International Journal of Research in Social Sciences
Vol. 8 Issue 5, May 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gate as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Crop Combination and Groundwater Exploitation in Haryana: A Geographical Study

Ravinder Gautam
Department of Geography, Maharshi Dayanand University, Rohtak, Haryana, India
E-mail: ravinder.gautam.mdu@gmail.com

Abstract: The study of crop combination regions constitutes an essential aspect of agricultural geography as it provides a good basis for agricultural regionalization. The present study aims to determine the significant crop and crop combination regions of Haryana state, as there is variation in the different areas of the meteorological variables such as temperature and rainfall. This study seeks to explore the relationship between crop combinations and groundwater exploitation, assessing how different cropping patterns affect the sustainability of water resources in Haryana. The present study is based on secondary data. The data has been collected from various statistical abstracts of Haryana from 1980-81 to 2014-15 and the Central Groundwater Board (CGWB) report, 2017. Weaver's (1954) crop combination technique has been adopted to delineate crop combination regions. The analysis shows that the part of the northern and central zones, where the wheat and rice crop combination was registered and remained constant throughout the study, shows the massive pressure on groundwater resources. In contrast, regions with a diversified crop combination, including pulses, cotton, oilseeds, and less water-intensive crops, show low pressure on groundwater resources. The spatial analysis of the area under wheat-rice cultivation and groundwater depletion reiterates the same finding, demonstrating a spatial correspondence between these two phenomena. A holistic approach is required in Haryana to balance crop combinations and groundwater use.

Keywords: Crop Specialization; Weaver method; Cropping Pattern; Groundwater; Haryana

1. Introduction

The study of Crop Combination is an essential aspect of Agricultural Geography. Studying crop combinations helps us understand crop patterns and concentrations in a particular area. It further helps to make a plan for inclusive production in agriculture. The crops are usually grown in a combination. A particular crop rarely occupies a position of total isolation from other crops in a given area unit at a given time (Gautam, 2012). The concept of "Crop Combination is a scientific technique to study the existing spatial relationship of crops in association with other crops and to establish the boundaries of the agricultural region based on statistical findings. It also studies the

dominances of crops on an orderly basis" (Gautam, 2012; Kumar, 2017; Ramasundaram, 2012). Agricultural regionalization is dividing an area into territorial units or uninterrupted regions with some homogeneity with a specific defined outer limit, which may be done with the help of the crop combination technique (Husain, 1972, 1996; NityaNand, 1972). This concept has gained much attention and has become essential among agricultural planners and geographers.

The study on crop combination and groundwater exploitation in Haryana is closely related to SDG 2 (Zero Hunger) and SDG 6 (Clean Water and Sanitation). Both SDGs are interlinked with ensuring sustainable agricultural practices and managing water resources wisely, directly affecting the region's environmental and socio-economic health. Crop combination strategies can help optimize agricultural output, improve food security, and increase farmers' income while minimizing the overuse of resources like water. Proper crop selection based on available resources can lead to sustainable agricultural practices, improving overall food production in the region. Groundwater exploitation is a key issue in Haryana, where excessive groundwater extraction for irrigation is unsustainable. A study addressing groundwater depletion and crop patterns would support efforts to manage water resources more sustainably and prevent further degradation of water systems (Singh & Singh, 2002). The state's agricultural practices and reliance on groundwater for irrigation have led to significant challenges related to groundwater depletion. This study seeks to explore the relationship between crop combinations and groundwater depletion, assessing how different cropping patterns affect the sustainability of water resources in Haryana.

2. Materials and methodology

2.1 Study Area

Haryana state is situated in the northwestern part of India. Haryana came into existence on 1st November 1966 as a result of the partition of the former state of Punjab under the "Punjab Reorganisation Act" 1966, and two separate states were created: Punjab (Punjabi speaking) and Haryana (Hindi speaking). The origin of the name "Haryana" has been a matter of severe controversy, with diverse interpretations. The "Imperial Gazetteer of India" says that the Haryana state is probably derived from the color name "Hari" or "Green," and it is perhaps a reminder of the times when it was a rich and fertile tract. Geographically, Haryana state is located in the middle of 27˚ 39' to 30˚ 35' north latitudes and 74˚ 28' to 77˚ 36' east longitudes, covering an area of 44,212 square kilometers. Geologically, it is a part of the "*Indo-Gangetic Plain*" in the northwestern part of India. Himachal Pradesh is bound by Haryana in the North, Uttar Pradesh and Delhi in the East, Rajasthan in the southwest, and Punjab and Chandigarh in the northwest.

International Journal of Research in Social Sciences
Vol. 8 Issue 5, May 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gate as well as in Cabell's Directories of Publishing Opportunities, U.S.A

2.2 Methodology

The present study is primarily based on secondary data, and the data has been collected from various Statistical Abstracts of Haryana from 1980-81 to 2014-15. The study has been correlated to the districts of Haryana, and all these districts are separated into the four Agro Climatic Zones.

