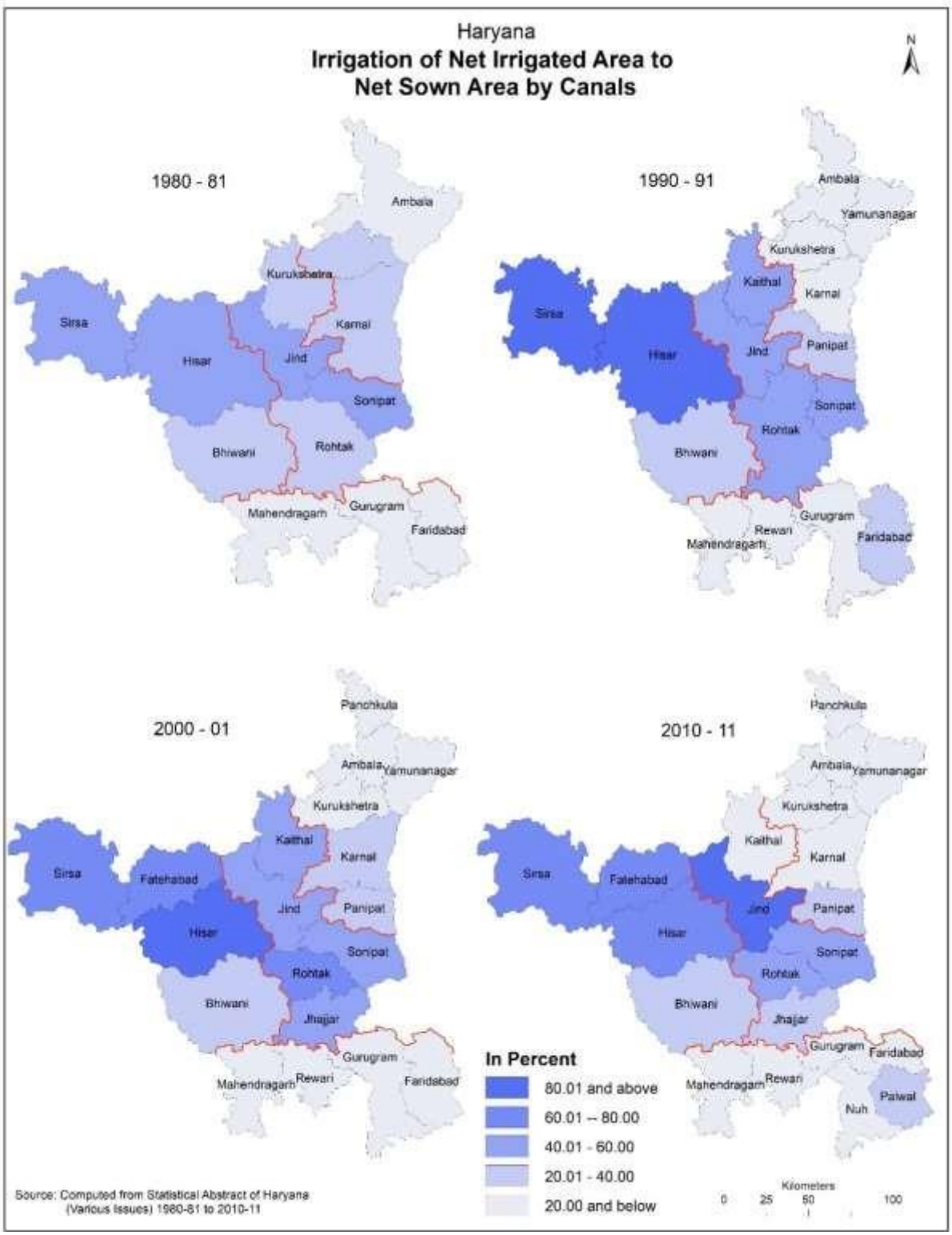

Haryana
Irrigation of Net Irrigated Area to
Net Sown Area by Canals
N
1980 - 81
Ambala
Kurukshetra
Sirsa
Karnal
Hisar
Jind
Sonipat
Bhiwani
Rohtak
Mahendragarh
Gurugram
Faridabad
1990 - 91
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Hisar
Jind
Panipat
Sonipat
Rohtak
Bhiwani
Gurugram
Rewari
Mahendragarh
Faridabad
2000 - 01
Panchkula
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Fatehabad
Jind
Panipat
Hisar
Sonipat
Rohtak
Bhiwani
Jhajjar
Gurugram
Mahendragarh
Rewari
Faridabad
2010 - 11
Panchkula
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Fatehabad
Jind
Panipat
Hisar
Sonipat
Rohtak
Bhiwani
Jhajjar
Gurugram
Faridabad
Mahendragarh
Rewari
Palwal
Nuh
In Percent
80.01 and above
60.01 -- 80.00
40.01 - 60.00
20.01 - 40.00
20.00 and below
Kilometers
0
25
50
100
Source: Computed from Statistical Abstract of Haryana
(Various Issues) 1980-81 to 2010-11

