



# Impact Of Cropping Pattern Changes On Groundwater In Haryana

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## ARTICLE INFO ABSTRACT

The purpose of this paper to finds out that, after green revolution the level of groundwater continuously decreasing. Because after introduction of green revolution new cultivation strategy has been adopted, which restricted the state to have only two crops, i.e., wheat and rice. The solo rice-wheat cropping system in the state has resulted in large scale groundwater exploitation. The present study is based on secondary data along with using weaver's method of crop combination, linear regression and step wise regression. This study reveals that in Kurukshetra, Karnal, Kaithal, Bhiwani, Fatehabad, Panipat, Rewari, Sirsa and Mahendragarh districts there is a huge depletion of groundwater due to rice and wheat cultivation. Statistically, it is proved that increasing in the area under rice crop is foremost cause of decline in the groundwater table in the state. Hence, there is an urgent necessity to go for crop diversification, sustainable & environment friendly methods of cultivation.

**Keywords:** groundwater, Haryana, cropping pattern, green revolution, regression.

## Introduction

In last few decades the agriculture of Haryana has undergone significant changes, which began in the mid-sixties, mainly with the advent of Borlang seed-fertilizer based technology also known as green revolution. Meanwhile, the state of Haryana was formed in 1966 (Sangwan, 2002). In the age of green revolution, the state has achieved self-sufficiency in the food grain production and transformed into food deficient to food surplus. But in Haryana due to green revolution changes in cropping pattern from traditional multiple cropping systems to input intensive mono-cropped rotation (rice-wheat) adopted by the farmers to gain large income profits. Monotonous cropping pattern has badly affected the groundwater resources of the state. The state's total water requisite is 20 million acre feet (MAF). The state obtains around 2.3 million acre feet water from rainfall and rivers i.e. Yamuna River and Bhakra system, whereas 12 million acre feet water is extracted using 8.47 lakh tube-wells. The state faces a shortage of 5.7 million acre feet water annually (Central Ground Water Board Haryana, 2021).

Ground water resources have played a major role in increasing food production and achieving food security in the state. An effort was always constituted to supplement the monsoon rain water with irrigation from the ground water. The north eastern part of the state is widely underlain by fresh ground water, while the remaining 28000 km square (about 60%) is covered by brackish to very saline groundwater (Haryana Kisan Ayog, 2010). In traditional farming, irrigation was used as a protective measure but in green revolution it is a necessity. The groundwater irrigation was a prime driver of green revolution and increasing cropping intensity & productivity of crops. In Haryana nearly 6.50 million hectare gross irrigated area occurred, about 63.33% area receives irrigation from a large number of tube wells and about 36.67% from the vast canal network (Haryana Kisan Ayog, 2021). It represents that how much pressure on the groundwater resources of the state. In Haryana the decline rate of ground water has been estimated about 35 cm per annum (Chatterjee and Purohit, 2009) and annual groundwater extraction is 12.42 bcm in 2022.

## Study Area

Haryana is located in the Northwest part of India almost encircling Delhi. It extends from 27° 39'N to 30° 55'N latitude and 74° 27' 8" E to 77° 36' 5" E longitude (fig. 1.1). The area of the Haryana state is 44212 sq. kms.

Haryana was created on November 1, 1966. At present, the state having twenty-two districts. Haryana is essentially a plain area: 94 percent below 300 metres. The plain extends between the hilly tract in the northeast and the sand dune sprinkled desert topography in the south and southwest. The outliers of the Aravallis make their appearance in the southern part of the state. As such, Haryana assumes the shape of a saucer with its depression in the tract around Rohtak.

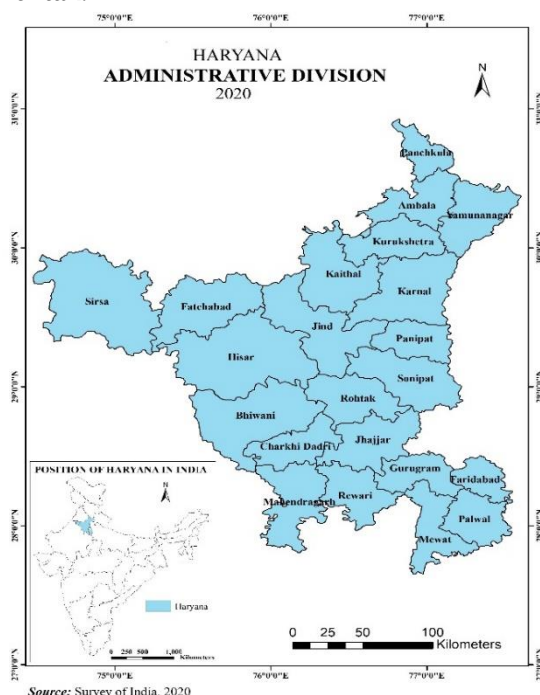


Fig. 1.1

The only perennial river of the state is flowing along its eastern border that is the Yamuna. The state benefits from a couple of other streams like Ghaggar, Sahibi, Markanda, Indori, Rakshi, Landoha, Dohan and Karavati, which are more or less seasonal. The climate of the state varies from sub-tropical, semi-arid to sub-humid, continental and monsoonal. Summers are very hot (up to a high of 47° Celsius) and winters are very cold (1°Celsius). The average annual rainfall recorded in the state is about 650 mm and varies from less than 300 mm in south western parts to over 1000 mm in the Siwalik Hills region. The soil of Haryana is basically alluvial in nature. (Pandey et.al., 2004)

### Objectives

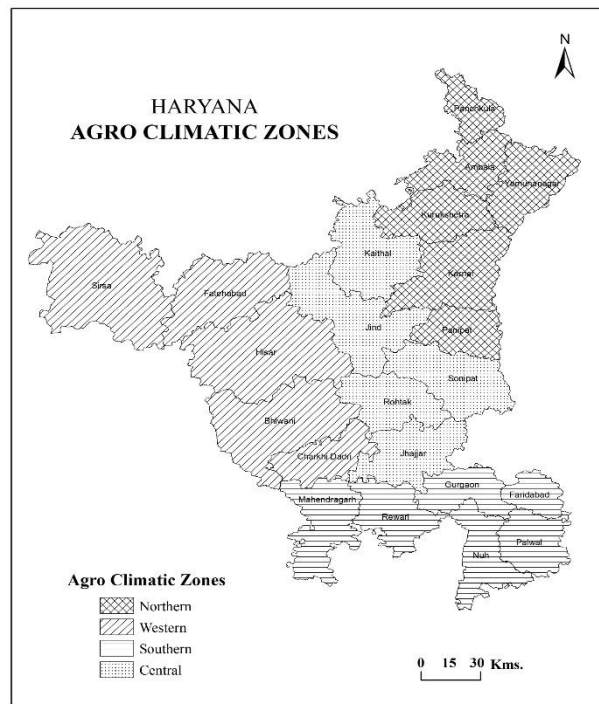
The main objectives of the study are-

- To study the fluctuations in groundwater table in Haryana.
- To examine the impact of changing cropping pattern on groundwater table in Haryana.

### Data Base and Methodology

The study is based on secondary source of information. Major sources of the data are ground water year book (2022) published by central groundwater board and groundwater cell, agriculture department, government of Haryana and statistical abstract of Haryana. The study is carried out during the time period from 1980-81 to 2020-21, but for groundwater, year 1974 data has been used due to not availability of data of groundwater of the year 1980-81. This study has been done at the level of state, agro climatic zones, district and block. Economic and Statistical Organization, Planning Department Haryana, (2007) has divided the state into four agro climatic zones (fig. 1.2) and the districts comprises there in which are:

1. **Northern Zone-** Panchkula, Ambala, Yamunanagar, Kurukshetra, Karnal and Panipat districts.
2. **Central Zone-** Kaithal, Jind, Sonipat, Rohtak and Jhajjar districts.
3. **Western Zone-** Bhiwani, Charkhi Dadari, Hisar, Fatehabad and Sirsa districts.