1. Northern Agro Climatic Zone: Ambala, Kurukshetra, Karnal, Yamunanagar, Panipat, Panchkula
2. Central Agro Climatic Zone: Sonipat, Rohtak, Jind, Kaithal, Jhajjar
3. Western Agro Climatic Zone: Bhiwani, Hissar, Sirsa, Fatehabad
4. Southern Agro Climatic Zone: Faridabad, Gurugram (Gurgaon), Mahendragarh, Rewari, Palwal, Nuh (Mewat)

Weaver's method (1954) has been adopted to delineate the Crop Combination region in the study area. In Weaver's method, "the crop combination is measured by calculating the deviation of real percentages of crops (occupying over 1 percent of the cropped area) for all possible combinations in the areal units against a theoretical standard" (Weaver, 1954). The theoretical curve for the standard measurement is employed as follows: -

Table: 1

Monoculture	100 percent of the total harvested cropland in one crop
Two Crop Combination	50 percent in each of the two crops
Three Crop Combination	33.3 percent in each of the three crops
Four Crop Combination	25 percent in each of the four crops
Five Crop Combination	20 percent in each of the five crops
Six Crop Combination	16.67 percent in each of the six crops
Seven Crop Combination	14.29 percent in each of the seven crops
Eight Crop Combination	12.50 percent in each of the eight crops
Nine Crop Combination	11.11 percent in each of the nine crops
Ten Crop Combination	10 percent in each of the ten crops

For the determination of the minimum deviation, the "Standard Deviation Method" is used, applying the following formula: -

$$SD = \sqrt{\frac{\sum d^2}{n}}$$

where,

d - is the difference between the actual crop percentage in a given unit and the appropriate percentage in the theoretical curve and

n - is the number of crops in a particular combination.

As J. C. Weaver pointed out, the relative, not absolute value being significant, square roots were not extracted, so the actual formula used was as follows: -

$$d = \frac{\sum d^2}{n}$$

So, first of all, the "percentage of individual cropped area to the total cropped area of each district has been calculated. Thereafter, the values of each crop are arranged rank-wise from highest to lowest, and then the deviation is calculated by applying the formula mentioned above. The lowest value of the deviation of actual percentages from the theoretical curve is denoted as crop combination resulting in the identity and the number of crops in the basic combination" (Weaver, 1954).

3. Results and Discussion

In the field of agricultural geography, J. C. Weaver (1954) was the first geographer to use statistical techniques to establish crop combinations in the Midwest (USA) (Gautam, 2012). The Crop Combination Regions are defined here based on techniques given by J. C. Weaver (1954). This study considers the "percentage of crop area to the total cropped area." The present study has identified five crop combinations in the study area.

Table 2: Agro Climatic Zone-wise Crop Combination Pattern in Haryana 1980-81 to 2014-15

Agro Climatic Zone	1980-81	1990-91	2000-01	2010-11	2014-15
Northern Zone	WRMGSu	WR	WR	WR	WR
Central Zone	WBaGJR	WRBaR/MJ	WRBaJC	WRBa	WR
Southern Zone	BaWBeGR/M	WBaR/MG	WBaR/M	WBaR/M	WBaR/M
Western Zone	GBaWCR/M	WGCBaR/M	WCBaR/MR	WCBaR/MR	WCR/MRBa
Haryana	WBaGRC	WRGBaC	WRBaCR/M	WRBaR/MC	WRCR/Mba

Source: Computed from Statistical Abstract of Haryana (Various Issues) 1980-81 to 2014-15.
Note: "Wherever The Crop Combinations are more than five the names of the first five crops are mentioned". W-Wheat, R-Rice, M-Maize, Su-Sugarcane, Ba- Bajra, C- Cotton, R/M- Rapeseed and Mustard, J- Jowar, G- Gram, Be- Barley.

Table 2 shows the Crop Combination Regions in Haryana by Agro Climatic Zone-Wise at five points from 1980-81 to 2014-15. When we discuss the first-rank crop in the state, it may be noticed that wheat is the primary crop throughout the state. In the northern and central zones, wheat was the first-ranked crop throughout the entire period from 1980-81 and from 2014-15. During 1980-81, in the southern and western zones, Bajra and Gram were the first-rank crops; thereafter, they were replaced by wheat crops, and wheat became the first-rank crop throughout the state.

When we discuss the first two crop combinations, Bajra was the second-ranked crop in 1980-81; thereafter, due to the emergence of new irrigation facilities, Rice became the second-ranked crop in the state. Rice was the second-ranked crop throughout the period in the northern zone, and the northern zone became the Wheat-Rice crop belt. During 1980-81, in the central zone, Bajra was the second-rank crop; thereafter, the Rice crop replaced it, and Rice became the second-rank crop, and Bajra became the third-rank crop. In the southern zone, Wheat was the second-ranked crop in 1980-81; thereafter, Bajra replaced it, and Bajra became the second-ranked crop. In the western zone, Bajra was the second-ranked crop in 1980-81; thereafter, Gram replaced it in 1990-91, Cotton became the second-ranked crop, and the western zone became a Wheat-Cotton belt.

