International Journal of Aquatic Science
ISSN: 2008-8019
Vol 12, Issue 03, 2021

Groundwater Depletion And Agriculture Profitability In Haryana: A Case Study Of Karnal District

Ravinder Gautam[1], Prof. (Dr.) Binu Sangwan[2]

[1]*Ph.D. Research Scholar, Department of Geography, M. D. University, Rohtak, Haryana, India*
[2]*Professor, Department of Geography, M. D. University, Rohtak, Haryana, India*

E-mail: [1]ravinder.gautam.mdu@gmail.com, [2]Binusangwan1@gmail.com

Abstract: Purpose – To study the consequence of depleting groundwater resources on the cost of cultivation and to study the comparative analysis of the profitability of rice-wheat cultivation in different irrigation systems.
Design/methodology/approach – The data are collected by simple random sampling method from 300 sample farming households, drawn from three villages of Karnal district are analyzed and presented in this paper.
Findings – The data indicated that the maximum cost is incurred by rice crops than wheat crops in all irrigation systems. The main reason for this comparative difference in Cost of cultivation is basically due to the higher hired average cost of irrigation. It is noticed here that the cost of hired irrigation is increasing with groundwater depletion. Rice and wheat crop productivity has stabilized, and farm incomes are reported to be stagnant and insufficient for a decent living. It is noticed here that the proportion of fertilizers, insecticides, and hired laborers applications are decreased with groundwater depletion, but the proportion of tubewell irrigation applications are increased with groundwater depletion for both crops rice and wheat. It is observed that the canal-dependent irrigation system has performed better net returns as compared to the overexploited groundwater irrigation system.
Social implications – The rise in the cost of cultivation and the decline in farmers' net income are significant issues confronting present-day agriculture in Haryana. Degradation of land and depletion of water resources has led to rising discontent among the farming community due to their failure to get aspired farm incomes. The gap in income between small and large farmers is increased day by day. The resource-poor (small) farmers are exploited by resource-rich (large) farmers.
Originality/value – This is the first paper to study the agriculture profitability across rice-wheat cultivation in Haryana state (Karnal district) across different irrigation systems.

Keywords – Groundwater-Depletion, Agriculture Profitability, Irrigation Systems, Rice-Wheat.
Paper type – Research paper

1. INTRODUCTION

The rise in the cost of cultivation and the decline in farmers' net income are significant issues confronting present-day agriculture in Haryana. The main problem of increasing cost was seen as declining input use efficiency in agriculture. The increase in the cost of cultivation is mainly due to over-mechanization, labor, irrigation costs, green revolution inputs like fertilizers, seeds, pesticides, etc. For example, the number of tubewells (electric and diesel) has increased by more than 300 percent during the period 1974-75 to 2012-13, while the density per thousand hectares during the same period has increased from 46 to 170 (Kasana and Singh, 2017). The irrigation charges per hectare have increased from Rs. 109.60 to Rs. 1,906.19, and the cost of seeds per hectare, have also increased from Rs. 96.74 to Rs. 1,013.50 from 1970-71 to 2004-05. On the other hand, the fertilizer charges per hectare have increased from Rs. 111.09 to Rs. 2,396.26, and the cost of insecticides per hectare, has also increased from less than Rs. 1.00 to Rs. 802.79 in the corresponding period (Raghavan, 2008). In the context of all these observations, it is a matter of interest to analyze the costs and returns to agriculture for different irrigation systems, across significant crops.

2. OBJECTIVES

1. To study the consequence of depleting groundwater resources on the cost of cultivation.
2. To study the comparative analysis of profitability of rice-wheat cultivation in different irrigation systems.

3. STUDY AREA

The present study figure 1 is basically about the state of Haryana and specifically the Karnal district.

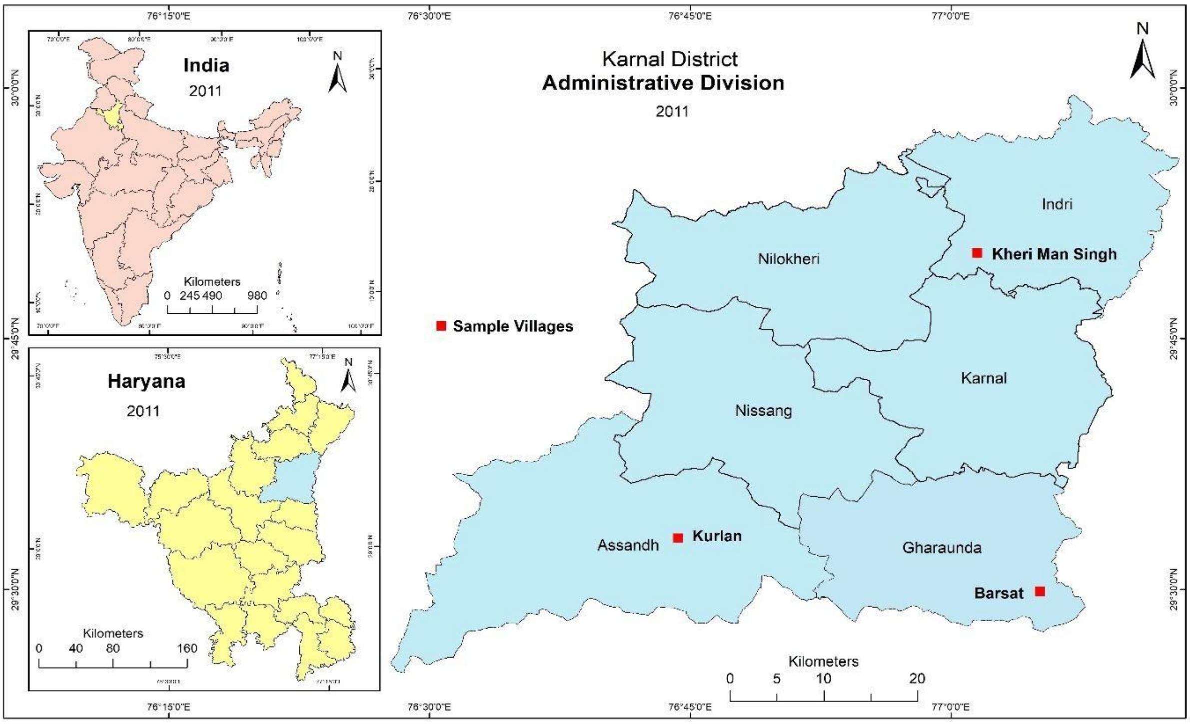


Fig. 1: Location Map of the Study Area

Karnal district lies between 29˚ 25' 05" to 29˚ 59' 20" North Latitudes and 76˚ 27' 40" to 77˚ 13' 08" East Longitudes, on the western bank of the Yamuna River, which forms its Eastern boundary and separates Haryana state from Uttar Pradesh. It falls in parts of Survey of India Toposheets Nos. 53C and 53G and the total geographical area of the Karnal district is 2,520 square kilometers, i.e., 5.69 percent of the state area.
Karnal district is mainly an agricultural-based district with the majority of its population living in rural areas. Agriculture is the single largest source of occupation and livelihood to the population. Kharif and Rabi are the two predominant crop harvests in a year. The principal Kharif crops are Rice, Cotton, Sugarcane, and Maize, and the Rabi crops are Wheat and Barley. Karnal district is a two-crop combination region with Rice-Wheat as the dominant cropping pattern.

4. DATA BASE AND RESEARCH METHODOLOGY

The present study is primarily based on primary data. Three villages, namely Kheri Man Singh, a mixed irrigated village selected from Indri block (safe zone), Barsat, a tubewell irrigated village selected from Gharaunda block (over-exploited condition) and Kurlan, a tubewell irrigated village with problems of groundwater depletion selected from Assandh block (highly over-exploited condition) are surveyed and selected by Purposive Sampling Method. These villages are also having the highest percentage of gross cropped area under irrigation.
The 300 households are selected by the Simple Random Sampling method. Primary survey collection methods such as questionnaires, interviews, and focus group discussions are used for data collection. The primary surveyed data has been classified into four categories on the basis of different types of substrata of landholding size i.e. marginal (less than two acres), small (two-four acres), medium (four-ten acres), and large (more than ten acres) households from three villages, 100 households from each village.