**Fig 1.2**

**4. Southern Zone-** Faridabad, Gurugram, Palwal, Nuh, Rewari and Mahendragarh districts.

In this study percentage method has been used to identify the percentage share of individual crop in total cropped area from 1980-81 to 2020-21 (taking three-year average) and Weaver's method for demarcation of crop combination regions. Further, linear regression and step wise regression techniques also applied to calculate impact of changes in cropping pattern on the groundwater table with the help of suitable variables which are:

- Area under Rice Cultivation
- Area under Wheat Cultivation
- Percentage of net sown area to total
- Per cultivator net sown area
- Per hectare consumption of fertilizer
- Intensity of cropping
- Irrigation Intensity
- Average size of land holding
- Average yield of food grain per hectare of net sown area

**Cropping Pattern Changes in Haryana**

The cropping pattern of the study area exposes that there are changes occurred in cropping pattern from 1966-67 to 2020-21. The nature of shifts in cropping pattern, is one of the main elements of economic profits in an area's agriculture. After green revolution significant changes in cropping pattern have been take place in the state. It is observed from the figure 1.3 that the cropped area under wheat and rice crop continuously increasing as comparison to other cereals and cash crops. The cropped area under wheat has been increased from 16.16 percent in 1966-67 to 37.18 percent in 2020-21, followed by rice crop from 4.17 percent to 23.46 percent respectively.

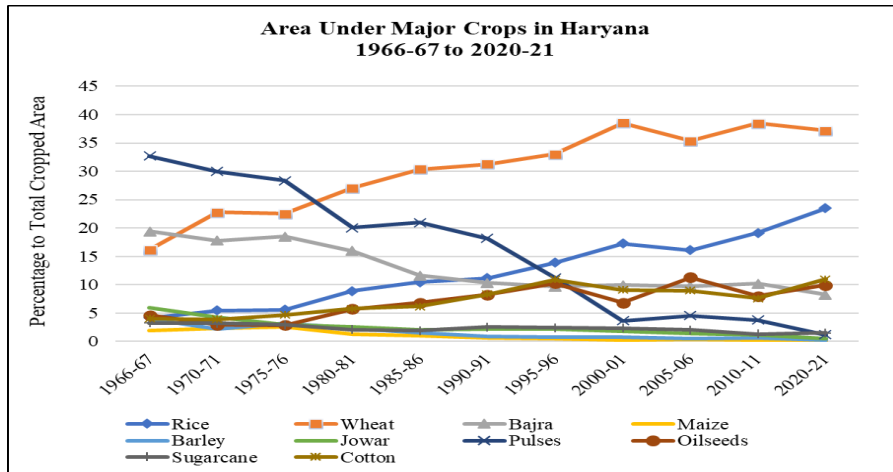


Fig 1.3

Source: Statistical Abstract of Haryana, (Various Issues)

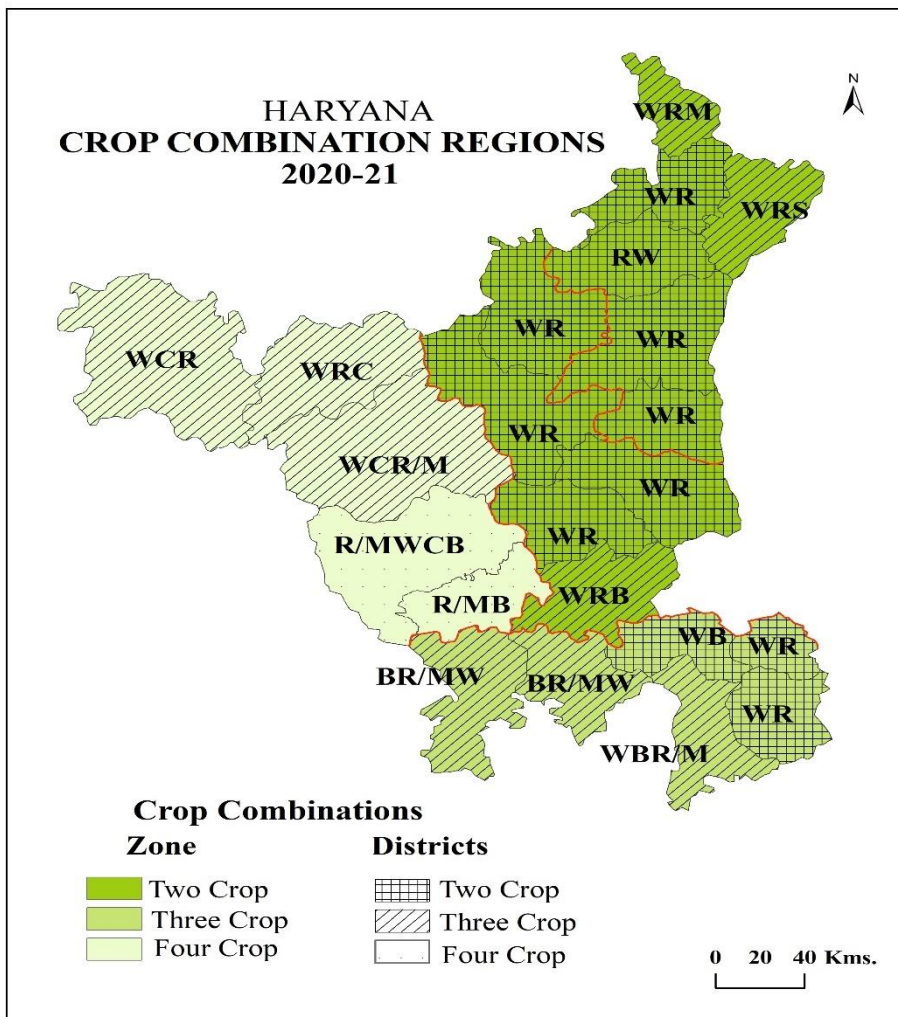


Fig. 1.4

On the other hand, the cropped area under bajra, maize, barley and jowar declined over the time period. The cropped area under oilseeds and cotton shows increasing trend. But the rise in the cropped area of oilseeds and cotton crop has relatively slower than wheat and rice crops. Rice crop has not been a traditional crop before

green revolution in the state. However, after green revolution its share has been increases in the total cropped area.

**Source:** Computed from Statistical Abstract of Haryana (Various Issues).

**Note:** Wheat-W, Rice-R, Maize-M, Bajra-B, Barley-Ba, Jowar-J, Cotton-C, Rapeseed & Mustard-R/M, Gram-G, Sugarcane-S, Residual crop=RC.

It is well noted that much of the increase in green revolution wheat and rice crops has come from the areas where traditional rain-fed crops were grown in the state. High yield of both crops obtained only under certain optimum conditions like optimal irrigation, high consumption of fertilizers and pesticides (Glaeser, 1987). That's why, there has been more development of irrigation facilities in Haryana. Consequently, Haryana state undergo specialization where maximum districts have become dominant rice-wheat crop region. Ten districts namely Ambala, Kurukshetra, Karnal, Panipat, Kaithal, Sonipat, Rohtak, Jind, Faridabad and Palwal dominated by wheat-rice crops (fig 1.4). In Panchkula, Yamunanagar and Jhajjar districts also wheat-rice are the main crops along with the third crop also is the part of their crop cycle. All these findings shows that cropping pattern changes in the state, in favor of wheat and rice crop. As a result, the water table is depleting continually in the Haryana.

### Groundwater Table Changes

Haryana has experiencing decline in the groundwater due to over exploitation over and above the recharge capacity. Ground water plays an impotent role in the agricultural development since rainfall accomplishes 20 percent of irrigation requirement only. To attain the present level of crop production, the demand for water surpasses its supply from different sources. The additional demand is fulfilled through the over exploitation of groundwater; thus, water table is successively declining. The average water table depth was 10.44 m in June 1974 and 21.58 m in June 2022, it representing a fall of 11.14 m over the period in the state.