When we discuss the first three crop combinations, Gram was the third-ranked crop from 1980-81 to 1990-91; thereafter, Bajra became the third-ranked crop in the state, and Cotton replaced it in 2014-15. Maize was the third-ranked crop in 1980-81; thereafter, only two crop combinations (wheat and rice) were seen in the northern zone. In the central zone, Gram was the third rank crop in 1980-81; thereafter, it was replaced by Bajra, and Bajra became the third rank crop; further, in 2014-15, in the central zone, only two crop combinations (wheat and rice) were seen. In the southern zone, Barley was the third-ranked crop in 1980-81; thereafter, it was replaced by Rapeseed and Mustard, and Rapeseed and Mustard became the third-ranked crop. There is variation in the third-rank crop in the western zone. In the western zone, wheat was the third-ranked crop in 1980-81; thereafter, cotton in 1990-91, and Bajra, Rapeseed replaced it, and Mustard replaced it.

In the first four and five crop combinations, Rice and cotton were the fourth and fifth ranked crops in 1980-81. However, due to the emergence of better irrigation facilities, HYV seeds, and rural electrification, rice became the second-ranked crop in 2014-15. Rapeseed, Mustard, and Bajra were the fourth and fifth-ranked crops in 2014-15. Gram and Sugarcane were the fourth and fifth ranked crops in 1980-80 in the northern zone. In the central zone, Jowar and Rice were the fourth and fifth-rank crops in 1980-80, but thereafter, only two crops, wheat and rice replaced them. In the southern zone, Gram, Rapeseed, and Mustard were the fourth and fifth rank crops in 1980-81. However, in 1990-91, a crop combination replaced it, and Gram was constant in fourth rank; further southern zone was seen as a crop combination (Wheat-Bajra-Rapeseed and Mustard) region till 2014-15. In the western zone, Cotton and Rapeseed Mustard were the fourth and fifth rank crops in 1980-81, but thereafter, it was replaced by Rice and Bajra; therefore, Cotton and

Rapeseed Mustard became the second and third rank crops in 2014-15.

It is clear from the above discussion that the northern and central zones are becoming highly intensive two-crop combination regions (Wheat-Rice), which are highly water-intensive crops. The southern zone emerged as a three-crop combination region (Wheat-Bajra-Rapeseed and Mustard) after 2000-01 because the southern zone lacks water resources, and these crops are less water-intensive. Thus, they are cultivated in the southern region by different farmers. During the study period, the western zone was constantly observed as a five-crop combination region, where wheat and cotton were major cultivated crops.

Table 3 District-Wise Crop Combination Pattern in Haryana (1980-81 to 2014-15)

Districts	**1980-81**	**1990-91**	**2000-01**	**2010-11**	**2014-15**
Ambala	WRMGSu	WRMSuG	WR	WR	WR
Kurukshetra	WR	WR	RW	RW	RW
Karnal	WR	WR	WR	RW	WR
Yamunanagar	--	WSuR	WRSu	WRSu	WRSu
Panipat	--	WR	WR	WR	WR
Panchkula	--	--	WMR	WRM	WRM
Northern zone	**WRMGSu**	**WR**	**WR**	**WR**	**WR**
Sonipat	WJBaRSu	WRJSuR/M	WR	WR	WR
Rohtak	WBaGJSu	WR/MJBaG	WJRBaSu	WRBaJR/M	WRJCBa
Jind	WGBaRC	WBaRCG	WRBaC	WRCBa	WRC
Kaithal	--	WR	RW	WR	WR
Jhajjar	--	--	WJBaR/MR	WBaRR/MJ	WRBaR/MJ
Central zone	**WBaGJR**	**WRBaR/MJ**	**WRBaJC**	**WRBa**	**WR**
Faridabad	WBaJBeR/M	WBaJR/MSu	WRJBaSu	WRBaJR/M	WRBaJR/M
Gurugram	WBaBeJR/M	WR/MBaJG	WBaR/MJR	WBa	Wba
Mahendragarh	BaWGBeR/M	BaGR/MW	BaR/MW	BaR/MW	BaR/MW
Rewari	--	R/MBaWG	WR/Mba	BaR/MW	R/MbaW
Palwal	--	--	--	WRJBaR/M	WRBaJC
Nuh	--	--	--	WBaR/MJR	WBaR/MJR
Southern zone	**BaWBeGR/M**	**WBaR/MG**	**WBaR/M**	**WBaR/M**	**WBaR/M**
Bhiwani	BaGR/MW	GBaWR/M	BaWR/MGC	BaWR/MG	WR/MCBaG
Hissar	GCWBaR/M	WCGR/Mba	WCBaRR/M	WCR/MBaR	WCR/MRBa
Sirsa	GCWR/M	WCGR/M	WCRR/M	WCRR/M	WCRR/M
Fatehabad	--	--	WCR	WRC	WRC
Western zone	**GBaWCR/M**	**WGCBaR/M**	**WCBaR/MR**	**WCBaR/MR**	**WCR/MRBa**
Haryana	**WBaGRC**	**WRGBaC**	**WRBaCR/M**	**WRBaR/MC**	**WRCR/Mba**

Source: Computed from Statistical Abstract of Haryana (Various Issues) 1980-81 to 2014-15.
Note: "Wherever the Crop Combinations are more than five the names of the first five crops are mentioned". W-Wheat, R-Rice, M-Maize, Su-Sugarcane, Ba- Bajra, C- Cotton, R/M- Rapeseed and Mustard, J- Jowar, G- Gram, Be- Barley.