Table 1: Selection of sample villages

Villages	**Basis for selection**
Kheri Man Singh	“Mixed irrigation system (approximately 38 percent irrigated by canal and 62 percent by tubewells). The average depth of water-table is 70 feet and faces least problem of groundwater depletion both because of conjunctive irrigation and also because farmers who do not have tubewells resort to canals for irrigation or exchange water in lieu of farm labour or cash.”
Barsat	“Tubewell irrigation system (100 percent irrigated by tubewells). The average depth of water-table is 90 feet and faces lesser problems of groundwater depletion.”
Kurlan	“Tubewell irrigation system (100 percent irrigated by tubewells). The average depth of water-table is 150 feet and faces severe constraints to agricultural production due to groundwater depletion as many tubewells have dried up.”

Table 2: Profile of sample villages

Geographical Characteristics			
Name of Village	**Kheri Man Singh** (Mixed Irrigation Village)	**Barsat** (Tubewell Irrigation Village)	**Kurlan** (Tubewell Irrigation Village With Problems of Groundwater Depletion)
Block	Indri	Gharaunda	Assandh
Geographical Area (Hectare)	647	1202	1738
Slope	Gentle	Gentle	Gentle
Prevalent Soil Type	Alluvial	Alluvial	Alluvial
Demographic and Social Characteristics			
Total Number of Households	560	2057	779
Population of Village	3050	10815	4072
Male Population of the Village	1598	5677	2164
Female Population of the Village	1452	5138	1908
Literacy Rate	67.4	52	73.05
Agricultural Characteristics			
Type of Irrigation	Mixed	Groundwater	Groundwater
Cultivated Area (NSA)	491.1	926.3	539.2
Gross Cropped Area (GCA)	1019.7	1811.6	1065.6
Cropping Intensity (Percentage)	207.6	195.6	197.6
Sources of Irrigation	Canals & Tubewells	Tubewells	Tubewells
Irrigated Area by Source (In Percent)	Canal - 38 % Tubewell - 62 %	Tubewells – 100 %	Tubewells – 100 %
Average Depth of Watertable Below	70 Feet	90 Feet	150 Feet

Relative Profitability of Agriculture across Different Irrigation Systems

An irrigation system appropriates the valuable water resources and allocates them according to a certain quantity and timings. There are several alternatives to develop irrigated agriculture using a variety of sources of irrigation. All the different irrigation systems are constrained by some other limiting resources that decide their effectiveness and economic returns. Before deciding which irrigation source is sustainable and profitable, it is essential to make an economic analysis of various irrigation systems. The empirical study of the Haryana state's irrigation development reiterates that the state is undergoing a significant shift in irrigation sources' composition. While canal irrigation has declined over the years, tubewell irrigation is distinctively on the rise. The farmers have shifted to tubewell irrigation because tubewell irrigated systems enjoy an assured and stable water supply quality, leading to high and stable yields. On the other hand, "canal irrigated areas, particularly in semi-arid regions like Haryana, are generally associated with fluctuations in yield due to uncertain water supply, which is particularly acute in the tail-reach of the canal irrigated areas." Coupled with the structural change in the irrigation system, a shift towards a water-intensive cropping system has also taken place in the state, leading to groundwater depletion, causing primary concern in its agricultural development. Groundwater mining has reached such an alarming level that it threatens the state's tubewell irrigation systems' future sustainability. The literature on efficiency and sustainability of tubewell irrigation system reiterates the fact that the pioneer phase of groundwater development in Haryana is almost over as the groundwater balance in the state is becoming precarious with time, risings doubts about the technological, economic, social, and ecological sustainability of the tubewell irrigation system. Thus, we contend that tubewell irrigated systems that have been exploited beyond the sustainable limit are expected to experience an increase in yield uncertainties, slowing down production, increased cost of cultivation, and declining net returns. There is an indication that the private cost of installing tubewell and its operation and maintenance is substantially lower than marginal returns to irrigation. In a mixed irrigation system, the conjunctive use of canal water and private tubewells reduces groundwater irrigation pressure by recharging the groundwater. It makes the system cost-efficient and sustainable in the long run, and it also provides more significant equity among farmers by providing an alternative water source for farmers who do not have private sources of irrigation or no longer can afford tubewell irrigation (Shah, 1991). In light of the above discussions, the study seeks to analyze the comparative performances of the primary sources of irrigation in Haryana's state and capture the relative agricultural profitability of the different irrigation systems in the face of depleting groundwater situations. Three different irrigation systems have been selected, which represent a different stage of groundwater development. The main objective is to compare the economic efficiency of different irrigation systems operating under various degrees of water supply flexibility and reliability by analyzing the cost of cultivation, input use pattern, yield, gross output, and net returns. Kheri Man Singh is a village with a mixed irrigation system with conjunctive use of surface and groundwater. Both Barsat and Kurlan have tubewell irrigation systems with complete dependence on groundwater, where the former exhibits comparatively higher groundwater levels and faces fewer problems of groundwater depletion, and the latter experienced problems of groundwater depletion and faces scarcity of groundwater due to excessive groundwater mining with the steady decline in groundwater table each year.

5. RESULTS AND DISCUSSION

Comparative Analysis of Profitability of Rice-Wheat Cultivation in Different Irrigation Systems

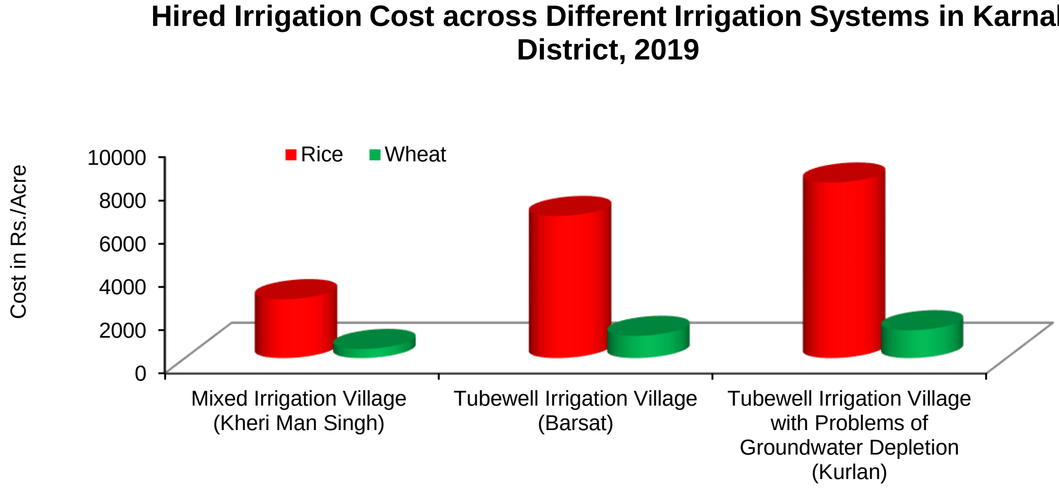
In this section, the cost of cultivation and net returns to agriculture is compared across different irrigation systems, emphasizing the two dominant crops, i.e., Rice and Wheat, separately. The cost of cultivation of these two crops is calculated based on adding all actual expenses in cash and kind incurred in production by the owner, which includes the cost of seeds, irrigation, fertilizer and micronutrient, insecticides, weedicides, and pesticides, labor, and rent of leased inland (Table 3). Where, "Cost A1 = all actual expenses in cash and kind incurred in production by owner, Cost A2 = Cost A1+ rent paid for leased inland and, Cost A2=RCDsl = Cost A2+ imputed cost of tubewell irrigation if all pumps were run by diesel." The Irrigation cost includes the cost of Canal Irrigation, Tubewell Irrigation, in which pump set run by electricity (electricity bill), and Hired Irrigation cost, set by own will of water buyers in water markets.