It is well remarked that much of the increase in green revolution wheat and rice crops as well as commercial crop like sugarcane area of the state has come from the areas in which traditional rain-fed crops were grown. Farmers initiated to cultivate more water intensive crops which need protective irrigation that was fulfilled by ground water pumping. Thus, the net area irrigated by tube wells has increased 971.67 thousand hectares (44.47 percent to total irrigated area) in 1980-81 to 2128 thousand hectares (63.33 percent to total irrigated area) in 2020-21 in the state. Due to increase of irrigation facilities by tube well, average yield of rice and wheat crops increased from 2367 kg./hectare in 1980-81 to 4139.5 kg./hectare in 2020-21. (table 1.2). All these combined together have put a huge pressure on the water resources. The continuous extracting of water nearly throughout the year by tube wells has lowered the underground water table.

**Table 1.1- Haryana: Average Depth and Fluctuations of Groundwater (meters) in Agro Climatic Zones and Districts from June 1974 to June 2022**

Districts/Agro climatic zones	Period		Fluctuations June, 1974 to June, 2022
	June-1974	June-2022	
Ambala	6.15	14.00	-8.3
Panchkula	11.62	18.06	-6.44
Yamunanagar	7.3	12.6	-5.3
Kurukshetra	12.91	40.93	-28.02
Karnal	7.38	20.63	-13.25
Panipat	6.98	22.05	-15.07
<b>Northern</b>	<b>8.72</b>	<b>21.45</b>	<b>-12.73</b>
Kaithal	7.28	32.02	-24.74
Sonipat	5.1	10.5	-5.4
Rohtak	5.84	3.74	2.1
Jhajjar	4.92	4.31	0.61
Jind	10.88	15.54	-4.66
<b>Central</b>	<b>6.8</b>	<b>13.22</b>	<b>-6.42</b>
Faridabad	7.84	21	-13.16
Palwal	5.96	12.77	-6.81
Gurugram	14.26	30.09	-15.83
Nuh	6.03	12.15	-6.12
Rewari	10.8	30.75	-19.95
Mahendragarh	23.05	49.33	-26.28
<b>Southern</b>	<b>11.32</b>	<b>26.01</b>	<b>-14.69</b>
Bhiwani	20.4	29.88	-9.48

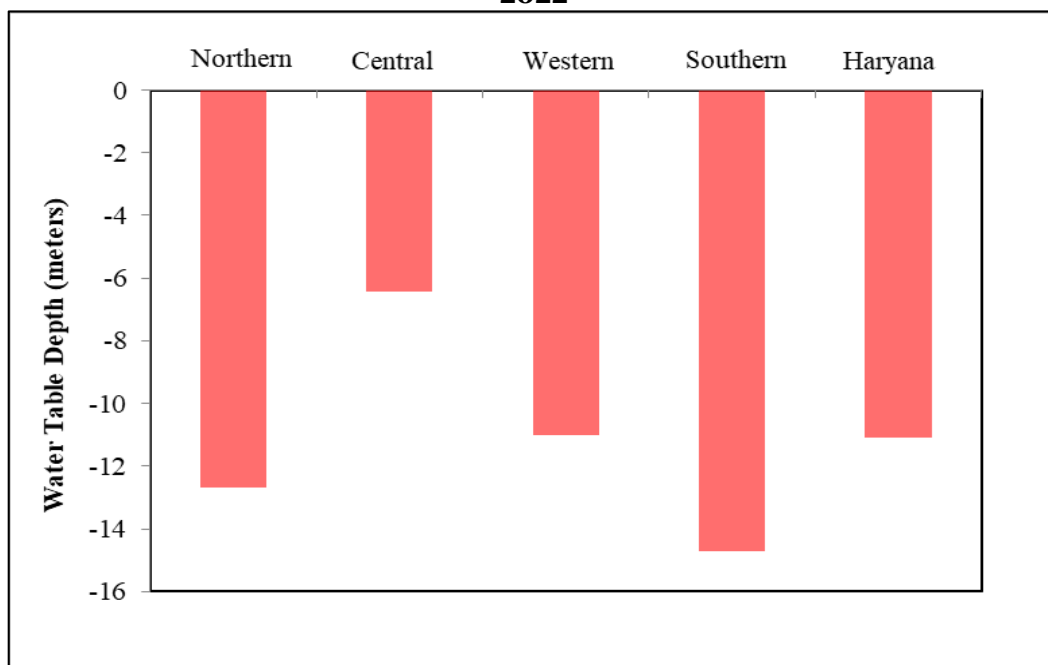
Charkhi Dadari	16.73	30.85	-14.12
Hisar	14.48	7.43	7.05
Fatehabad	9.14	32.86	-23.72
Sirsa	11.7	23.64	-11.94
<b>Western</b>	13.93	<b>24.93</b>	<b>-11</b>
<b>State Average</b>	10.44	<b>21.58</b>	<b>-11.14</b>

Source: Groundwater Cell, Panchkula

**Groundwater Table Changes in Agro Climatic Zones of Haryana**

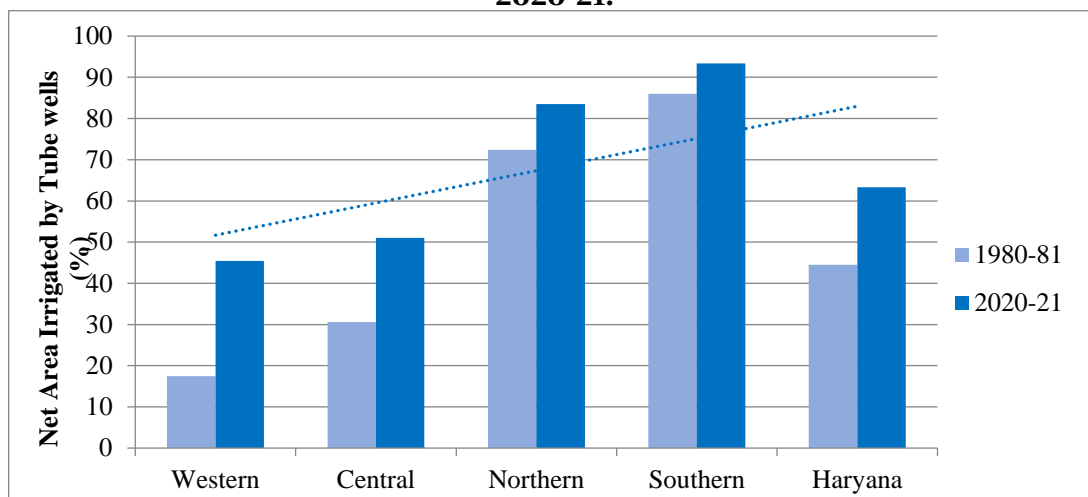
In the agro climatic zones i.e., northern, central, western and southern of Haryana there are variations in the depletion of ground water table (fig. 1.5). Southern agro climatic zone has represents highest decline of -12.54 meters in the ground water table from June 1974 to June 2016, while in central agro climatic zone it shows a decline of -6.25 meters. As comparison to other agro climatic zones, in central agro climatic zone low depletion of ground water appeared. In northern and western agro climatic zones also the depth of water table declined that is -11.83 meters and -7.82 meters over the time period. The reason which is behind the depletion of water table is changing in the cropping pattern in the agro climatic zones. The area under rice and wheat crops increased in all the agro climatic zones and the area under sugarcane crop increased in northern