International Journal of Research in Social Sciences
Vol. 8 Issue 5, May 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gate as well as in Cabell's Directories of Publishing Opportunities, U.S.A

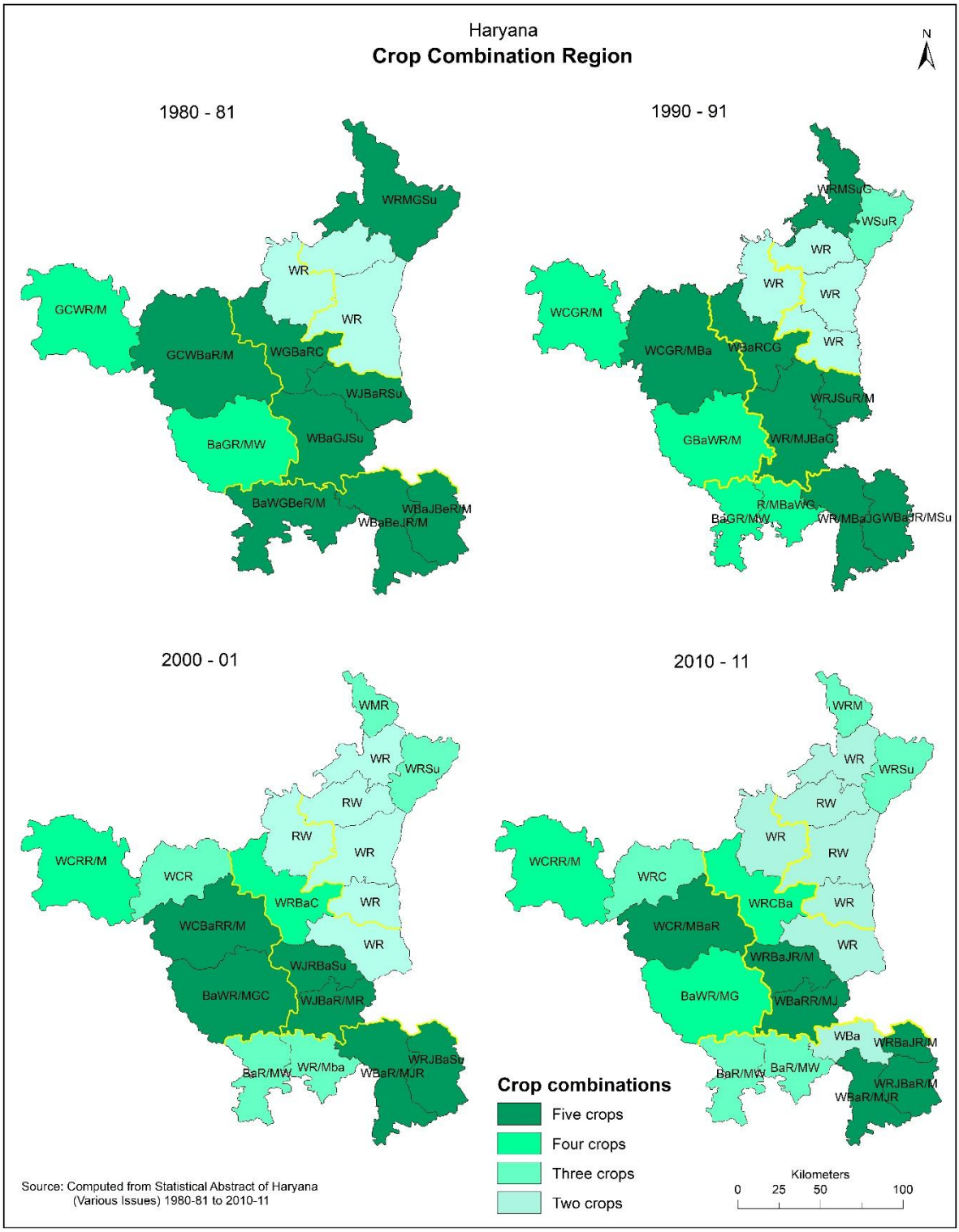

Fig. 1

International Journal of Research in Social Sciences
Vol. 8 Issue 5, May 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gate as well as in Cabell's Directories of Publishing Opportunities, U.S.A