Table 3: Cost of Cultivation of Rice and Wheat across Different Irrigation Systems in Karnal District, 2019

Particulars	Mixed Irrigation Village (Kheri Man Singh)	Tubewell Irrigation Village (Barsat)	Tubewell Irrigation Village with Problems of Groundwater Depletion (Kurlan)
Rice Crop			
Inputs			
Seeds (Rs./Acre)	899	898	954
Fertilizer and Micronutrient (Rs./ Acre)	1,989	2,093	1,981
Insecticides, Weedicides, and Pesticides (Rs./Acre)	2,056	1,812	1,776
Canal Irrigation Cost (Rs./Acre)	100	0	0
Tubewell Irrigation (Rs./Acre)	110	191	243
Hired Irrigation Cost (Rs./Acre)	2,720	6,570	8,120
Hired Labour (Rs./Acre)	9,411	9,709	9,378
Land Rent (Rs./Acre)	23,260	21,944	20,115
The imputed cost of Tubewell Irrigation if all pumps were run by Diesel (RCDsl)	15,912	17,055	20,802
Cost of Cultivation (Rs./Acre)			
Cost A1	17,285	21,273	22,452
Cost A2	40,545	43,217	42,567
Cost A2+RCDsl	56,457	60,270	63,369
Wheat Crop			
Inputs			
Seed (Rs./Acre)	1,310	1,295	1,306
Fertilizer and Micronutrient (Rs./Acre)	1,950	1,956	1,892
Insecticides, Weedicides, and Pesticides (Rs./Acre)	1,034	1,095	1,183
Canal Irrigation Cost (Rs./Acre)	70	0	0
Tubewell Irrigation Cost (Rs./Acre)	16	28	36
Hired Irrigation Cost (Rs./Acre)	420	1,026	1,285
Hired Labour (Rs./Acre)	6,212	6,486	6,130
Land Rent (Rs./Acre)	17,220	15,056	16,125
The imputed cost of Tubewell Irrigation if all pumps were run by Diesel (RCDsl)	2,368	2,563	3,039
Cost of Cultivation (Rs./Acre)			
Cost A1	11,012	11,886	11,832
Cost A2	28,232	26,942	27,957
Cost A2+RCDsl	30,600	29,505	30,996

Source: Questionnaire Surveys in Various Villages from May to September 2019Note:
Note: Cost A1= All actual expenses in cash and kind incurred in production by owner
Cost A2= Cost A1+Rent paid for leased inland
Cost A2+RCDsl= Cost A2+ imputed cost of tubewell irrigation if all pumps were runby Diesel

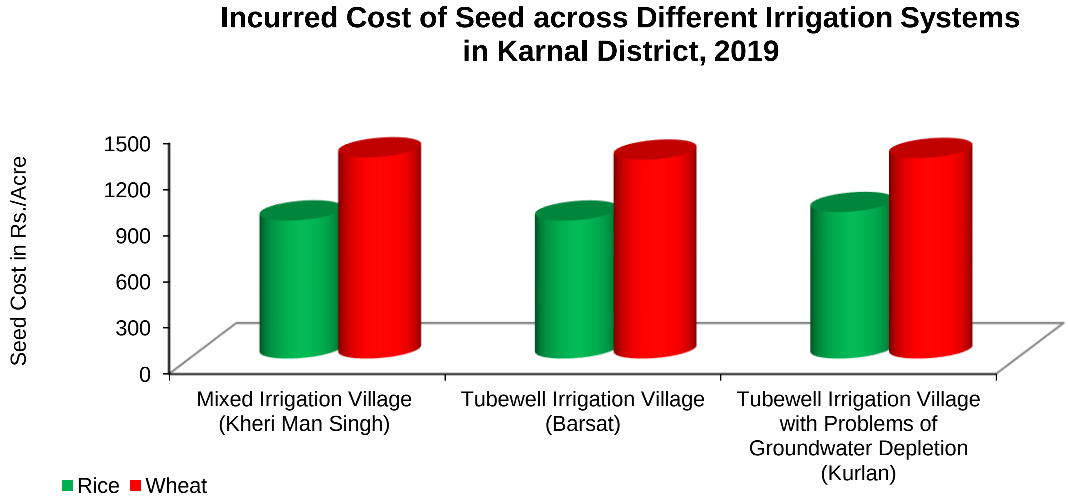
The cost of cultivation (**Cost A1)** for rice crops is highest in the Kurlan village, about Rs. 22,452.00 and it is followed by Barsat village about Rs. 21,273.00 and it is lowest in Kheri Man Singh village about Rs. 17,285.00. The main reason for this comparative difference in Cost A1 is basically due to the higher hired average cost of irrigation in Kurlan village, as many farmers in Kurlan village resort to buying irrigation water to irrigate the paddy fields, especially when they do not have a tubewell or have fragmented landholdings. It is noticed here that the cost of hired irrigation is increasing with the groundwater depletion; thus, the cost of hired irrigation is a minimum of about Rs. 2,720.00 in the mixed irrigation systems of Kheri Man Singh village and the maximum in the groundwater depleted village of Kurlan about Rs. 8,120.00 (Figure 2).



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig.2

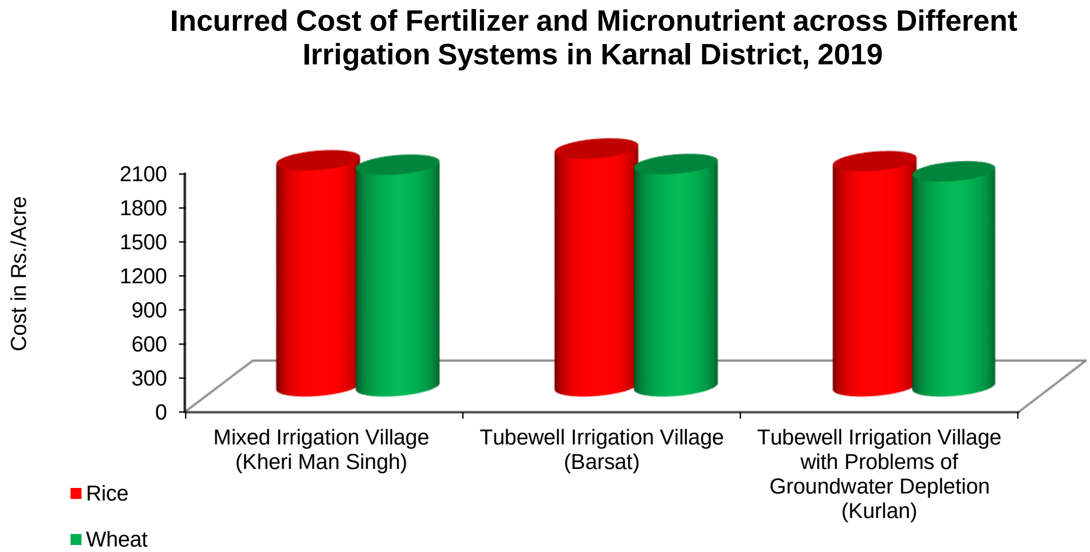
Due to groundwater depletion in this irrigation system, wateris scarce, which has increased the private or hired cost of irrigation. In the other two irrigation systems (Kheri Man Singh and Barsat village) in Kheri Man Singh village, the farmers have less need for buying water for irrigation purposes because they have an alternative of canal water for irrigation when they have additional needs of water for irrigation.