**Figure 1.5- Haryana: Fluctuations of Ground Water Depth in Agro Climatic Zones, 1974 to 2022**



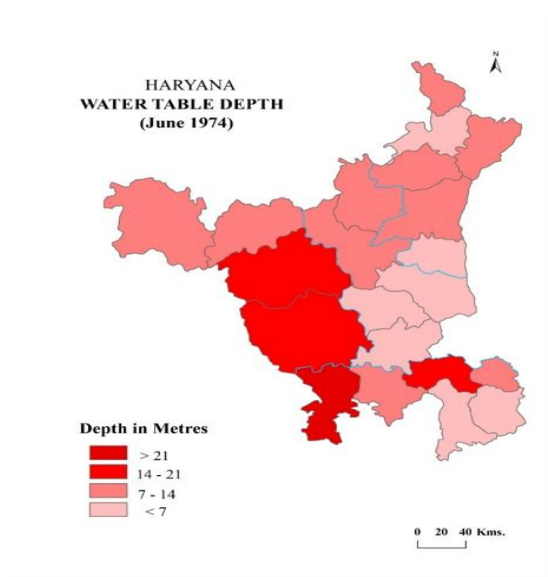
Source: Groundwater Cell, Panchkula

**Figure 1.6- Haryana: Net Irrigated Area by Tube Wells in Agro Climatic Zones, 1980-81 to 2020-21.**

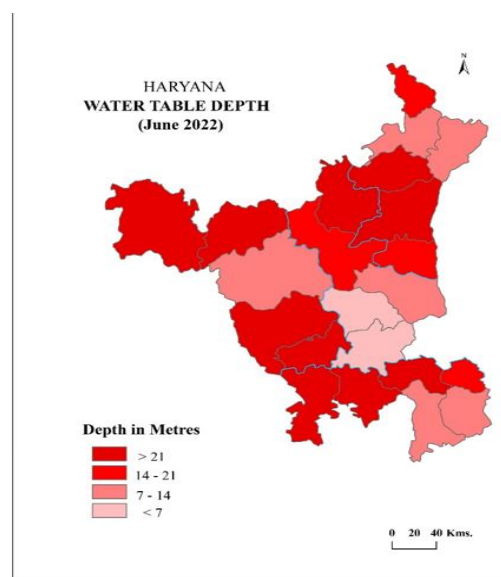


**Source:** Statistical Abstract of Haryana, (Various Issues)

agro climatic zone from 4.34 percent in 1980-81 to 4.82 percent in 2020-21 as comparison to another zone. Moreover, the area under bajra, barley and jowar crops decreased in all the agro climatic zones. Due to change in the cropping pattern in the zones more towards rice-wheat crop system the necessity of irrigation also increased. So, two modes of irrigation canals and tube wells have become important with the passage of time. Therefore, in those areas where irrigated area by tube wells higher the depletion in the groundwater sources also higher while areas having larger area under canal irrigation low decline in water table identified. That's why in southern agro climatic zone due to larger area irrigated by tube wells which is 85.99 percent in 1980-81 and 93.40 percent in 2020-21 as comparison to canals 13.22 percent & 6.6 percent respectively, depletion in ground water sources is higher in this zone (fig. 1.6, table 1.3). While in central agro climatic zone, larger area irrigated by canals nearly 45.78 per cent (2020-21), hence shallow water table noticed in this zone. The nature of change in the water table has not been the same in the agro climatic zones, moreover the figure 1.7 and 1.8 revealed that in the districts also it's not the similar.



**Fig.1.7**



**Fig. 1.8**

**Groundwater Table Changes in Districts of Haryana**

The depth of the groundwater differs substantially in the districts also. Deeper water level 49.33 m is disclosed in the Mahendragarh district, while it ranges between 21 to 40 m in the Kurukshetra, Kaithal, Bhiwani, Fatehabad, Charkhi Dadari, Panipat, Gurugram, Rewari, Sirsa and Karnal districts in June 2022. In Ambala, Faridabad, Panchkula and Jind districts groundwater level vary between 14 to 21 metres. Shallow water level (below 14 m) noted in the Rohtak (4.16 m) and Jhajjar (5.07 m) districts, i.e. in the central parts of the state,

followed by Hisar in west, Palwal and Nuh in the south, Ambala in the north through Yamunanagar and Sonipat districts in the east.

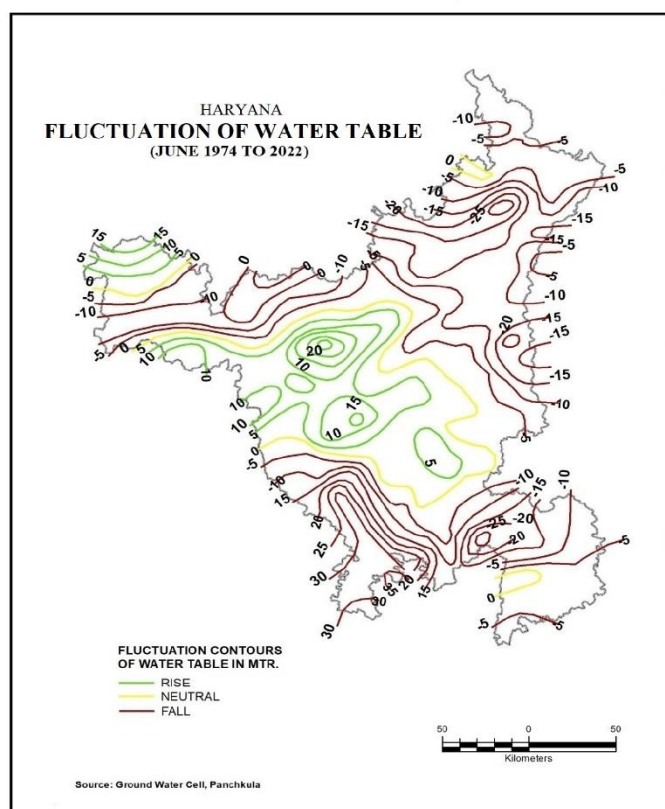


Fig. 1.9

Water table level has recorded a reduction in the areas of fresh water, while an increase in saline groundwater parts. Therefore, water level has declined in the most parts of Kurukshetra (-28.02), Kaithal (-24.74), Fatehabad (-23.72), Rewari (-19.95), Karnal (-13.25), Panipat (-15.07), Gurugram (-15.83), Faridabad (-13.16) and Sirsa (-11.94) districts during June 1974 to June 2022. In these districts the depletion in water table is above -10 m over the period. On the other hand, groundwater level has increased in the Hisar and Rohtak Districts, while in Jhajjar district it represents minor increase of 0.61 m. Overexploitation of groundwater identified mainly in the north-eastern and southern districts, that's why Kurukshetra and Mahendragarh districts experiencing high fall of -28.02 and -26.28 m in the water table. Whereas rise in water table marked in the central and western areas of the state (fig. 1.9).

Table 1.2- Haryana: Average Yield of Rice & Wheat crops, 1980-81 & 2020-21

Districts/Agro climatic zones	Average Yield of Rice & Wheat (kg/hect.)	
	1980-81	2020-21
Ambala	1866	4605
Panchkula	-	3585
Yamunanagar	-	4620
Kurukshetra	2499	4867
Karnal	2463	4471
Panipat	-	4058
<b>Northern</b>	<b>2276</b>	<b>4387</b>
Kaithal	-	4478
Sonipat	1718	4013
Rohtak	1445	3809
Jhajjar	-	3615
Jind	2200	4103
<b>Central</b>	<b>1788</b>	<b>4003</b>
Faridabad	1685	2994
Palwal	-	3713

Gurugram	1458	3804
Nuh	-	3191
Rewari	-	3780
Mahendragarh	1136	2421
<b>Southern</b>	<b>1427</b>	<b>3541</b>
Bhiwani	1020	3258
Hisar	2579	3949
Fatehabad	-	4633
Sirsa	2673	4118
Charkhi Dadari	-	3730
<b>Western</b>	<b>2091</b>	<b>3937</b>
<b>State Average</b>	<b>2367</b>	<b>4139</b>

**Source:** Statistical Abstract of Haryana, (Various Issues),

**Note:** (-) Districts not formed in 1980-81.

The above analysis exposed that the level of groundwater in the districts is depleting abruptly. This adverse situation of the water table is appeared because of the crop land use has shifted towards rice-wheat crops, due to better and well-organized marketing facilities. Furthermore, this has encouraged the farmers to take up rice-wheat cropping system even in the non-rice growing parts at a large extent. Kurukshetra, Karnal, Panipat, Mahendragarh, Rewari, Gurugram, Faridabad, Kaithal, Fatehabad and Sirsa districts are the rice-wheat dominated areas except Gurugram and Rewari. The negative impact of this cropping system, in conjunction with tubewell irrigation, on groundwater may be noted in some detail. Assurance of adequate and timely supply of tubewell water, adversely affect the water table these areas. In Kurukshetra district net area irrigated by tubewells is 81.73% percent, in Faridabad (100%), Yamunanagar (98.19%), Rewari (100%), Ambala (97.97%), Gurugram (100%), Fatehabad (70.09%), Kaithal (63.11%) in 2020-21. Mahendergarh, Nuh and Bhiwani districts comprised of harsh arid climate, and low rainfall (300-400mm), therefore dominated by tubewell irrigation through sprinklers and leads to its decline.