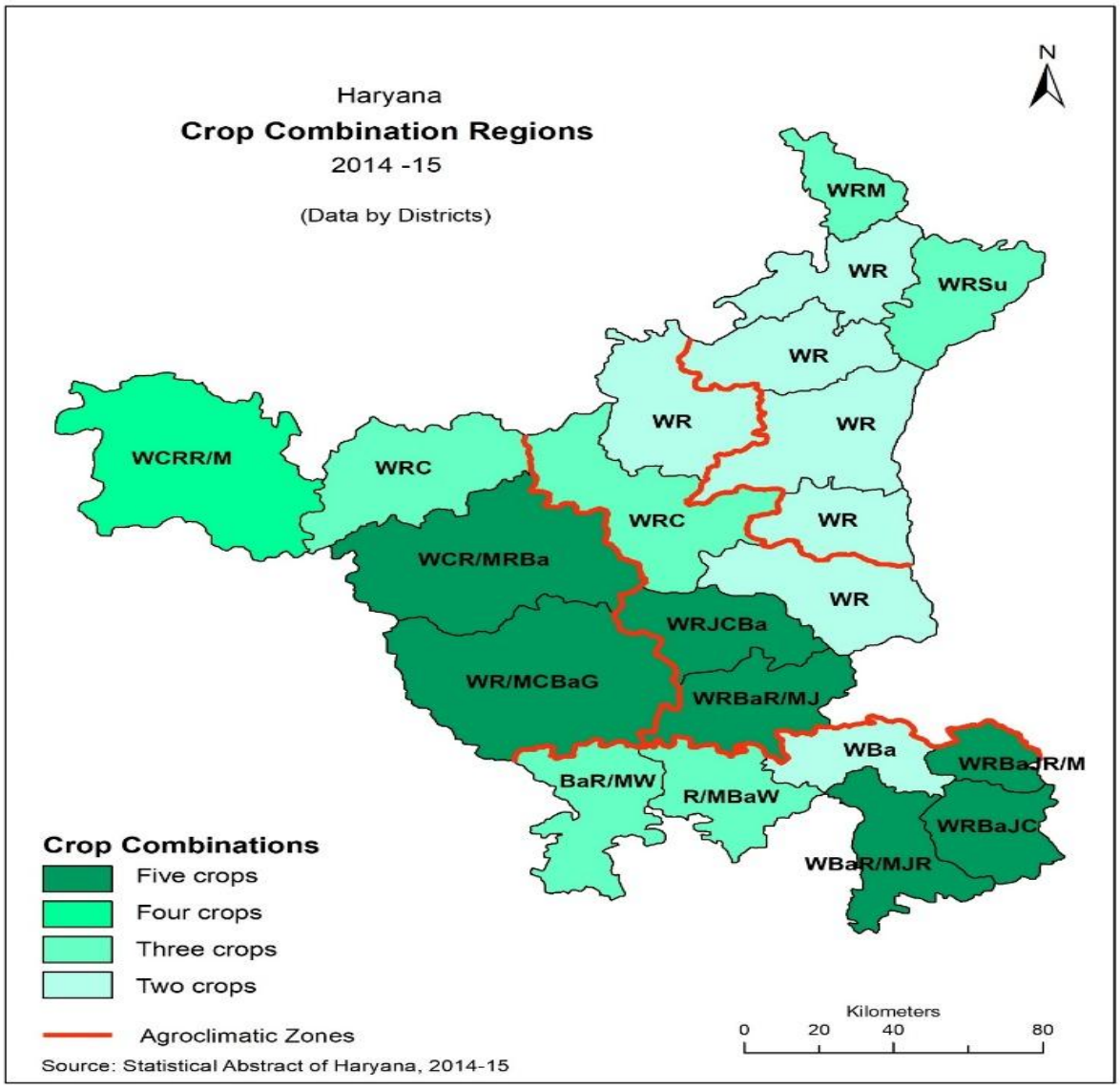

Fig. 2

Table 3 and figures 1 and 2 show the Crop Combination Regions in Haryana by District-Wise at five points from 1980-81 to 2014-15. It is clear from the figures that the Northern districts of Haryana are undergoing specialization, whereby most districts have become a dominant Wheat-Rice crop region. Four districts, i.e., Karnal, Kurukshetra, Kaithal, and Panipat, have shown a Wheat-Rice crop cycle from 1980-81 and 1990-91 onwards, and there have been no shifts till 2014-15. In 1980-81 and 1990-91, two districts, Ambala and Sonipat, observed five crop combinations; in 2000-01 and onwards, it was replaced by two Wheat and Rice crop combinations. Three crop combination regions in the Northern Agro Climatic Zone have been observed in Yamunanagar and Panchkula districts. In the Yamunanagar and Panchkula districts, sugarcane and maize are the third most dominant crops. Three districts of the state i.e., Rohtak (Wheat, Bajra, Gram, Jowar, and Sugarcane), Faridabad (Wheat, Bajra,

Jowar, Barley, and Rape/Mustard), and Hissar (Gram, Cotton, Wheat, Bajra and Rape/Mustard) have shown a five crop combinations from 1980-81 onwards and there have been no shifts till 2014-15.