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 3

In Barsat village, the maximum area is cultivated by the large farmers, and they have also owned tubewell, which is sufficient for irrigation, so they have no need for buying water for irrigationpurposes. In Barsat village, the marginal and small farmers are totally dependent on hired irrigation, so they have spent much money, about Rs. 6,480.00 and Rs. 6,642.00 respectively for rice cultivation. As a result of this discrepancy, the higher average private or hired cost of irrigation is borne by the farmers in Kurlan village about Rs. 8,120.00 and it is followed by Barsat about Rs. 6,570.00 and it is lowest in Kheri Man Singh village about Rs. 2,720.00. The most significant investment is on hired labor, followed by fertilizer, insecticides, and seeds, among all the inputs. A change in work culture has taken place in Haryana, where the farmers have stopped doing manual farm work and have become dependent on migrant labor, contributing to a rise in the cost of cultivation. It is also noticed that 100 percent of the households surveyed used migrant labor for transplanting rice seedlings and harvesting applications. Most of the fertilizer and pesticide application is also made by hired labor. About 90 percent of the households used migrant labor for spraying pesticides and insecticides. Thus, the greater the quantity of these inputs applied to the crops, the more will be the cost of these inputs, and the greater will be the hired labor charges. The wheat crop needs more significant investment for the seeds than the rice crop (Figure 3).

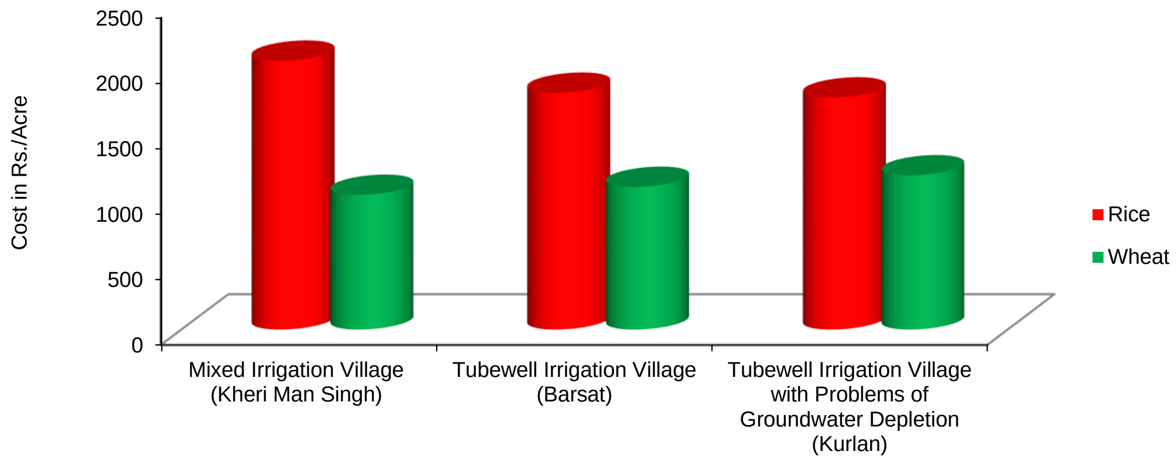


Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 4

Nevertheless, when the fertilizer and micronutrient costs are compared, the higher cost was incurred for rice crops than for wheat crops (Figure 4). Similarly, the cost incurred for insecticides, weedicides, pesticides (Figure 5), and labor is much higher in rice crops than wheat (Figure 6). If costs of various inputs are considered, the maximum cost is incurred on rice crop than on Wheat crop in all irrigation systems. For the same reason, the cost of the cultivation of ricecrops is much higher than that of wheat crops.

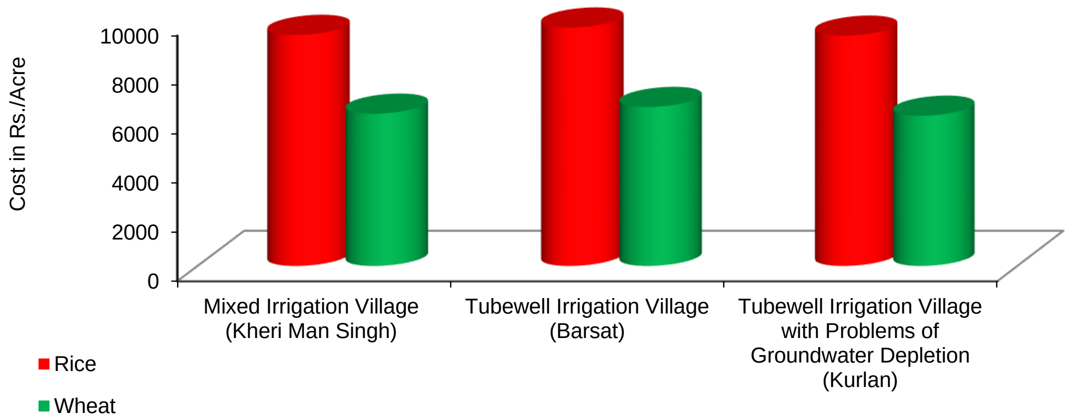
Incurred Cost of Insecticides, Weedicides and Pesticides across Different Irrigation Systems in Karnal District, 2019



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 5

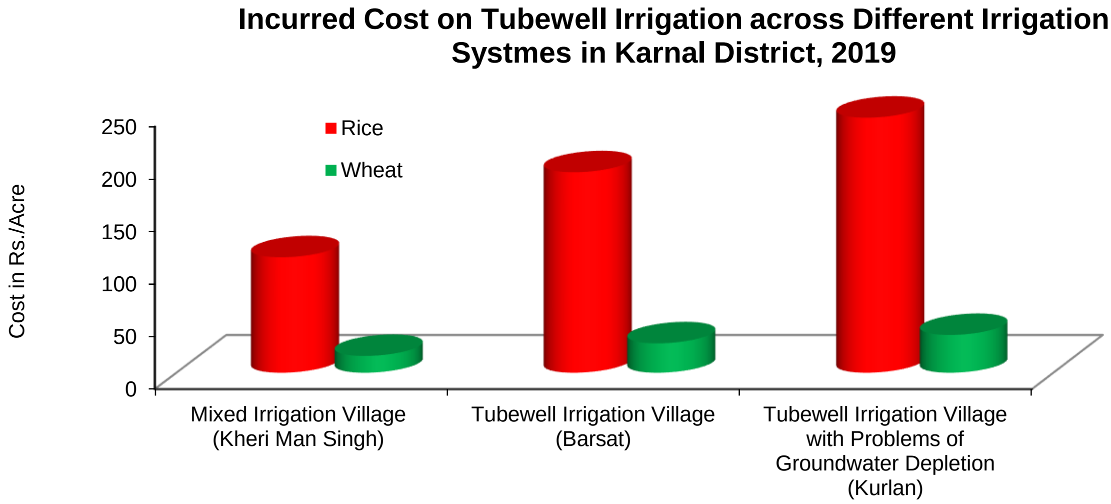
Hired Labour Cost across Different Irrigation Systems in Karnal District, 2019