**Table 1.3- Haryana: Net Irrigated Area by Tubewell, 2020-21**

Districts/Agro climatic zones	Net Irrigated Area by Tube wells (in percentage)
Ambala	97.97
Panchkula	100.00
Yamunanagar	98.19
Kurukshetra	81.73
Karnal	66.94
Panipat	66.78
<b>Northern</b>	<b>84.95</b>
Kaithal	63.11
Sonipat	83.55
Rohtak	38.69
Jhajjar	61.25
Jind	23.51
<b>Central</b>	<b>54.22</b>
Faridabad	100.00
Palwal	79.20
Gurugram	100.00
Nuh	83.52
Rewari	100.00
Mahendragarh	99.17
<b>Southern</b>	<b>93.64</b>
Bhiwani	58.54
Charkhi Dadari	72.91
Hisar	29.37
Fatehabad	70.09
Sirsa	23.92
<b>Western</b>	<b>50.96</b>
<b>State</b>	<b>63.33</b>

**Source:** Statistical Abstract of Haryana, (Various Issues)

The districts having high per hectare average yield of rice and wheat also responsible for the decline in the water table. Highest average yield of rice and wheat identified in Fatehabad district 4633 kg/hectare, followed by Kurukshetra, Yamunanagar, Sirsa, Karnal, Ambala, Kaithal, Panipat and Sonapat in 2020-21. It is observed from the table 1.1 that all these districts have experienced decline in groundwater from -5 m to 26.05 m. Some districts like Faridabad, Gurugram and Panchkula have low groundwater level because of urbanization. The green revolution in the state has stimulated the process of urbanisation, so requirement of water increased. These areas generally met their water necessity from the sub-surface source, which negatively affect the water table.

In general decline in the northern, eastern and southern part of the state, is because of the extreme groundwater exploitation through tubewells (fig. 1.6), which is the outcome of changing cropping pattern in favour of water intensive crops (fig. 1.2), whereas decrease in the flow of natural streams of Sahibi nadi, Krishanawati and Dohan (HIRMI) in southern part of the state is also an additional factor for decline in the water table. While, in those areas, where, canal irrigation is prominent and tubewell irrigation is subordinate, marked a rise in the water table, as can be observed in the central and western parts (Hisar, Rohtak and Jhajjar) of the state.

According to National Academy of Agricultural Sciences, "62 percent area showed depletion in groundwater table in Haryana" in this study further mentioned that, "In Haryana, only 25 percent of the water is exploited within the safe limits while 13 percent over-exploitation has reached a semi-critical to a critical stage". The pattern of water table dynamics in the state varies according to the cropping pattern as have evolved and the related water management practices and pursued policies.

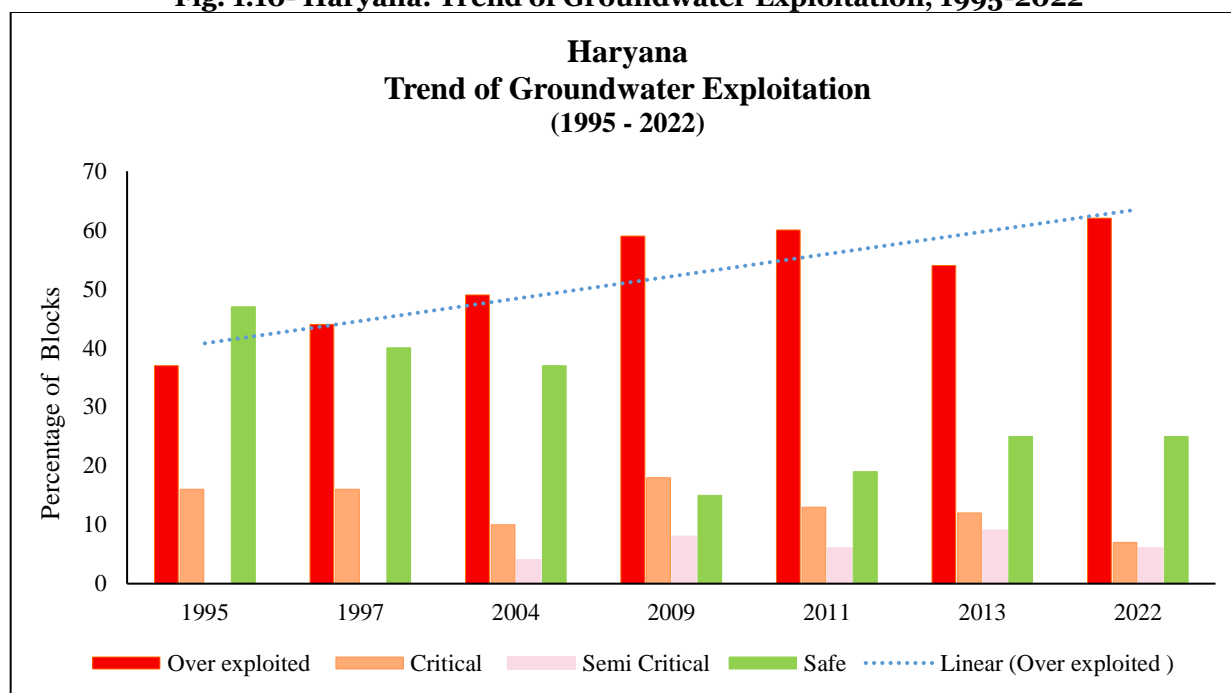
### Groundwater Table Changes in the Blocks of Haryana

Central Ground Board under the ministry of Water Resources assessed 7089 block (in March, 2022) in the country, out of which 1006 has been considered as overexploited. These over exploited blocks have been situated in Haryana (88), Andhra Pradesh (45), Karnataka (49), Punjab (117), Rajasthan (219), Tamil Nadu (360) and Uttar Pradesh (63). In these states the rechargeable quantum of groundwater has been surpassed and withdrawal of static reserves has begun. The dropping in the water table in the country has threatened the sustainability of the groundwater resources, because the level of groundwater has gone deep away from the economic lifts of pumping. The total annual groundwater recharge has been projected 437 billion cubic meters in the country and annual extractable groundwater resource is 398 billion cubic meters. The total current groundwater extraction is 239 billion cubic meters (March, 2022). The uncontrolled exploitation of groundwater resources has resulted into increase in the overexploited blocks from 253 in 1985 to 1006 in 2022. Haryana entered in dark zone, decrease in water table is far from control (Dainik Bhaskar, 2006). On the basis of projected stage of ground water development, the

**Table 1.4- Haryana: Number of Blocks in Different Categories of Groundwater Exploitation, 1995 - 2022**

Categories of Blocks	1995	1997	2004	2009	2011	2013	2022
Over exploited	40	47	55	70	71	64	88
Critical	17	17	11	22	15	14	10
Semi Critical	-	-	5	9	7	11	9
Safe	50	42	42	18	23	30	36
Total Blocks	107	107	113	119	119	119	143
<b>Percentage of Blocks in Different Categories</b>							
Categories of Blocks	1995	1997	2004	2009	2011	2013	2022
Over exploited	37	44	49	59	60	54	62
Critical	16	16	10	18	13	12	7
Semi Critical	-	-	4	8	6	9	6
Safe	47	40	37	15	19	25	25
Total Blocks	100	100	100	100	100	100	100

**Source:** Various Reports of Central Ground Water Board, North Western Region, Chandigarh

**Fig. 1.10- Haryana: Trend of Groundwater Exploitation, 1995-2022**

**Source:** Various Reports of Central Ground Water Board, North Western Region, Chandigarh

groundwater cell, Panchkula has suggested the categorization of blocks for the purpose of further development of groundwater resources (Table 1.4). The blocks have been categorized as over exploited, critical, semi-critical and safe. Those blocks where the extraction of groundwater is 100% or more than 100% enclosed in the over exploited category and critical, where the extraction of groundwater is exists in the range of 90-100%, then semi-critical category comes next where the range is between, 70-90% and last the safe category where groundwater exploitation is less than 70%.