Only one district, Sirsa, has observed four crop combinations from 1980-81 to 2014-15. In Sirsa district, the Gram, Cotton, Wheat, and Rape/Mustard combinations were seen in 1980-81, and in 2014-15, it was replaced by the combination of Wheat, Cotton, Rice, and Rape/Mustard crops. Rewari and Fatehabad, two districts, have observed three crop combinations from 2000-01 onwards, and there have been no changes till 2014-15. Rewari (Wheat, Rape/Mustard, and Bajra) and Fatehabad (Wheat, Cotton, and Rice) are the dominant crops in their entire period. Gurugram district, with a diversified cropping pattern (five or more than five crop combination regions), has shown significant shifts from 1980-81 to 2010-11. Gurugram district has shifted to a bi-crop system of Wheat and Bajra after 2000-10.

Table: 4 Classifications of Districts by Crop Specialization (1980-81 to 2014-15)

Years	Crop Combination	Districts
1980-81	2	Kurukshetra and Karnal
	3	Nil
	4	Bhiwani and Sirsa
	5	Ambala, Sonipat, Rohtak, Jind, Faridabad, Gurugram, Mahendragarh and Hissar
1990-91	2	Kurukshetra, Karnal, Panipat, and Kaithal
	3	Yamunanagar
	4	Mahendragarh, Rewari, Bhiwani and Sirsa
	5	Ambala, Sonipat, Rohtak, Jind, Faridabad, Gurugram and Hissar
2000-01	2	Ambala, Kurukshetra, Karnal, Panipat, Sonipat and Kaithal
	3	Yamunanagar, Panchkula, Mahendragarh, Rewari and Fatehabad
	4	Jind and Sirsa
	5	Rohtak, Jhajjar, Faridabad, Gurugram, Bhiwani and Hissar
2010-11	2	Ambala, Kurukshetra, Karnal, Panipat, Sonipat, Kaithal and Gurugram
	3	Yamunanagar, Panchkula, Mahendragarh, Rewari and Fatehabad
	4	Jind, Bhiwani and Sirsa
	5	Rohtak, Jhajjar, Faridabad, Palwal, Nuh and Hissar
2014-15	2	Ambala, Kurukshetra, Karnal, Panipat, Sonipat, Kaithal and Gurugram
	3	Yamunanagar, Panchkula, Jind, Mahendragarh, Rewari and Fatehabad
	4	Sirsa
	5	Rohtak, Jhajjar, Faridabad, Palwal, Nuh, Bhiwani and Hissar

Source: Computed from Table 3

The status of crop specialization is also studied at the district level (Table 5). Such differentials can be attributed to the improvements in the technologies of different crops and inter-regional

variations in the agro-infrastructure of other regions. At the district level, there is an increase in crop specialization in eleven districts of the state. The number of essential crops in nine districts, according to their acreage, has remained constant during the entire study period. These districts (Kurukshetra, Karnal, Yamunanagar, Panipat, Panchkula, and Kaithal) cover mainly the part of the northern and central zones, where the Wheat and Rice crop combination was registered and remained constant in the entire study period, which shows the massive pressure on groundwater resources. The districts with a high degree of specialization are Ambala, Sonipat, and Jind, where five or more than five crop regions have specialized in a Wheat-Rice crop cycle. In the case of Rohtak, Faridabad, Palwal, Hissar, and Sirsa, the combination of crops has changed, but the number of crops has remained constant. The number of important crops in the Bhiwani district has decreased according to their acreage.

Table: 5 Classifications of Districts by Status of Crop Specialization (1980-81 to 2014-15)

Increased Specialization	Remained Constant	Decreased Specialization
Ambala (3)	Kurukshetra	Bhiwani (1)
Sonipat (3)	Karnal	
Jind (2)	Yamunanagar	
Gurugram (3)	Panipat	
Mahendragarh (2)	Panchkula	
Rewari (1)	Kaithal	
Rohtak (1)	Jhajjar	
Faridabad (1)	Nuh	
Palwal (1)	Fatehabad	
Hissar (1)		
Sirsa (1)		

Note: According to Weaver's method, the figures in parentheses indicate the increase/decrease in the number of crops in the critical combination of specialization (diversification). In the case of Rohtak, Faridabad, Palwal, Hissar, and Sirsa, the combination of crops has changed, but the number of crops has remained constant.

As discussed above, the Northern districts of the Haryana state are undergoing specialization whereby maximum districts have become a dominant Rice-Wheat crop region, facilitated by increasing irrigation, particularly tubewell irrigation, where groundwater exploitation is likely to be associated phenomena. Four districts of the state, i.e., Karnal, Kurukshetra, Kaithal, and Panipat, have shown a Rice-Wheat crop cycle from 1980-81 and 1990-91 onwards, and there have been no shifts till 2014-15. The spatial analysis of the area under Rice-Wheat cultivation and groundwater depletion reiterates the same finding. Figures 3 and 4 depict the comparative

International Journal of Research in Social Sciences
Vol. 8 Issue 5, May 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gate as well as in Cabell's Directories of Publishing Opportunities, U.S.A

situation of crop combination regions and groundwater exploitation at the district level, demonstrating a spatial correspondence of these two phenomena. The districts (Kurukshetra, Kaithal, Karnal, Panipat, and Fatehabad) with a wheat-rice combination are the ones that have been exploited beyond 80 percent of their respective groundwater potential. It may be observed that Yamunanagar and Jind, which have a three-crop combination with Rice as the second crop, do not show such high levels of groundwater exploitation.