Fig. 7

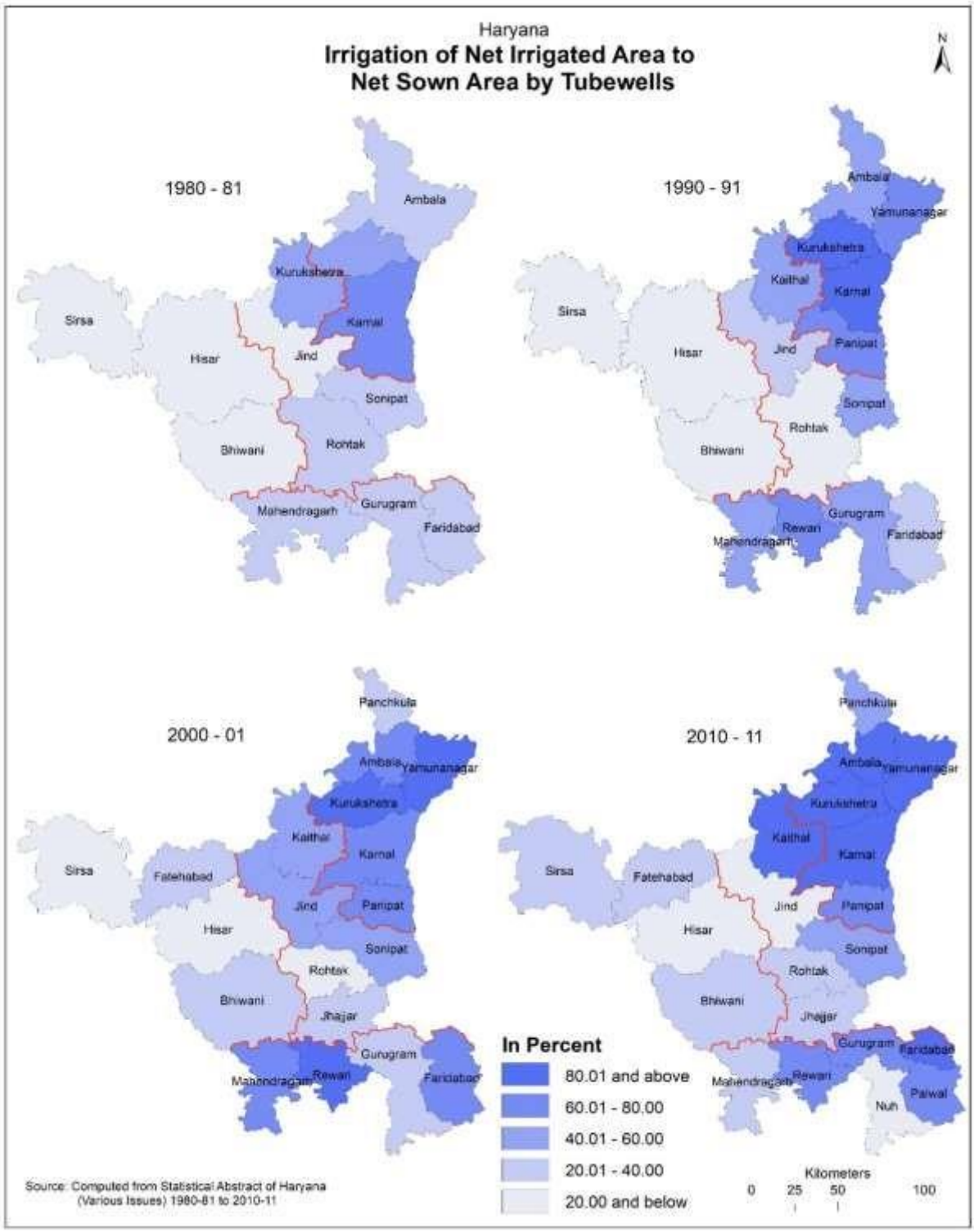

Haryana
Irrigation of Net Irrigated Area to
Net Sown Area by Tubewells
N
1980 - 81
Ambala
Kurukshetra
Karnal
Sirsa
Hisar
Jind
Sonipat
Bhiwani
Rohtak
Mahendragarh
Gurugram
Faridabad
1990 - 91
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Hisar
Jind
Panipat
Sonipat
Rohtak
Bhiwani
Gurugram
Rewari
Mahendragarh
Faridabad
2000 - 01
Panchkula
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Fatehabad
Jind
Panipat
Hisar
Sonipat
Rohtak
Bhiwani
Jhajjar
Gurugram
Mahendragarh
Rewari
Faridabad
2010 - 11
Panchkula
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Fatehabad
Jind
Panipat
Hisar
Sonipat
Rohtak
Bhiwani
Jhajjar
Gurugram
Faridabad
Mahendragarh
Rewari
Nuh
Palwal
In Percent
80.01 and above
60.01 - 80.00
40.01 - 60.00
20.01 - 40.00
20.00 and below
Kilometers
0 25 50 100
Source: Computed from Statistical Abstract of Haryana
(Various Issues) 1980-81 to 2010-11