It is evident from the figure 1.10 that exploitation of groundwater resources to such a large extent in Haryana, the crisis of its depletion is now becoming a reality. Table 1.4 has revealed the long-term decline in groundwater level in the state from 1995 to 2022. It is observed from the table that the number of over-exploited blocks has been increased as comparison to other categories of blocks over the time period. In 1995, out of total 107 blocks, only 40 blocks (37 percent) fall in the category of overexploited and this number has been increased to 88 blocks (62 percent) in 2022. On the other hand, number of blocks in the safe category has been decreased from 50 blocks (47 percent) in 1995 to 36 blocks (25 percent) in 2022. It indicates that, if the exploitation of groundwater continuously goes on at this rate, it may lead to scarcity of groundwater resources in Haryana. Not only at state level but similar picture appeared in the districts also.

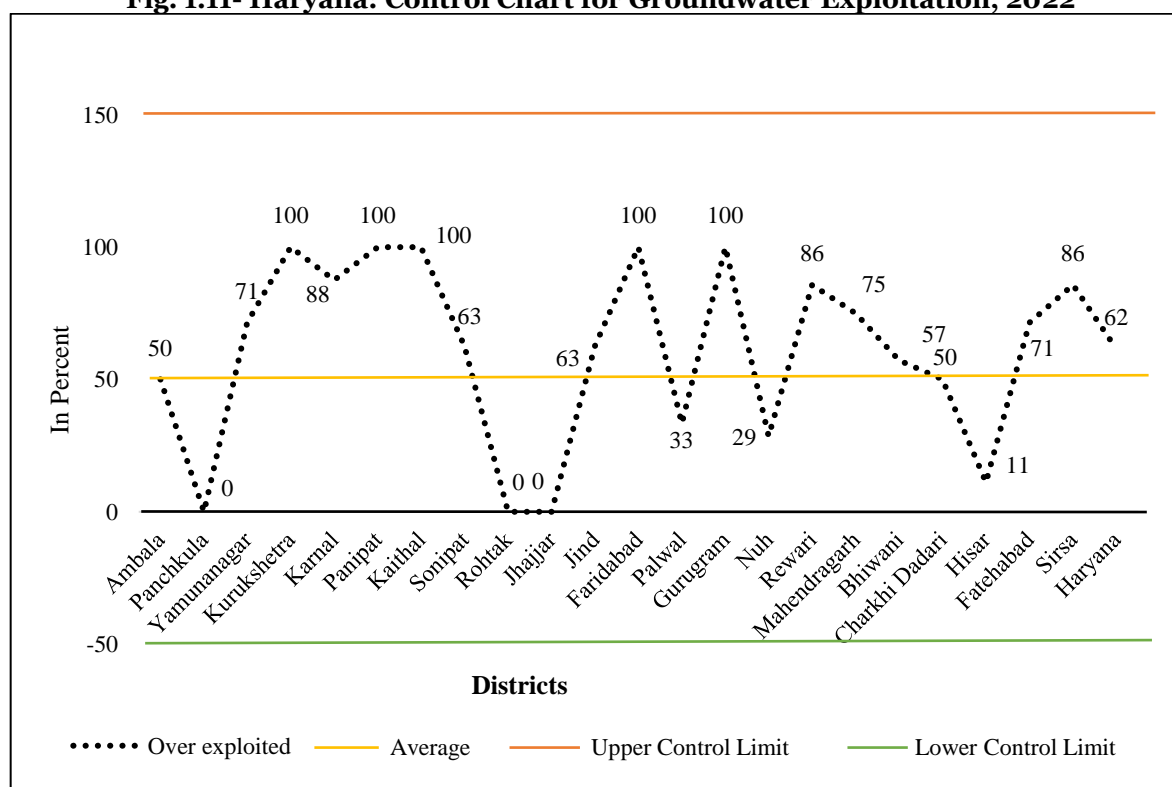
According to Central Ground Water Board total annual groundwater recharge has been evaluated as 9.48 bcm in the state and extractable groundwater resources is 8.61 bcm. The total current (March, 2022) annual groundwater extraction is 11.54 bcm and stage of groundwater withdrawal is 134%. It has been revealed from the table 1.5 that out of the total 143 blocks in the Haryana, 88 have been 'Over-exploited', 10 as 'Critical', 9 as 'Semi-critical' and 36 as 'Safe' in 2022. Kurukshetra, Kaithal, Panipat, Karnal, Gurugram, Faridabad, Yamunanagar, Fatehabad, Rewari, Sirsa and Mahendragarh districts are the worst affected, having largest numbers in the blocks of water extraction status (fig. 1.11). The water level in the blocks of these districts has been lessening one metre every year (Kumar, R. 2016). The groundwater level has dropped by 20-60 metres in 12 of the 22 districts (in 2022), with southern part of the state and areas along the GT Road belt recording the sharpest decline. On the other hand, the most of the blocks in the Rohtak, Hisar, Jhajjar districts have witnessed increased groundwater level. The surplus of water and groundwater salinity has led to waterlogging in the blocks of these districts and also some blocks of Jind district.

**Table 1.5 - Haryana: District-Wise number of blocks in different categories of exploitation in Haryana**

Districts/Agro climatic zones	Total No. of Blocks	Safe		Semi Critical		Critical		Over Exploited	
		No.	%	No.	%	No.	%	No.	%
Ambala	6	0	0	2	33	1	17	3	50
Panchkula	3	2	67	0	0	1	33	0	0
Yamunanagar	7	0	0	2	29	0	0	5	71
Kurukshetra	7	0	0	0	0	0	0	7	100
Karnal	8	0	0	0	0	1	13	7	88
Panipat	6	0	0	0	0	0	0	6	100
Kaithal	7	0	0	0	0	0	0	7	100
Sonipat	8	3	38	0	0	0	0	5	63
Rohtak	5	5	100	0	0	0	0	0	0
Jhajjar	7	7	100	0	0	0	0	0	0
Jind	8	2	25	1	13	0	0	5	63
Faridabad	4	0	0	0	0	0	0	4	100
Palwal	6	2	33	1	17	1	17	2	33
Gurugram	5	0	0	0	0	0	0	5	100
Nuh	7	4	57	1	14	0	0	2	29
Rewari	7	0	0	0	0	1	14	6	86
Mahendragarh	8	0	0	0	0	2	25	6	75
Bhiwani	7	3	43	0	0	0	0	4	57
Charkhi Dadari	4	2	50	0	0	0	0	2	50
Hisar	9	6	67	1	11	1	11	1	11
Fatehabad	7	0	0	0	0	2	29	5	71
Sirsa	7	0	0	1	14	0	0	6	86
<b>Haryana</b>	<b>143</b>	<b>36</b>	<b>25</b>	<b>9</b>	<b>6</b>	<b>10</b>	<b>7</b>	<b>88</b>	<b>62</b>

**Source:** Report on “Dynamics Groundwater Resources of India” (as on March 2022), Central Ground Water Board, Ministry of Water Resources, 2022

**Note:** Morni block of district Panchkula not assessed due to complete hilly area

**Fig. 1.11- Haryana: Control Chart for Groundwater Exploitation, 2022**

**Source:** Report on “Dynamics Groundwater Resources of India” (as on March 2022), Central Ground Water Board, Ministry of Water Resources, 2022

The depleting groundwater level in Haryana can be predominantly attributed to the changing cropping pattern in support of water intensive crops. At the time of the formation of the state, 1.92 lakh hectares of land was under the cultivation of rice crop, which went up to 15.42 lakh hectares in 2022, a seven-fold increase. An acre of rice is required to be flooded nearby 26 times, in other words, 5389 litres of water have essential for every kilogram of rice produced and sugarcane required 1500 to 3000 litres.

### Regression Analysis

Regression method is very useful to study the simultaneous variation of two or more characters. In the present research work linear regression and step wise regression both methods have been used. Simple linear regression technique helps in finding the linear relationship among two variables. This method also plays an important role in find out the functional form of the relationship. On the other hand, stepwise regression involves developing a sequence of linear models through variables entry as determined by computer algorithms. This method used widely because it acts like a variable selection method, which also helps to solve the problem of multicollinearity. Step wise regression also helps in to get rid of insignificant predictors and identify the best of the predictors.