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 6

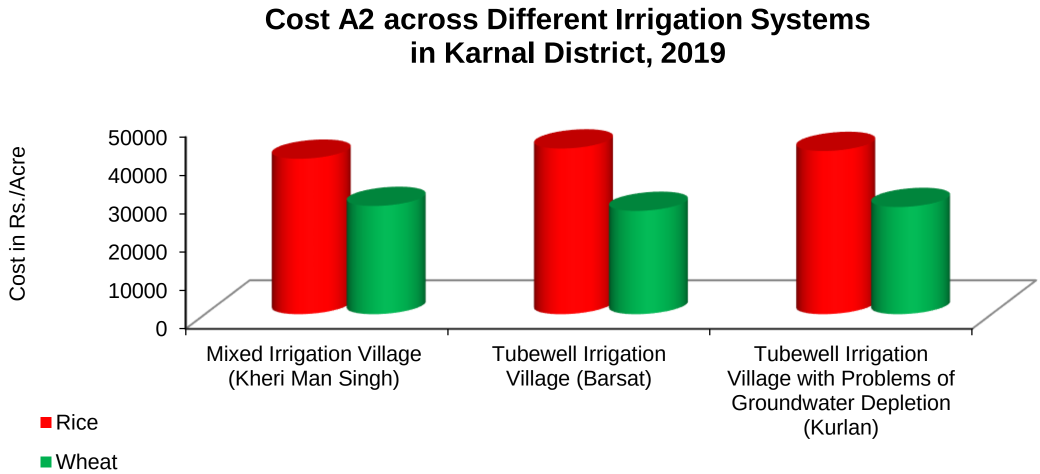
The costs incurred on different rice crop inputs show variability across different irrigation systems, which correspond to the quantity and quality of irrigation available. The tubewell irrigation system of Barsat village shows maximum input of fertilizer and micronutrients whose application is positively related to the number of irrigation. The input cost of insecticides, weedicides, and pesticides is comparatively higher in Kheri Man Singh village's mixed irrigation systems than in Barsat and Kurlan, indicating a higher production frontier for Kheri Man Singh for being economically more prosperous than the others. The cost of canal irrigation about Rs. 100.00 is incurred only by the mixed irrigation systems of Kheri Man Singh village for rice cultivation and Rs. 70 for wheat cultivation. There are no canal facilities in Barsat and Kurlan village; farmers of these villages are totally dependent on tubewell irrigation, so they incurred higher hired cost of tubewell irrigation as electricity bill than farmers of Kheri Man Singh village (Figure 7).



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 7

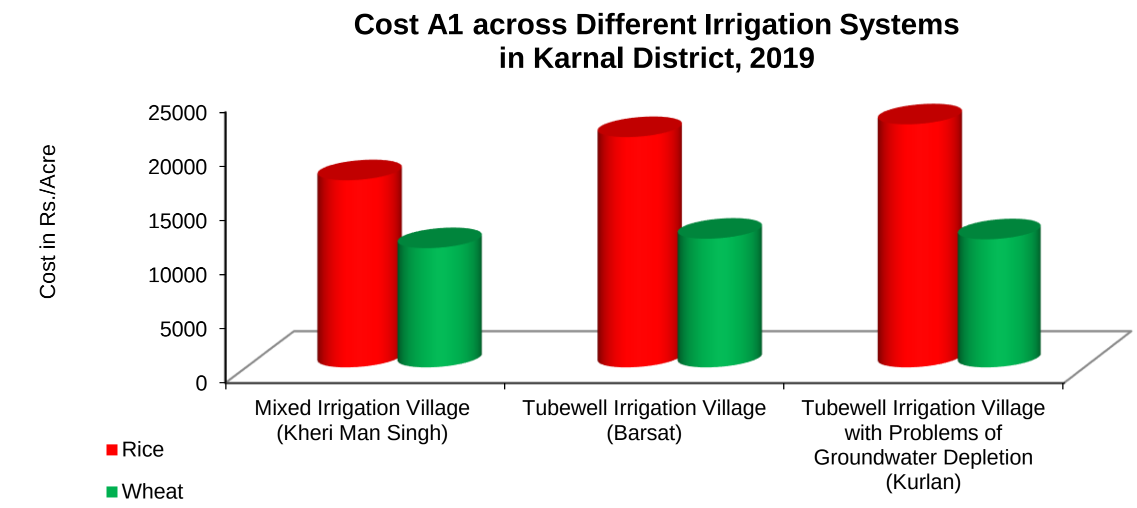
Figure 8 shows that for the rice crop, the **Cost A2** is highest in the tubewell irrigation systems of Barsat village, about Rs. 43,217.00 and Kurlan village Rs. 42,567.00, and it is followed by mixed irrigation systems of Kheri Man Singh village about Rs. 40,545.00, but the land lease rent is highest in the mixed irrigation system of Kheri Man Singh village. It is noticed here that the land lease rent is decreasing with the groundwater depletion and increasing with the better facilities of irrigation. The highest land leased rent cost is incurred by Kheri Man Singh village farmers, about Rs. 23,260 for rice crop and it is followed by Barsat village about Rs. 21,944.00 and it is lowest in Kurlan village at about Rs. 20,115.00. The cost of wheat cultivation across different irrigation systems shows different results with a meager difference.



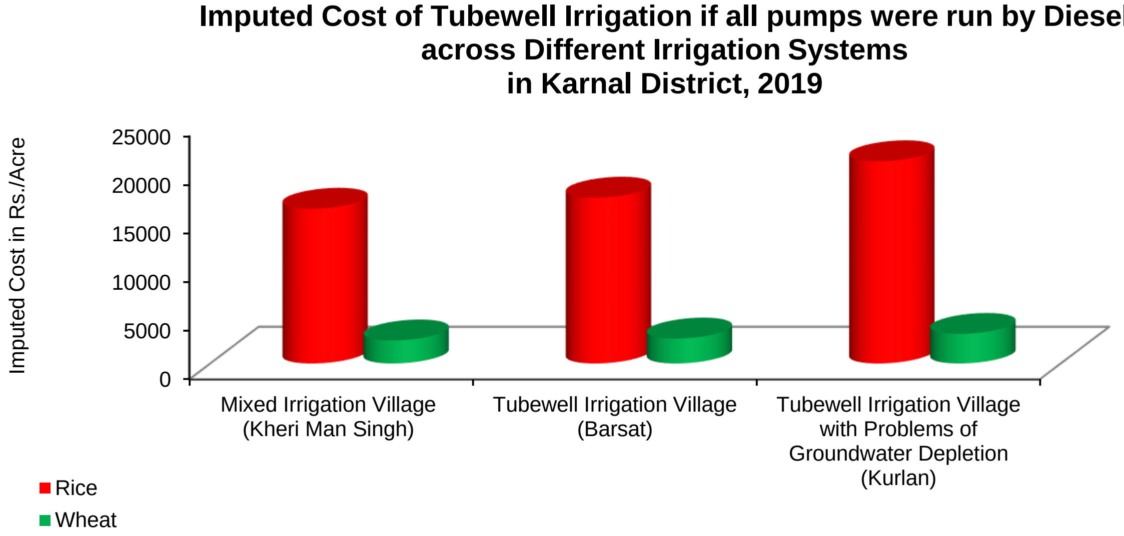
Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 8

Figure 9 shows that the cost of cultivation (Cost A1) is highest in Barsat village, about Rs. 11,886.00, and it is followed by Kurlan village about Rs. 11,832.00 and it is lowest in Kheri Man Singh village about Rs. 11,012.00. The differences inCost A1 are mainly because of the variations in hired irrigation and labor costs across different irrigation systems. It is noticed here that the cost of hired irrigation is increasingwith groundwater depletion. Thus, the cost of hired irrigation is the minimum in Kheri Man Singh village's mixed irrigation systems, about Rs. 420.00 and the maximum in the groundwater depleted village of Kurlan about Rs. 1,285.00. Wheat crop is given around three to four irrigations in their growing period depending on the number of winter rains. Thus, the hired irrigation cost variations in all the three irrigation systems of Kheri Man Singh, Barsat, and Kurlan village are not very high, as seen in the case of rice cultivation.



