Management of Groundwater in Overexploited Areas in Gujarat: Use of Micro Irrigation Systems (MIS)

Mona Khakhar and Aishani Goswami

Abstract

Groundwater, a vital freshwater source globally, is heavily exploited for agriculture, leading to environmental and economicchallenges. This paper investigates the use of micro-irrigation systems (MIS) as a solution in overexploited regions, focusing onGujarat, India. The study area, Dehgam taluka, faces severe groundwater depletion, with 25 talukas, including Gandhinagar,being overexploited. Analyzing three villages, this research explores the impact of drip irrigation on water use efficiency andagricultural economics. The study reveals that adopting drip irrigation reduces water consumption by 36%, electricity costs by28%, labor expenses by 68%, and fertilizer costs by 13%. Crop yields increase by 49%, offering farmers higher returns.However, barriers such as small land holdings, lack of awareness, and perceived risks hinder technology adoption. Combiningdemand-side interventions like drip irrigation with supply-side strategies, such as groundwater recharge and lake filling,positively impacts groundwater levels. Tailored, localized interventions are crucial in addressing groundwater overexploitation.

Keywords

Groundwater management · Micro-irrigation systems · Drip irrigation · Water-saving technologies · Groundwater depletion · Overexploited areas · Supply-side management

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1 Introduction

One of the essential freshwater sources in the world is groundwater. However, groundwater's environmental, social, and economic values are often not recognized and valued sufficiently (Moench & Burke, 2000). Agriculture is a sector consuming a significant amount of groundwater, followed by domestic and industrial consumption globally (Taylor et al., 2013; Siebert et al., 2010, 2013). Between 1950 and 2008–09, the irrigated area increased three times, with a 61% contribution from groundwater irrigation in India (Infrastructure Development Finance Company (IDFC), 2011). Out of the total annual groundwater extraction, 89% is used for irrigation, and the rest is for domestic and industrial use (CGWB 2019–20). Several studies have shown that there is extensive groundwater depletion in north-western India and the whole Indo-Gangetic basin (Rodell et al., 2009; Tiwari et al., 2009; Aeschbach-Hertig & Gleeson, 2012; Bhanja et al., 2018). Further, according to a recent World Bank report (2018), the states, viz. Maharashtra, Haryana, Karnataka, Rajasthan, and Gujarat are some of India's most heavily exploited groundwater states.

Irrigation uses 95% of extractable groundwater compared with 5% for domestic and industrial uses in Gujarat (CGWB, 2021). It is reported that there are 25 talukas under the ‘over exploited’ category with more than 100% groundwater extraction, most of which are in North Gujarat (CGWB, 2021). With the limited surface water, the area is highly dependent on groundwater for irrigation (Kumar & Singh, 2007). Hence, there is a need to use, plan, and recharge this source carefully. Out of the total overexploited talukas, Gandhinagar is one of northern Gujarat's crucial districts, with an overall groundwater extraction of 123.42%. There are two talukas, viz. Dehgam and Gandhinagar that are under the ‘overexploited’ category out of four talukas in the district (CGWB, 2021). As per groundwater resource potential, out of the net annual

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groundwater availability of 13,048.31 ha. m in Dehgam taluka, 97.3% is used for irrigation purposes, and the remaining is for domestic and industrial supply (CGWB, 2014). Thus, a few villages in Dehgam taluka were selected to study the modes of water-saving technologies/micro-irrigation systems such as drip used for irrigation in the study area and, thereby, the impact on the groundwater resource. The present research tries to address the following questions:

- Is the use of micro-irrigation systems (MIS) a positive solution for water-stressed areas that would help the farmers to achieve greater water use efficiency and give an economic advantage?
- What are the factors/reasons for the limited use of such technologies?

2 Study Area

Dehgam is a taluka with 91 villages in the Gandhinagar district. Fifty percent of wells in the Dehgam taluka saw a decline in groundwater levels from 2002 to 2012 (CGWB, 2014). The variation in water level in a few wells in Dehgam is shown in Fig. 2. The water levels are more profound in the wells in the northern part of the taluka ranging around 90 m, whereas in the eastern and north-eastern regions, the blue clay is encountered between 40 and 100 m below ground level. The wells in this area have meager discharges. Thus, a few villages, such as Nandol, Salaki, and Sampa, within the Dehgam taluka are adopted as the study area for the present research as shown in Fig. 1.

3 Methodology

The study is based on the primary survey done under this research in three selected villages. The snowball sampling method was used for the analysis. The sample was chosen to include all the farmers considering their water source and irrigation practice. The irrigation practices include using MIS, such as drip irrigation or conventional furrow irrigation. The water sourcing method consists of any formal or informal institutional mechanism for sharing the water from a common source, having their bore well as a source of water and farmers buying water from other farmers. Table 1 lists the category of farmers with respect to the water source for irrigation and irrigation/farming practices.