In regression analysis dependent and independent variables has been take into the account. In the present research work dependent variable is water table depth and nine independent variables which are area under rice cultivation, area under wheat cultivation, per hectare consumption of fertilizer, intensity of cropping, irrigation intensity, average yield of food grain per hectare of net sown area, percentage of net sown area to total, per cultivator net sown area and average size of land holdings has been selected. For applying regression technique to identify the linear relationship between dependent and independent variables, it is supposed that the data for independent variables is being normally distributed.

**Table 1.6- Results of linear regression**

Sr. No.	Independent Variable	Correlation Coefficient (r)	Coefficient of Determination ( $r^2$ )	Per cent explained variation ( $r^2 \times 100$ )
1	Area under Rice Cultivation	0.98	0.96	96.18
2	Area under Wheat Cultivation	0.93	0.85	85.87
3	Percentage of net sown area to total	-0.92	0.84	84.15
4	Per cultivator net sown area	-0.91	0.83	83.63
5	Per hectare consumption of fertilizer	0.92	0.83	83.88
6	Intensity of cropping	0.93	0.86	86.31
7	Irrigation Intensity	0.92	0.85	85.51
8	Average size of land holding	-0.89	0.80	80.28
9	Average yield of food grain per hectare of net sown area	0.97	0.94	94.33

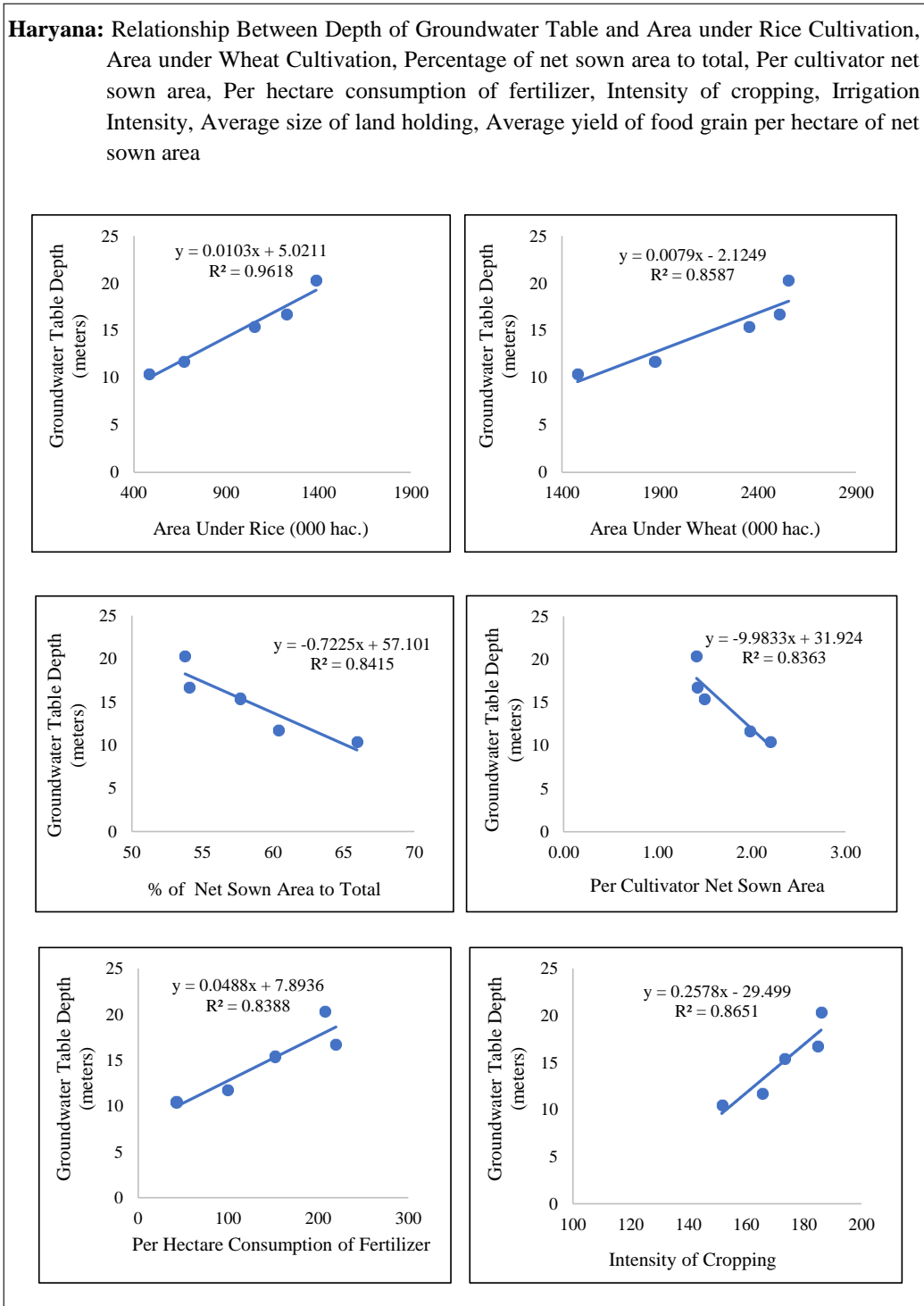
**Source:** Computed by the author

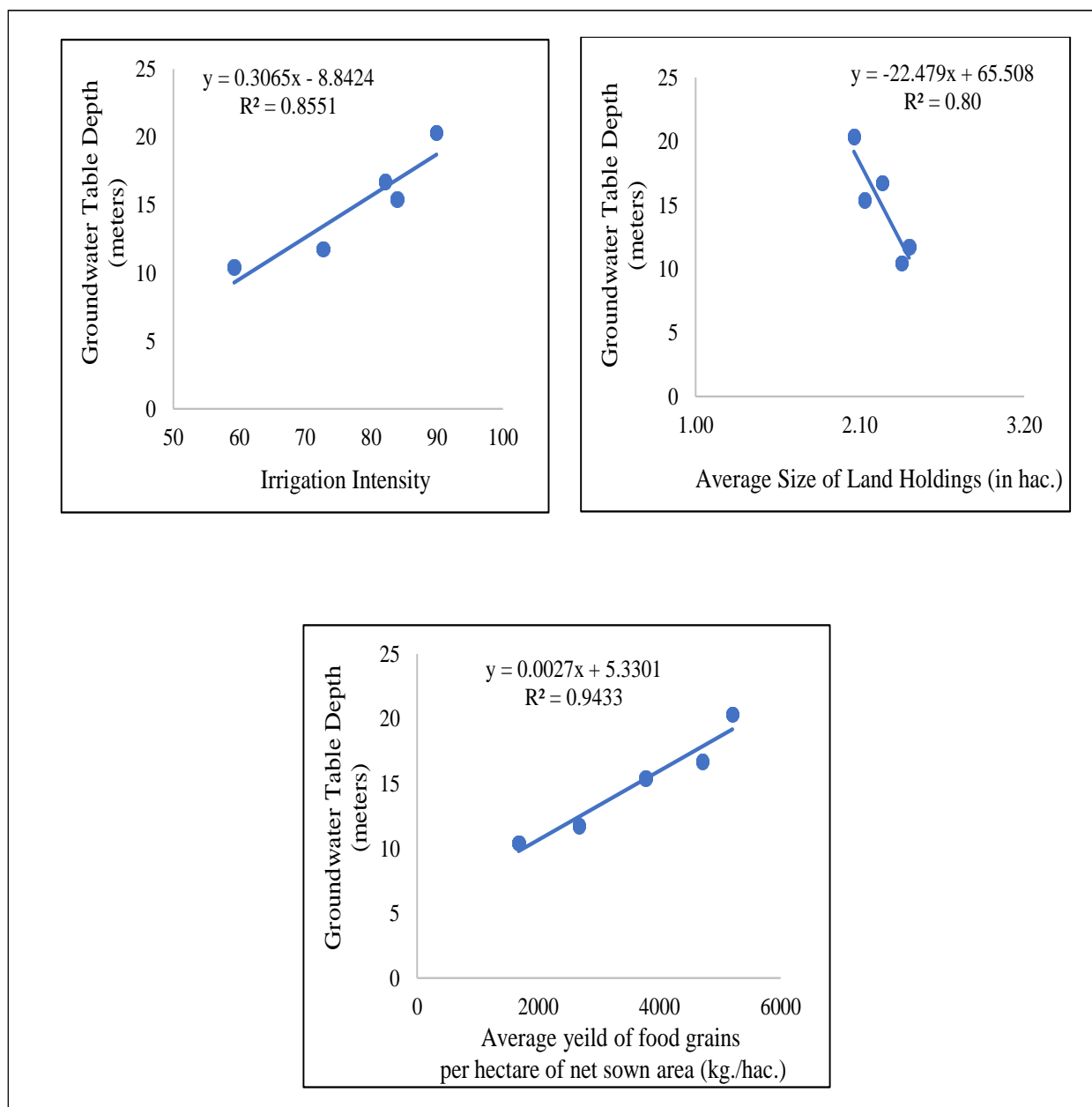
It is observed from the table 1.6 that the six variables i.e., area under rice cultivation (0.98), area under wheat cultivation (0.93), per hectare consumption of fertilizer (0.92), intensity of cropping (0.93), irrigation intensity (0.92) and average yield of food grain per hectare of net sown area (0.97) shows high degree positive correlation with the water table depth. It indicates that if the area under rice and wheat increases the depth of water table also increases. On the other hand, percentage of net sown area to total (-0.92), per cultivator net sown area (-0.91) and average size of land holding (-0.89) negatively correlated with groundwater. All these variables which are highly positively and negatively correlated plays an important role in spatial and temporal disparities in change in groundwater table depth of the state.