Fig. 8

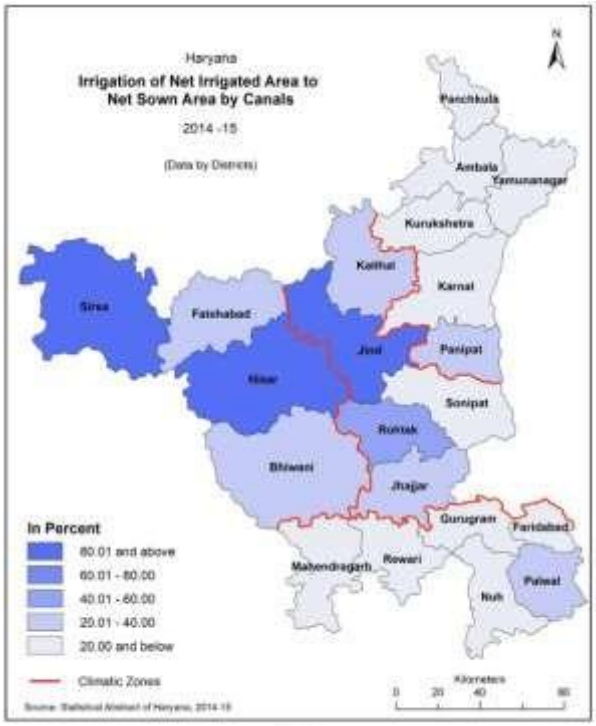


Fig. 9

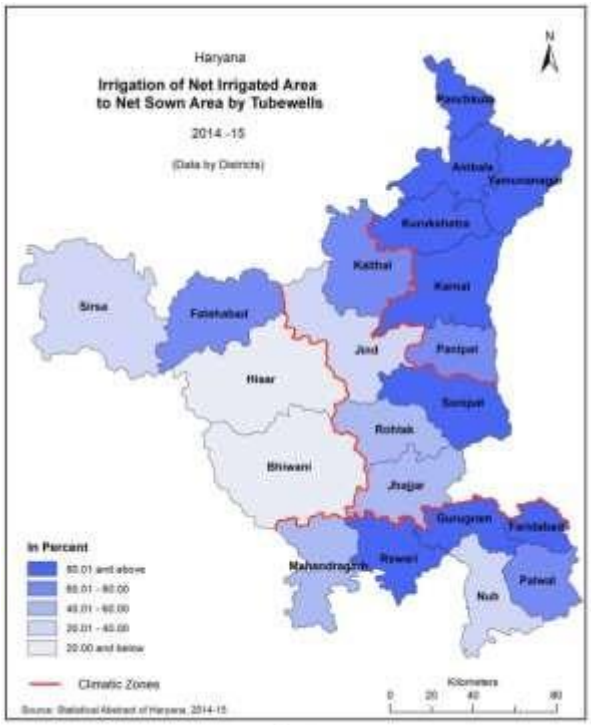


Fig. 10

To summarise the above-discussed facts of the changing structure of irrigation in Haryana's different districts over the five points of the present study, two categories of the districts have been identified for both Canal Irrigation and Tubewell Irrigation separately. They are depicted in table 4. Since the area under irrigation by other sources is negligible, it is not included in the table.

1. Below State Average.
2. Above State Average.

Table: 4 Regional Variations in Share Under Different Sources of Net Irrigated Area with Respect to Haryana State

Years	Categories	Net Irrigated Area by Canals	Net Irrigated Area by Tubewells
of			
Districts			
1980-81	1	Mahendragarh, Ambala, Gurugram, Hissar, Jind, Sirsa, Bhiwani, Rohtak, Faridabad, Karnal, Kurukshetra Sonipat	Rewari, dabad, Bhiwani, Fatehabad, Rewari, mbala, Jhajjar, Sonipat, hkula, Kurukshetra, dragarh, Rewari, pat, Karnal, Nuh, Palwal, Fatehabad, Panipat, Jhajjar, Kaithal
	2	Sonipat, Rohtak, Bhiwani, Jind, Kurukshetra, Karnal, Faridabad, Sirsa, Hissar Gurugram, Ambala, Mahendragarh , Yamunanagar,	Rohtak, Jind, Hissar, Sirsa, Bhiwani