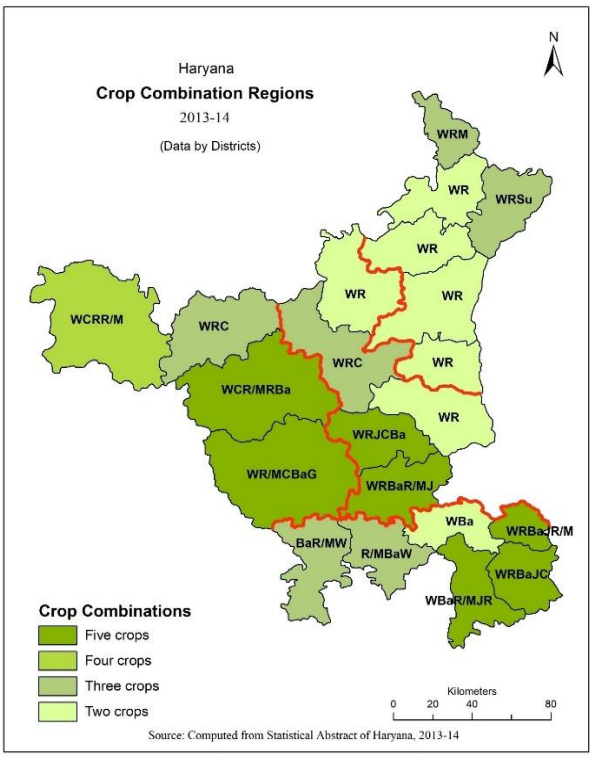

Fig. 3

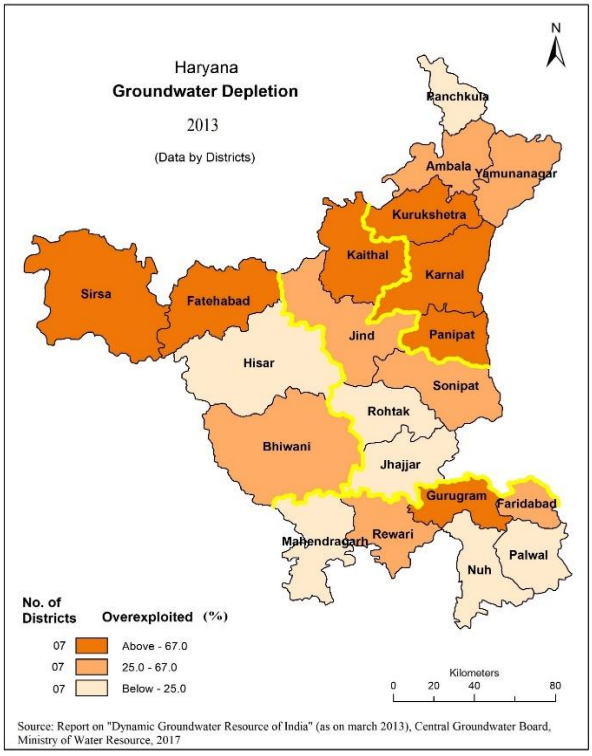

Fig. 4

"The accelerated pace at which the groundwater resources have been exhausted, without replenishment, has thrown the most valuable ingredient of the modern agricultural system out of gear. Tubewell irrigation acted as the most decisive harbinger of the Green Revolution. Technology was largely responsible for introducing new crops and reshaping existing crop combinations and was the most domineering instrument in pushing up cropping intensity. It is now inflicting technological and commercial infirmities, not only on the small and marginal farmers but also on the medium and large farmers. The depletion of groundwater resources now stands among the most serious concerns for irrigation availability, agricultural productivity, cost of production and efficiency, income distribution, and the total edifice of agriculture in many parts of the Indian economy" (Bhalla, 2007; Anil, 2016). As a result, all farmers in an area may be

forced to upgrade their pumps or abandon tubewell irrigation. The supply of free and highly subsidized electricity for agricultural use further encourages the process. Given human nature, anything supplied free and at a highly subsidized charge is likely to be misused. In such a scenario, if all farmers switch to submersible pumps, which are much more energy-intensive than centrifugal pumps, the groundwater exploitation rate will be intensified further.

Over-exploitation has two significant consequences: an increase in pumping depths, a reduction in tubewell yields, a rise in the cost of pumping groundwater, and a "widespread and acute scarcity of groundwater in summer months for irrigation and drinking uses" (Jeet, 1999; Maggirwar, 2002). In such cases of groundwater depletion, the cost of cultivation increases, leading to declining profitability. On the other hand, the rising economic cost of scarce resources leads to widespread inequity in the use and accessibility of these common property resources (Dhawan, 1995). On both counts stated above, sustainability suffers. With over-exploitation, the physical availability of water declines, and due to an increase in pumping depths, it raises serious consequences for the economic accessibility of groundwater to various sections of society. While depletion of groundwater endangers ecological sustainability, creating intra-generational inequity to the accessibility of groundwater, the rising costs of extracting the resource endangers economic sustainability, creating inter-generational inequity to accessibility to this precious resource.