Source: Questionnaire Surveys in Various Villages from May to September 2019
Fig. 9



Source: Questionnaire Surveys in Various Villages from May to September 2019
Fig. 10

For the wheat crop, the Cost A2 is highest in Kheri Man Singh village's mixed irrigation systems, about Rs. 28,232.00 and it is followed by Kurlan village about Rs. 27,957.00 and it is lowest in Barsat village Rs. 26,942.00. It is noticed here that the pattern of the Cost A2 and the land leased rent cost is found the same across different irrigation systems. The highest land leased rent cost is incurred by Kheri Man Singh village farmers, about Rs. 17,220.00 and it is followed by Kurlan village about Rs. 16,125.00 and it is lowest in Barsat village at about Rs. 15,056.00. A comparative analysis of the imputed cost of diesel for rice and wheat crops across different irrigation systems brings to light; the cost incurred in rice irrigation is much higher in the tubewell irrigated village of Kurlan, about Rs. 20,802.00 and Barsat Rs. 17,055.00 than in the mixed irrigated village of Kheri Man Singh Rs. 15,912.00. The imputed cost of diesel in wheat cultivation also shows a similar trend with Kurlan, about Rs. 3,039.00, which incurred the highest diesel cost and is followed by Barsat village about Rs. 2,563.00 and it is lowest in Kheri Man Singh village about Rs. 2,368.00 (Figure 10). The comparatively low diesel cost in Kheri Man Singh village's mixed irrigation systems for rice and wheat crops is due to canal irrigation, which supplements groundwater irrigation. In reality, the farmers do not have any decent idea of how many irrigations they give to their rice cultivation. In low running cost of tubewells (Rs. 110.00 in mixed irrigation systems of Kheri Man Singh to tubewell irrigation with groundwater depletion of Kurlan village is Rs. 243.00), they continue to keep their motors open all day for the first one and half months of the crop when they have need irrigation. The government provides only six to eight hours of electricity with power cuts for agriculture to restrict the number of hours of irrigation; the farmers irrigated a maximum of six to eight hours per day for per irrigation. The irrigation is stopped only fifteen to twenty days before harvesting. The rest of the time, regular irrigation of three to four hours is provided every day for per irrigation. Considering these facts, one can approximately calculate the number of irrigation for rice at present in Haryana to be around 25 to 30 with the number of monsoon rains.

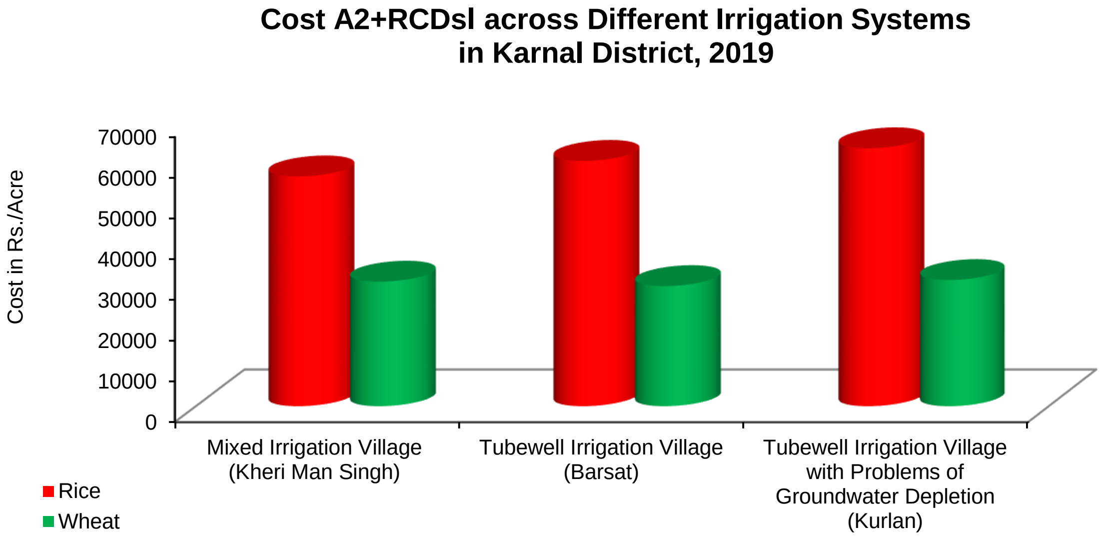
Table 4: Share of Input Cost in Cultivation of Rice and Wheat Crop across Different Irrigation Systems in Karnal District, 2019

(Percent to Cost A1)

Particulars (Inputs)	Mixed Irrigation Village (Kheri Man Singh)	Tubewell Irrigation Village (Barsat)	Tubewell Irrigation Village with Problems of Groundwater Depletion (Kurlan)
Rice Crop			
Seed	5.20	4.22	4.25
Fertilizer and Micronutrient	11.51	9.84	8.82
Insecticides, Weedicides, and Pesticides	11.89	8.52	7.91
Canal Irrigation Cost	0.58	0.00	0.00
Tubewell Irrigation	0.64	0.90	1.08
Hired Irrigation Cost	15.74	30.88	36.17
Hired Labour	54.45	45.64	41.77
Wheat Crop			
Seed	11.90	10.90	11.08
Fertilizer and Micronutrient	17.71	16.46	15.99
Insecticides, Weedicides, and Pesticides	9.39	9.21	10.00
Canal Irrigation Cost	0.64	0.00	0.00
Tubewell Irrigation Cost	0.15	0.24	0.30
Hired Irrigation Cost	3.81	8.63	10.86
Hired Labour	56.41	54.57	51.81

Source: Questionnaire Surveys in Various Villages from May to September 2019

Table 4 revealed the share of input cost in cultivation to the percentage of Cost A1 of rice and wheat crop across different irrigation systems. When the proportion of various costs incurred in the production of rice and wheat is calculated, it is seen that the highest percentage of cost is incurred for hired irrigation water about 36.17 percent in Kurlan village and it is followed by Barsat village about 30.88 percent and Kheri Man Singh village about 15.74 percent for rice crop. The farmers in Kurlan village pay this 36.17 percent in buying water on account of having dried tubewells because of groundwater depletion. This is the cost incurred by the farmers in Kurlan, Barsat, and Kheri Man Singh village for buying water from the groundwater market prevailing in the villages. In the Rabi season, the same villages' farmers incur only 10.86 percent, 8.63 percent, and 3.81 percent of the cost of buying water for the wheat crop. It is pertinent to note that, while the maximum cost is incurred in hired laborers, fertilizers, and insecticides in rice and wheat cultivation, rice is much higher than wheat on account of the additional cost incurred on irrigation water. It is noticed here that the proportion of fertilizers, insecticides, and hired laborers applications are decreased with the groundwater depletion, but the proportion of tubewell irrigation applications are increased with the groundwater depletion for both crops rice and wheat.