4 Results and Discussions

The details about the farming practices from the survey for the cluster of villages are discussed below.

4.1 Cluster 1: Use of Micro-Irrigation Systems for Farming

4.1.1 Water Sources for Irrigation and Groundwater Levels

In this cluster, Nandol and Salaki rely on groundwater for irrigation. Few of the farmers own one or more bore wells and irrigate their fields with the groundwater extracted from these bore wells, while the other farmers who do not own a

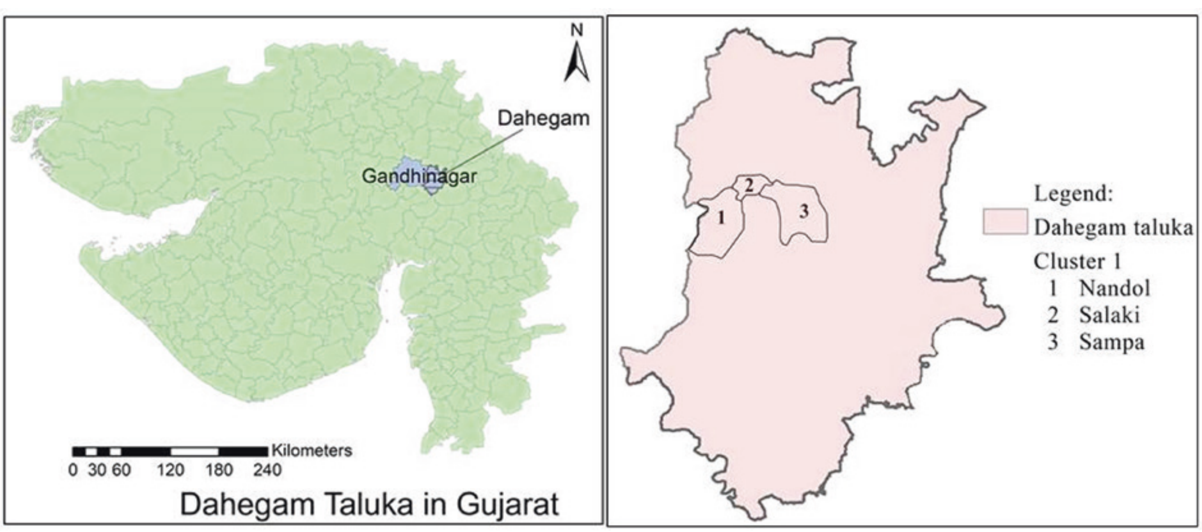

Fig. 1 Location map of the study area in Dehgam Taluka

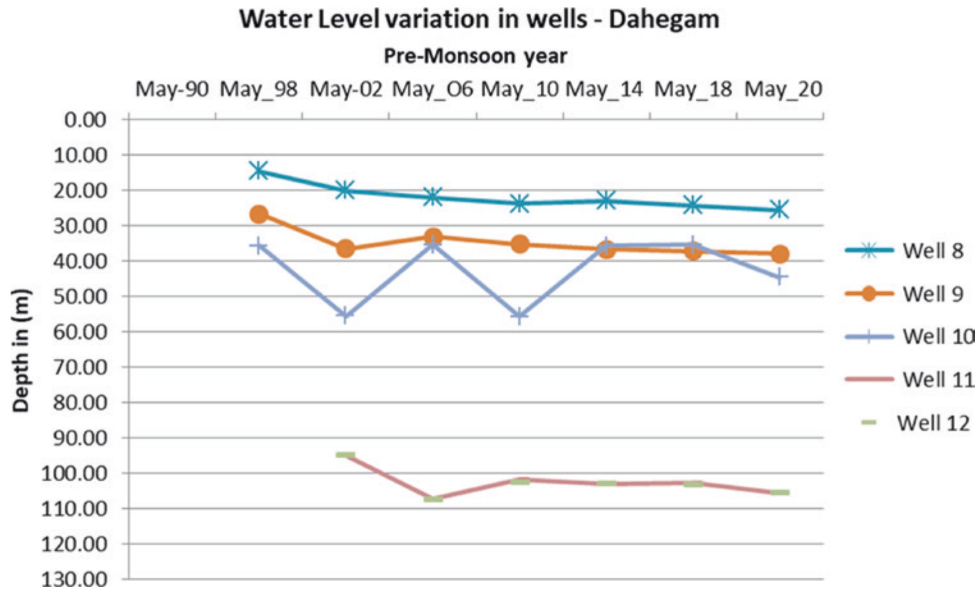

Fig. 2 Water level variation in sample wells of Dehgam village

Table 1 Categories of the farmers with respect to the water source and irrigation practice