		Mahendragarh, Gurugram, Kurukshetra, Karnal, Panipat, Kaithal, Faridabad, Sonipat	Sirsa, Hissar, Rohtak, Bhiwani, Jind Kaithal, Sonipat, Faridabad, Panipat, Karnal, Kurukshetra, Gurugram, Ambala, Mahendragarh, Yamunanagar, Rewari,
	2	Jind, Bhiwani, Rohtak, Hissar, Sirsa	Hissar, Sirsa, Rohtak, Fatehabad, Bhiwani, Jhajjar, Jind, Kaithal
			Sonipat, Karnal, Panipat, Faridabad, Gurugram, Kurukshetra, Ambala, Panchkula, Yamunanagar, Mahendragarh, Rewari
			Jind, Hissar, Sirsa, Rohtak, Fatehabad, Sonipat, Jhajjar, Nuh
			Bhiwani, Panipat, Palwal, Kurukshetra Karnal, Panchkula, Kaithal, Ambala, Mahendragarh, Gurugram, Faridabad, Yamunanagar, Rewari
			Bhiwani, Sirsa, Hissar, Jind, Rohtak Kaithal, Jhajjar, Panipat, Fatehabad, Palwal, Nuh, Karnal, Sonipat, Ambala, Yamunanagar, Mahendragarh, Rewari, Gurugram, Faridabad, Kurukshetra, Panchkula

Source: Computed from table 1. Note: 1 = Below State Average, 2 = Above State Average

Note 2. the names of the districts in each category have been given in ascending order

To have a better understanding of the different structure of irrigation, categorizations of the different districts have been done in Table 5, where all the districts have been shown in six categories i.e.