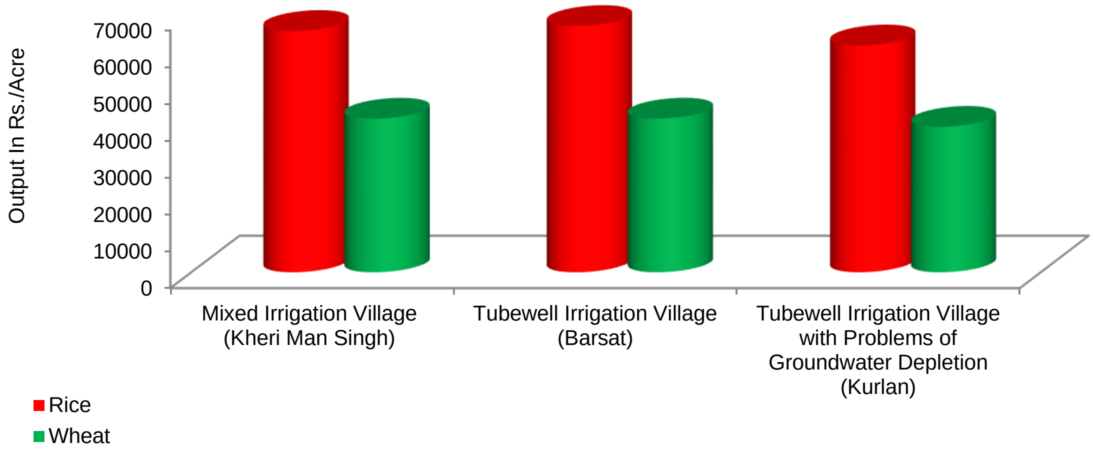


Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 11

The profitability of crop cultivation cannot be only assed by comparing the cost of inputs, yields, and gross outputs of the crops. The profitability can be captured by looking at the difference between the gross output and cost of inputs, called the net returns. The net returns of different crops depend on the cost of inputs made for its production, yield response to these inputs applied, the yield of individual crops, and farm harvest prices. Irrigation is a critical determinant influenced on the agricultural yield, so the yield for rice crop is seen to be the highest in the mixed irrigation systems of Kheri Man Singh village about 23 quintals per acre and it is followed by Barsat village about 22 quintals per acre, and it is lowest in Kurlan village about 20 quintals per acre. It is noticed here that the yield of rice crops is decreasing with the groundwater depletion and increasing with the better facilities of irrigation. The Gross Output for rice crop is seen to be the highest in the Barsat village at about Rs. 66,875.00, and it is followed by Kheri Man Singh village about Rs. 65,534.00 and it is lowest in Kurlan village at about Rs. 61,601.00 (Figure 12). While comparing the net returns over Cost A1 for the rice crop, it is seen that Kheri Man Singh has the highest net returns among the three irrigation systems selected for the study. The highest net returns over Cost A1 for rice crops have been recorded in Kheri Man Singh village, about Rs. 48,249.00 and it is followed by Barsat village about Rs. 45,602.00 and it is lowest in Kurlan village at about Rs. 39,149.00. The low net returns for rice in Kurlan are because of comparatively lower yields, high cost of cultivation as many farmers resort to buying water as either their tubewells have dried up or had low water yields. The net returns over Cost A1 to rice cultivation in the tubewell depleted irrigation system of Kurlan village is almost less than Rs. 9,100.00 to the mixed irrigated village of Kheri Man Singh (Figure 13).

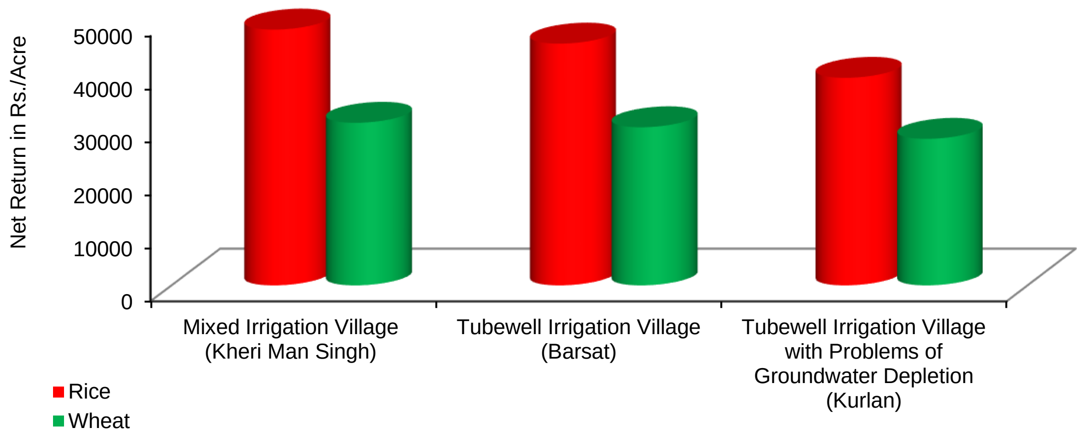
Gross Output across Different Irrigation Systems in Karnal District, 2019



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 12

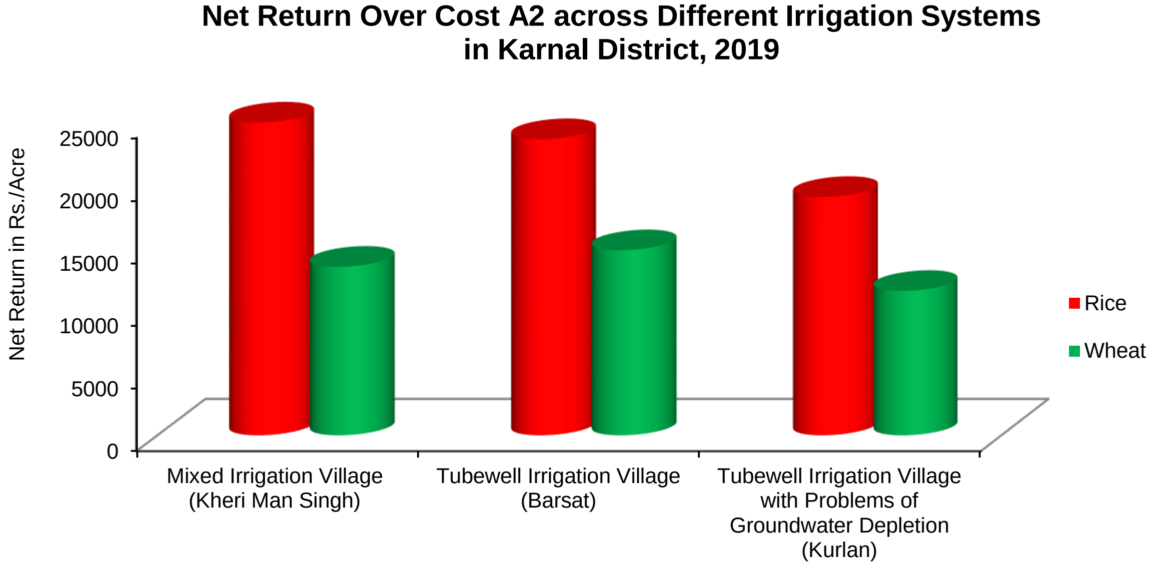
Net Return Over Cost A1 across Different Irrigation Systems in Karnal District, 2019



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 13

We can also state that with acute problems of groundwater depletion, a completely groundwater-dependent irrigation system becomes economically and technically less efficient, leading to low economic returns for a water-intensive crop like rice. These observations further strengthen the argument that under conditions of depletion, the so-called reliable and most productive tubewell irrigation system gives lower returns because falling groundwater tables reduce the tubewell irrigation systems'reliability and flexibility, making it superior to the other sources of irrigation. The net returns over Cost A1 for the wheat crop are seen to be highest in Kheri Man Singh village, about Rs. 30,668.00 and it is followed by Barsat Rs. 29,823.00 and Kurlan Rs. 27,640.00. The two groundwater-dependent irrigation systems' wheat crop's comparative returns show a lower net return in Kurlan village than in Barsat. It can be explained by the lower physical and economic efficiency of the agricultural system in Kurlan on account of falling groundwater levels (Figure 13). The net returns over Cost A2 for rice crops are seen to be the highest in the mixed irrigation systems of Kheri Man Singh village, about Rs. 24,989.00 and it is followed by Barsat village Rs. 23,658.00 and it is lowest in Kurlan village at about Rs. 19,034.00. It is interesting to note that the net returns over Cost A2 for rice crops are higher than wheat crop in all irrigation systems, and the difference between the net returns decreases with the groundwater depletion. The net returns over Cost A2 for the wheat crop are seen to be the highest in Barsat village, about Rs. 14,767.00, and it is followed by Kheri Man Singh Rs. 13,448.00 and it is lowest in Kurlan village at about Rs. 11,515.00 (Figure 14).