Cluster 1	Farmers with bore wells (16)				Farmers without bore wells (13)					
Total farmers	Private bore		Private bore + Narmada water		Buy water from other bore-well		Buy water from Narmada water		Depend on rains	
29	12 (41.3%)		4 (13.8%)		11 (37.9%)		1 (3.5%)		1 (3.5%)	
Irrigation method D—drip C—conventional	D	C	D	C	D	C	D	C	D	C
	3	9	4	0	1	10	0	1	0	1

bore well buy water from the well owners at an hourly rate ranging from ₹ 80 to ₹ 150 or share a part of the harvest. Sampa, the third village studied in this cluster, depends on groundwater and surface water from the Narmada canal. This water from the canal is brought through pipelines, filling six of their village lakes used for irrigation. The farmers have created an association for the use of lake water. This association of farmers allows the use of lake water and pays the rent to the government. The farmers using this water for irrigation pay ₹ 300 per hectare if they are implementing drip irrigation, while the farmers using the conventional method are required to pay ₹ 850 per hectare to the association. Thus, the system provides an incentive to adopt water-saving technology.

4.1.2 Farming Practices and the Use of Resources

Major summer crops grown in this region are millet (bajri) and sorghum (juvaar), groundnut and cotton in monsoon, and potato and wheat in winter. During monsoon, pulses, vegetables, and castor are also sown. In Nandol and Sampa, several farmers use drip irrigation for cultivation, whereas in Salaki, the farmers mostly resort to conventional irrigation practices. From the present survey, the categorization of farmers is as per Table 1.

It is seen from Table 1 that out of the total, 24.2% of farmers owning bore wells and only 3.4% of the farmers not owning bore wells have adopted drip irrigation. On the other hand, 31% of farmers who own a bore well and 41.4% who do not own a bore well pursue conventional irrigation. Thus, there is much scope to further adopt the technologies like drip irrigation.

4.2 Analysis of the Use of Micro-Irrigation Techniques for Farming in Cluster 1

Specific observations and comparisons for irrigating the same crop by the conventional method and drip irrigation are made. A comparison of traditional furrow irrigation vs. drip irrigation for each crop is made for the following criteria:

1. Water consumption per hectare is the crop's total hours of water supply,
2. Yield per hectare in 'Man.' 'Man' is the local unit of measurement (1 man is 20 kg),
3. Labor required per hectare as the number of people,
4. Electricity consumption per hectare as cost, and
5. Fertilizer requirement per hectare as cost.

It is found in Table 2 that for drip irrigation for the potato crop, there is a decrease in water consumption, labor, electricity, and fertilizer cost by 41.62%, 54.76%, 20.33%, and 24.24%, respectively, while the yield has increased by 40.94%. Hence many farmers in this cluster have ventured to use drip irrigation for the potato crop. Further, the survey observed that the potato crop's expenses/investments are relatively high. The cost of fertilizers, the quantity of water, the cost of seeds, storage after harvest, and storage of seeds are higher than the other crops. Yet, at the same time, the yield and often the selling rates of potato is relatively high, with the use of drip irrigation giving good returns to farmers.

Similarly, it is found that there is a decrease in water consumption, labor, electricity, and fertilizer cost for the groundnut crop by 18.98%, 78.42%, 24.53%, and 8.03%, respectively. The groundnut yield has increased by 84.7% for the drip irrigation method. It may be noted that the cost of electricity consumption for the groundnut crop is less as this crop is sown with the onset of the monsoon, and there is less need to pump groundwater for irrigation. The third most prominent crop grown in the study area is corn. Further, it is seen from Table 2 that there is a decrease in water consumption, labor, electricity, and fertilizer cost by 47.06%, 72.13%, 39.57%, and 6.06%, respectively, for the crop of corn with drip irrigation. The yield for the corn crop has increased by 20.68%. It may be noted that corn is also a monsoon crop. Therefore, it is observed that drip irrigation is beneficial to farmers as far as expenses on labor, electricity, and water consumption are concerned. Further, it may be noted that the cost of electricity consumption also includes pumping out groundwater to sell it to the farmers who do not have bore well. If the electricity used to fetch water for selling is removed, it will further reduce electricity consumption.