1. Districts where the maximum area is under canal irrigation over the entire period under study (above state average).
2. Districts were showing a consistent decline in area under canal irrigation.
3. Districts where a minimal area is under canal irrigation over the entire period under study (below state average).
4. Districts where the maximum area is under tubewell irrigation over the entire period under study (above 80 per cent of the irrigated area).
5. Districts were showing a consistent increase in area under tubewell irrigation.
6. Districts where a minimal area is under tubewell irrigation over the entire period under study (below state average).

Table: 5 Structure of Irrigation in Haryana

Sr.	Category of Districts	Districts No.
1.	Always a very high Canal Irrigation (Above State Average)	Rohtak, Bhiwani, Jind, Hissar, Sirsa
2.	A consistent decline in Canal Irrigation	Jhajjar, Palwal, Nuh, Fatehabad
3.	Always a very low Canal Irrigation	Ambala, Panchkula, Yamunanagar, Kurukshetra, Karnal, Panipat, Faridabad, Palwal, Gurugram, Rewari, Mahendragarh (Below State Average)
4.	Always a very high Tubewell Irrigation (Above 80 per cent)	Yamunanagar, Rewari, Mahendragarh (above 90 per cent), Ambala, Panchkula, Kurukshetra, Gurugram
5.	A consistent increase in Tubewell Irrigation	Panchkula, Yamunanagar, Kurukshetra, Karnal, Panipat, Sonipat, Jhajjar, Palwal, Nuh, Fatehabad, Faridabad, Gurugramrewari, Mahendragarh
6.	Always very low Tubewell Irrigation (Below State Average) Source: Computed from table 1	Rohtak, Jind, Hissar, Sirsa

Conclusion:

Water is the major limiting factor for crop production in semi-arid and arid regions of the Haryana. Due to low and uncertain annual rainfall in these regions the crop water requirement is mainly supplied by supplemental irrigation. The study indicates that irrigation development has significantly taken place in the study area. Irrigation is the lifeline of agricultural development, and it has assumed greater importance after the induction of modern technology in agriculture, i.e., after introducing high-yielding varieties of seeds, chemical fertilizers, pesticides, etc. The pattern and structure of irrigation in Haryana state shows that tubewells and canals are the two main irrigation sources. The Haryana state has transformed canal irrigation to tubewell irrigation to assure both quality and quantity of irrigation water. The adoption of tubewell irrigation varies across different districts according to the technological feasibility and natural setup. Nevertheless, the fact remains that, once the districts reach a maximum level of tubewell irrigation, overexploiting the groundwater resources, there is an apparent record of decline as they remain no longer sustainable. In the study area, the density of tubewell increases at a fast rate.

Consequently, the intensity of irrigation directly influences the intensity of cropping, cropping pattern, and crop combination in the study area.

References:

Ajmera, S. (2013). Water Distribution Schedule under Warabandi System Considering Seepage Losses for an Irrigation Project- A Case Study. *International Journal of Innovations in Engineering and Technology (IJIET),* 2(4), 178-187.

Brar, M., &Roychand, P. (2011). Risks, hazards and vulnerability associated with overexploitation of groundwater in northwest India. *Risk in Water Resources Management, (IAHS Publication),* 218-222.

Dhawan, B. D. (1982). Development of Tubewell Irrigation in India. New Delhi: *Agricole Publishing Academy.*

Dhawan, B. D. (1988). Irrigation in India's Agricultural Development: Productivity Stability and Equity. *New Delhi: Sage Publication.*

Dhawan, B. D. (1990). Studies in Minor Irrigation: With Special Reference to Groundwater. *New Delhi: Commonwealth Publication.*

Dubash, N. K. (2002). Tube Well Capitalism, Groundwater Development, and Agrarian Change in Gujarat. *New Delhi: Oxford University Press.*

Gautam, A. (2012). Agricultural Geography. *Allahabad: Sharda Pustak Bhawan.*

Gautam, R., & Singh, A. K. (2019). Jeopardy Situation of Depleting Groundwater Resources in Kurukshetra District, Haryana. *Research Review International Journal of Multidisciplinary,* 4(4), 753-759.

Gautam, R., & Sangwan, B. (2021a). A Geographical Analysis of Changing Cropping Pattern in Haryana. *Turkish Online Journal of Qualitative Inquiry (TOJQI*), 12(9), 33013332.