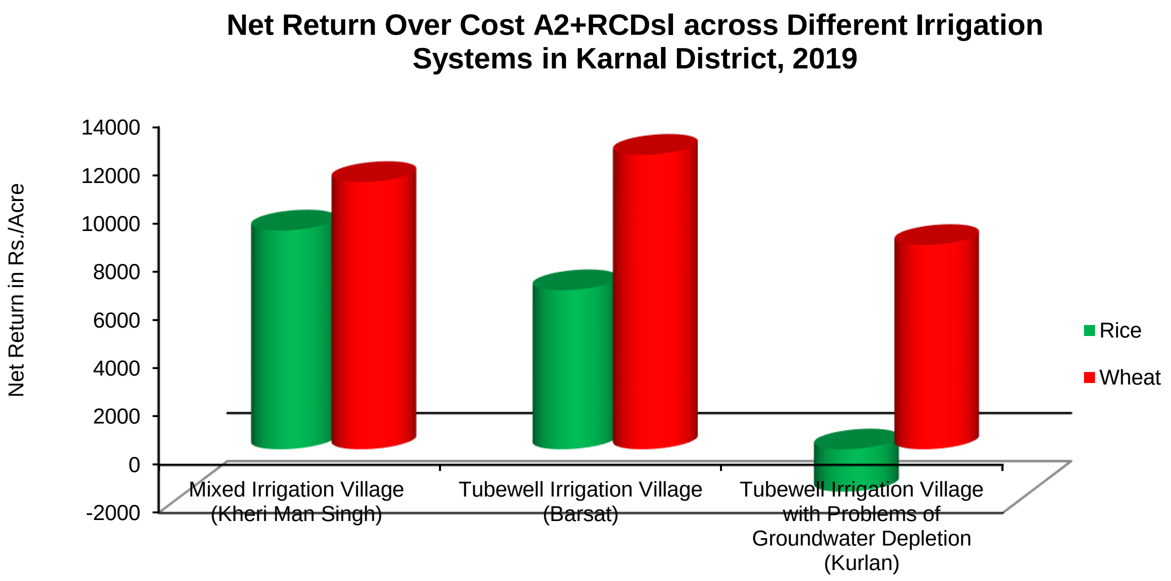


Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 14

The comparative returns over Cost A2 for wheat of the two groundwater-dependent irrigation systems show a lower net return in Kurlan than in Barsat. It can be explained by the lower physical and economic efficiency of the agricultural systems in Kurlan village on account of falling groundwater levels. In the earlier analysis, it has been concluded that the rice crop is economically much profitable only under massive government subsidy on electricity. Thus, it is essential to see the levels of profitability of rice crops in different irrigation systems with no subsidy on electricity and when the entire groundwater irrigation is dependent on diesel engines. Unlike flat electricity tariffs, the diesel prices are proportional to the amount of actual water pumped out for irrigation. The comparative net returns of the crops in the different irrigation systems lead to some critical conclusions.

Rice crops' economic profitability is much greater than wheat with the subsidy on electricity across all the irrigation systems. The highest net returns over Cost A1 and Cost A2 for rice crops are observed in Kheri Man Singh, followed by Barsat and Kurlan. Although their relative position remains the same, the differences in profit levels have come down in the mixed irrigation systems vis-a-vis tubewell irrigation system after considering the diesel cost in production cost (Figure 15). The difference in net returns over Cost A1, Cost A2, and Cost A2+RCDsl of the two groundwater-dependent agricultural systems show stark differences, with Barsat having much higher net returns of rice and wheat than Kurlan. Moreover, the net returns in Kurlan are also much lower than the mixed irrigated village of Kheri Man Singh. These empirical observations further reinforce our argument that water-intensive crops like rice are economically unsustainable in unsustainable tubewell irrigated systems with groundwater depletion problems. Instead, mixed irrigation on account of being simultaneously recharged through seepage is ecologically sustainable and economically more efficient.



Source: Questionnaire Surveys in Various Villages from May to September 2019

Fig. 15

Thus, if groundwater tables are uncontrollably brought down by unwarranted groundwater irrigation, its economic sustainability will be lost in the long run. In fact, in the face of groundwater depletion, the tubewell irrigation system's sustainability will depend on simultaneous recharge, which is only possible through seepage from canals and artificial recharge mechanisms. This implies that the development of canal irrigation is essential for the sustainability of tubewell irrigation systems, especially in semi-arid regions like Haryana. The conjunctive irrigation system's economic benefits are also noted in several studies (Reddy et al., 1989; Somnand et al., 1989). The mixed or conjunctive irrigation systems, where there is co-existence of canals along with tubewells, gives greater land productivity and is considered to be most sustainable as there is a possibility of simultaneous draft and recharge of the groundwater aquifer with the seepage of canal water. One of the consequences of the decline in the groundwater table is the reduction in tubewell discharge, which affects the command area of a tubewell and hence the cost of irrigation. The actual cost of groundwater is very low for the farmers' private cost of irrigation as they do pay a small amount of cash for the electricity used to operate tubewells, so their marginal cost of extracting groundwater is meager. Therefore, the private cost is unaffected while the social (hired irrigation) cost rises with progressive pumping. Nonetheless, the lower discharge rate affects the farm's overall irrigation efficiency with additional time to irrigate the same area. Thus, till the electricity subsidy is continued, the society will bear the burden of the additional cost of a decline in the water table.

6. CONCLUSION

The increase in cultivation costs and the decline in farmers' net income are two major issues confronting Haryana agriculture today. The data indicated that the maximum cost is incurred by rice crop than wheat crop in all irrigation systems. The main reason for this comparative difference in Cost of cultivation is basically due to the higher hired average cost of irrigation in tubewell irrigation system with problems of groundwater depletion (Kurlan village), as in this irrigation system many farmers resort to buying irrigation water to irrigate the paddy fields, especially when they do not have a tubewell or have fragmented landholdings. It is noticed here that the cost of hired irrigation is increasing with the groundwater depletion; thus, the cost of hired irrigation is a minimum of about Rs. 2,720.00 in the mixed irrigation systems of Kheri Man Singh village and the maximum in the groundwater depleted village of Kurlan about Rs. 8,120.00. Rice and wheat crop productivity has stabilized, and farm incomes are reported to be stagnant and insufficient for a decent living. Degradation of land and depletion of water resources has led to rising discontent among the farming community due to their failure to get aspired farm incomes. It is noticed here that the proportion of fertilizers, insecticides, and hired laborers applications are decreased with the groundwater depletion, but the proportion of tubewell irrigation applications are increased with the groundwater depletion for both crops rice and wheat. It is observed that the canal-dependent irrigation system has performed better net returns as compared to the overexploited groundwater irrigation system.

Acknowledgments
The authors sincerely thank Dr. Binu Sangwan, Dr. Nina Singh, and Dr. Parmod Bhardwaj, Professors in department of Geography, M. D. University, Rohtak, for their valuable suggestions, constant encouragement, inspiring suggestions and all meticulous counselling during the investigation and preparation of this manuscript.

7. REFERENCES

[1] Kasana, A. and Singh, O. (2017), “Groundwater Irrigation Economy of Haryana: A Glimpse into Spread, Extent, and Issues”, *Journal of Rural Development,* Vol. 36 No. 4, pp. 531-556. DOI:10.25175/jrd/2017/v36/i4/120624
[2] Raghavan, M. (2008), “Changing Pattern of Input Use and Cost of Cultivation”, *Economic & Political Weekly*, pp. 123-129. DOI:10.2307/40278909
[3] Reddy, M. A. and Thyagarajan, T. (1989), “Conjunctive Use of Irrigation Water in the Nizamsagar Command Area”, *Indian Journal of Agricultural Economics,* Vol. 44 No. 3, pp. 265-275.
[4] Shah, T. (1991), “Water Markets and Irrigation Development in India”, *Indian Journal of Agricultural Economics,* Vol. 46 No. 3, pp. 335-348. Doi: 10.22004/ag.econ.272602
[5] Somnand, J. S. et al. (1989). Cropping Pattern and Farm Income in Relation to Conjunctive Use of Water: An Economic Analysis. *Indian Journal of Agricultural Economics,* 44(3), 265-266.

Corresponding author
Ravinder Gautam can be contacted at: ravinder.gautam.mdu@gmail.com