4. Major Findings

- **Spatial Patterns of Groundwater Depletion:** Haryana's northern and central parts face more severe groundwater depletion due to extensive rice cultivation and insufficient surface water for irrigation. Areas with higher groundwater levels are generally found in regions that rely on a mix of rain-fed and groundwater-irrigated crops.
- **Impact of Crop Combinations:** Areas with more rice cultivation tend to experience faster groundwater depletion. In contrast, regions with a diversified crop combination, including pulses, cotton, oilseeds, and less water-intensive crops, show low pressure on groundwater resources. Rice cultivation, especially in the Kharif season, is highly detrimental to groundwater resources. The practice of sowing rice early in the season to match the monsoon rains increases water usage, leading to further depletion.
- **Sustainability of Current Cropping Patterns:** The current crop combination, especially the rice-wheat rotation, is not sustainable in the long term due to the heavy reliance on

groundwater for irrigation. The state's agricultural policies and support systems must encourage water-efficient cropping and sustainable farming practices.

5. Conclusion and Recommendations

Haryana, being one of India's most agriculturally productive states, has heavily relied on crop combinations and groundwater for its farming practices. While crop combinations have enabled farmers to maximize land productivity, ensure diverse income sources, and manage soil health better, they come with inherent challenges. The state's dependence on water-intensive crops, particularly in the wheat-rice cycle, places significant pressure on groundwater resources, leading to over-exploitation and declining water tables. The critical issue of groundwater exploitation in Haryana has emerged as one of the state's most pressing concerns for sustainable agriculture. Over-extraction of groundwater for irrigation and the promotion of high-water-consuming crops have resulted in a sharp drop in water tables, especially in regions that rely heavily on tube wells for irrigation. This, in turn, threatens the long-term viability of farming in Haryana, leading to both environmental and economic instability. Despite the benefits of crop combinations, such as increased productivity, soil fertility management, and better resource utilization, the sustainability of such practices is at risk without addressing the water crisis. Therefore, there is a need for agricultural diversification towards water-efficient crops, more sustainable irrigation techniques like drip and sprinkler systems, and recharge measures for groundwater aquifers. Additionally, supporting farmers with modern farming techniques, better access to water-efficient technologies, and alternative cropping patterns can significantly reduce dependence on over-exploited groundwater resources. A holistic approach is required in Haryana to balance crop combinations and groundwater use. This approach should include promoting sustainable agricultural practices, government policy reforms, and investment in water conservation efforts to ensure that agricultural productivity and water resources are maintained for future generations. Without such measures, Haryana's agrarian sector may face severe consequences, threatening its economy and millions of farmers' livelihoods.

References

- Anil. (2016). Trend and Pattern of Major Crops in Haryana: A Geographical Analysis. *International Journal of All Research Education and Scientific Methods (IJARESM).* 4(7), 1-6.
- Bhalla, P. (2007), Impact of Declining Groundwater Levels on Acreage Allocation in Haryana. *Economic and Political Weekly*, 2701-2707.
- Dhawan, B. D. (1995). Magnitude of Groundwater Exploitation. *Economic and Political Weekly*, 769-775.
- Gautam, A. (2012). *Agricultural Geography*. Sharda Pustak Bhawan, Allahabad.
- Husain, M. (1972). Crop Combination Regions of Uttar Pradesh: A Study in Methodology. *Geographical Review of India*, 34, 134-156.
- Husain, M. (1996). *Systematic Agricultural Geography*. Rawat Publication. Jaipur.
- Jeet, I. (1999). Factor Analysis to Identify Variables Responsible for Groundwater Depletion in Eastern Haryana. *Geographical Review of India*, 61(2), 132-144.
- Kumar, S. (2017). Crop Combination Regions of Jagadhari Block of Yamunanagar District of Haryana. *Remarking an Analisation*, 2(4), 118-121.
- Maggirwar, B. C. (2002). *Over-exploitation: A Critical Groundwater Problem. 28th WEDC Conference*, Kolkata, India.
- NityaNand. (1972). Crop Combination in Rajasthan. *Geographical Review of India*, 34(1), 46-60.
- Ramasundaram, M. (2012). A Study on Crop Combination Regions in Tamil Nadu, India Using MapInfo and GIS. *International Journal of Advances in Remote Sensing and GIS*, 1(1), 1-8.
- Singh, D. K., & Singh, A. K. (2002). Groundwater Situation in India: Problems and Perspectives. *Water Resources Development*, 18(4), 563-580.
- Weaver, J. C. (1954). Crop Combination Regions in the Middle West. *Geographical Review*, 44(2), 175-200.