Gautam, R., & Sangwan, B. (2021b). Groundwater Depletion and Agriculture Profitability in Haryana: A Case Study of Karnal District. *International Journal of Aquatic Science,* 12(3), 1943-1959.

Gautam, R. (2021). Comparative Analysis of Profitability of Rice and Wheat in Different Irrigation Systems across Different Landholdings Groups in Haryana: A Case Study of Karnal District. *Turkish Online Journal of Qualitative Inquiry (TOJQI*), 12(8), 4153-4174.

Hiremath, K. C. (1984). Report on Socio-Economic Impact of Irrigation Projects. *Indian Journal of Agricultural Economics,* 39(3) 559.

Hussain, M. (1996). Systematic Agricultural Geography. Jaipur: *Rawat Publication.*

Janakarajan, S. (1993). Economic and Social Implications of Irrigation: Some Evidence from South India. *Indian Journal of Agricultural Economics,* 48(1), 65-75. DOI: 10.22004/ag.econ.274859

Janakarajan, S., &Moench, M. (2006). Are Wells a Potential Threat to Farmer's Well-being? Case of Deteriorating Groundwater Irrigation in Tamil Nadu. *Economic and Political Weekly*, 41(37), 3977-3987. https://www.jstor.org/stable/4418705

Jeet, I. (1998). Impact of the River Yamuna on Groundwater Regime in Eastern Haryana – India. *Transactions of the Institute of Indian Geographers*, 20(2), 33-41.

Kasana, A., & Singh, O. (2017). Groundwater Irrigation Economy of Haryana: A Glimpse into Spread, Extent, and Issues. *Journal of Rural Development,* 36(4), 531-555. DOI:10.25175/jrd/2017/v36/i4/120624

Kaur, P., & Kumar, L. (2013). Vulnerable Districts in Perspective of Groundwater Irrigation: A Case Study of Haryana 2001. *International Indexed and Refereed Research Journal*, 4(43-44), 73-75.

Kaushik, S. P., & Omparkash (2010). Impact of Groundwater Level on Cropping Pattern: A Case Study of District Karnal. *Indian Journal of Regional Science,* 42(1), 107-115.

Khullar, D. R. (2017). Bhugol Mukhya Pareeksha ke Liye. *New Delhi: McGraw Hill Education (India) Private Limited,* 3.5-3.6.

Koli, P. A., & Bodhale, A. C. (2006). Irrigation Development in India. *New Delhi: Serials Publications.*

Kumar, M. D., Narayanamoorthy, A., & Singh, O. P. (2009). Groundwater Irrigation versus Surface Irrigation. *Economic & Political Weekly,* 44(50), 73-73. https://www.researchgate.net/publication/265564593_Groundwater_Irrigation_versus_Surface_Irrigation

Kumar, P., Kumar, S., Dhindwal, A. S., Sewhag, M., & Kumar, S. (2012). Irrigation water management: Theory and practical. *Hisar: Teaching Manual, Department of Agronomy, CCS Haryana Agricultural University*, 3-13.

Kumar, V. (2014). Economic benefits and ecological cost of Green Revolution: A case study of Haryana, India. *International Journal of Enhanced Research in Education Development (IJERED),* 2(6), 21-31.

Sangwan, B., & Gautam, R. (2019). Irrigation Development and Over-Exploitation of Groundwater Resources in Haryana: A Geographical Analysis. *Research Review International Journal of Multidisciplinary*, 4(2), 987-995.

Sangwan, B., & Gautam, R. (2020). A Geographical Analysis of Crop Combination Region in Haryana: 1980-81 to 2014-15. *Sambodhi,* 43(3), 160-170.

Sangwan, B., & Monica. (2017). Spatio-Temporal Trends in the Development of Irrigation in Haryana (1980-81 to 2010-11). *Amar: An Inter-Disciplinary Research Journal,* 3(3), 8088.

Singh, J. (1976). An Agricultural Geography of Haryana. *Kurukshetra: Vishal Publications.*