Table 1.6 also represents coefficient of determination. Coefficient of determination used for interpreting whether the computed correlation is strong, moderate and weak. It is the ratio of the variance of the computed Y to the variance of the observed Y. The variance of Y is that part of total variance which is described by the regression of Y on X. It is appeared from the above table that all the independent variables significantly related to the dependent variable. Although some of them i.e., area under rice cultivation (0.9618) and average yield of food grain per hectare of net sown area (0.9433) found relatively high in comparison to other independent

variables. It reveals that around 96 and 94 per cent of the variation of the groundwater table depth is explained by these two independent variables. On the other hand, rest of variables such as area under wheat cultivation (0.8587), per cultivator net sown area (0.8363), per hectare consumption of fertilizer (0.8388), intensity of cropping (0.8651), irrigation intensity (0.8551) and average size of land holding (0.8028) are found to explaining the variation in change in groundwater table depth nearly 85, 84, 83, 83.88, 86, 85 and 80 per cent respectively.

The relationship between dependent and independent variables become more evident when they are plotted on scatter diagram. Nine scatter diagrams (fig. 1.12) have been drawn which represents independent variables on the horizontal or 'X' axis and dependent variable on the vertical or 'Y' axis. These diagrams display the relationship between two variables which are apparently linear in character.





**Fig. 1.12**

**Step Wise Regression**

After identify the relationship between dependent variable (groundwater table depth) and the independent variables one by one. Now, it is required in the present research work to identify whether the relationship among dependent and independent variables is significant or not along with, which variable is more significant as comparison to other variables. Thus, stepwise regression also applied in the present study. After run this method in SPSS the results are as follows:

**Model Summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.981 <sup>a</sup>	.962	.949	.89542

a Predictors: (Constant), Area under Rice

It is observed from the above model summary table that R- Square value is 0.962, which indicates that independent variable i.e., area under rice causes 96.2 per cent change in the dependent variable that is water table depth. In other words, this model explains 96.2 per cent of the variance in the water table depth. It is a strong effect which is reported by the model.

#### ANOVA<sup>b</sup>

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	60.633	1	60.633	75.624	.003 <sup>a</sup>
	Residual	2.405	3	.802		
	Total	63.039	4			

a Predictors: (Constant), Area under Rice

b Dependent Variable: Groundwater Table Depth

The ANOVA table results disclose that the p-value is 0.003 ( $F(1, 3) = 75.624$ ,  $P < .003$ ) which is less than 0.05, hence it indicates that there is a significant relationship between independent variable (area under rice) and the dependent variable (water table depth).

#### Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.021	1.208		4.157	.025
	Rice	.010	.001	.981	8.696	.003

a Dependent Variable: Groundwater Table Depth

The above table shows the coefficient results. The value of unstandardized beta (B) demonstrates the slope for area under rice (independent variable). This beta value represents that for each unit increase in area under rice there will be an increase of .010 units in the depletion of water table depth. The next important reported statistic is the standardized beta ( $\beta$ ) value. This value tells how much standard deviations change in the independent variable will affect the dependent variable, also in standard deviation units. This is an important statistic because it is a measure of the relative importance of the independent variables in the equation.

Furthermore, coefficients have further assessed to ascertain the influence of each factor on the water table depth. The results represents that only one variable i.e., area under rice out of nine independent variables has a significant and positive impact on water table depth ( $B = 0.981$ ,  $t = 8.696$ ,  $p = .003$ ). In other words, there is a less than 5 per cent chance that two variables are unrelated and we are 95 per cent confident of the relationship that as the area under rice increases the water table depth will also increase gradually.

**Excluded Variables<sup>b</sup>**

Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
					Tolerance
Area under Wheat Cultivation	-.789 <sup>a</sup>	- 2.096	.171	-.829	.042
Percentage of net sown area to total	.448 <sup>a</sup>	1.042	.407	.593	.067
Per cultivator net sown area	.706 <sup>a</sup>	2.128	.167	.833	.053
Per hectare consumption of fertilizer	-.658 <sup>a</sup>	-1.873	.202	-.798	.056
Intensity of cropping	-.475 <sup>a</sup>	-.943	.445	-.555	.052
Irrigation Intensity	-.067 <sup>a</sup>	-.152	.893	-.107	.098
Average size of land holding	-.187 <sup>a</sup>	-.777	.518	-.482	.254
Average yield of food grain per hectare of net sown area	-.397 <sup>a</sup>	-.304	.790	-.210	.011

a Predictors in the Model: (Constant), Area under Rice

b Dependent Variable: Water Table Depth

Excluded variables table expose that out of nine variables eight variables are insignificant. The p value of these eight variables above 0.05 which represents that these variables are not significant.

### Conclusion

After a detailed study, it has been identified that in Haryana water table has been declined from 10.44 m in June 1974 to 20.34 m in 2022, representing a fall of 9.9 m over the period. In case of agro climatic zones southern zone has represents highest decline of -12.54 metres in the ground water table, followed by northern zone - 11.83 meters, western zone -7.82 meters and central zone -6.25 meters. The reason which is behind the depletion of water table is changing in the cropping pattern primarily in the favor of rice and wheat crops in the state. Accordingly, the necessity of irrigation also increased. In those areas where irrigated area by tube wells higher the depletion in the groundwater sources also higher. That's why in southern agro climatic zone due to larger area irrigated by tube wells depletion in ground water sources is higher. While in central agro climatic zone, larger area irrigated by canals (49 per cent, 2020-21), hence shallow water table noticed in this zone. In the districts also the depth of the groundwater differs substantially. Deeper water level (49.07 metres) is disclosed in the Mahendragarh district. The depth of groundwater ranges between 21 to 40 m in the Kurukshetra, Kaithal, Bhiwani, Fatehabad, Gurugram, Rewari, Sirsa and Karnal districts in June 2022. In Panipat, Faridabad, Panchkula and Jind districts groundwater level vary between 14 to 21 metres. Shallow water level (below 14 m) noted in the Rohtak (4.16 m) and Jhajjar (5.07 m) districts, i.e. in the central parts of the state, followed by Hisar in west, Palwal and Nuh in the south, Ambala in the north through Yamunanagar and Sonipat districts in the east. Statistically, it is proved that increasing in the area under rice crop is foremost cause of decline in the groundwater table in the state. Hence, there is an urgent necessity to go for diversification of agriculture, sustainable and environment friendly methods of cultivation.

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