The above data analysis for the potato, groundnut, and corn crops in the villages studied in Dehgam taluka indicates that adopting drip irrigation is a win–win situation for the farmers, giving a higher yield. Besides, it may also be noted that due to these demand-side interventions for groundwater, groundwater use for agriculture has economized. The reduction in hours of the water supply has resulted in saving on electricity expenses and the requirement of fertilizers. In addition, labor expenses have been reduced due to reduced costs of growing a crop with drip irrigation. It is also observed that the groundwater levels are not going down further in these villages. As observed in one of the private bore wells in Sampa, the water level from the 1990s to 2000s was of the order of 90 m, while it was 73 m in 2017 (Central Ground Water Board, 2017). The rise in water level can be attributed to the use of drip irrigation since 2010 and the filling of six lakes with Narmada water for irrigation after 2006–07. Besides, according to the farmers, when there was no drip irrigation and power was supplied at night, the laborer had to work at night, and there was a lot of water wastage. With drip irrigation, the only requirement is to ensure that all pipes are connected before switching on the bore. However, many farmers in Salaki and Nandol do not use drip irrigation even though the water levels are deep. The study investigated why farmers are not using drip irrigation, as given in Table 3.

As seen from Table 3, certain notions need to be addressed as they are based on short-term reasoning and lack of awareness, as discussed below.

1. One of the reasons for not adopting drip irrigation for 9.5% of the farmers is that they have either small land holding size. Few of them have more land in smaller parcels at considerably far distances. In such cases, the farmer has to get more labor to lay and remove pipes in each portion of the land. They consider installing drip for smaller, segregated land becomes expensive, so they are not adopting drip irrigation.
2. About 28.6% of farmers have a casual approach to installing the drip irrigation system. This is due to the fact that the groundwater, although deep, is available to them when they want. Therefore, the farmers do not want to change their irrigation practices. They are ignorant about saving water and feel that enough groundwater is available.
3. About 14.3% of farmers are less informed and unaware of the benefits of drip irrigation and installing the system.
4. 19% of the farmers have notions of more labor involvement to lay and remove pipes before sowing and after harvesting or perceive no economic benefits and cannot visualize the savings.
5. 9.5% of farmers have not adopted drip irrigation because they have no independent water source and are buying water from a bore well owner.
6. 19% of the farmers have not adopted drip irrigation despite knowing the benefits of using this method of irrigation. They see it as taking a risk and would be more confident to adopt the technique if some farmer in their village adopts it and they see the successful results.

It is observed from the survey that small and marginal farmers are not using drip irrigation to the maximum possible, and there is scope for improving possibilities to adopt water-saving technologies for them. Furthermore, as derived from the survey, there is significant variation in the quantity of water supplied and fertilizers used among farmers for the same crop. Such a variation indicates a lack of awareness about water and fertilizer requirements for crops. Thus, there is a great need to train the farmers on the proper use of drip irrigation and the knowledge about water and fertilizer requirements for each crop type for the soil condition in the village.

Table 2 Comparison between methods of irrigation for potato, groundnut, and corn

	Avg. water consumption per hectare (total hours of water supply for crop)		Avg. yield per hectare in 'man' (1 man = 20 kg)		Avg. labor per hectare (no. of people)		Cost of electricity consumption per hectare (₹)		Cost of fertilizer consumption per hectare (₹)	
Irrigation practice	C	D	C	D	C	D	C	D	C	D
Crop-Potato	376.54	219.75	2033.3	2864.2	56.48	25.56	68.94	54.93	35.96	27.25
% Increase				40.9						
% Decrease		41.6				54.7		20.3		24.2
Crop-Groundnut	121.6	98.76	178.39	329	53.33	11.48	18.38	13.87	17.42	16.0
% Increase				84.7						
% Decrease		18.98				78.42		24.53		8.03
Crop-Corn	209.87	111.1	1790.12	2160.49	39.87	11.1	5.33	3.22	18.8	17.7
% Increase				20.68						
% Decrease		47.06				72.13		39.57		6.06

₹: Indian rupee

Table 3 Reasons to not adopt drip irrigation

S. No.	Reasons for not adopting drip irrigation	Number of respondents
		Cluster 1
1	Not feasible (segregated land, small land size)	2 (9.5%)
2	Not willing to adopt due to availability of enough water for conventional farming practice	6 (28.6%)
3	No or less awareness	3 (14.3%)
4	Perceived–more labor in drip	1(4.8%)
5	Perceived–no economic benefits in drip	2 (9.5%)
6	Perceived–tedious to apply	1(4.8%)
7	No independent water source	2 (9.5%)
8	Aware but not confident about being successful since no one has used it in their village	4 (19%)
9	Non-availability of groundwater	0

5 Conclusion

It is concluded from the studied villages that the use of micro-irrigation techniques, such as drip irrigation, has reduced water use by a mean value of 36% and the cost of electricity by 28%. There is an average reduction in the labor cost for the crops sown in the villages by 68%, and mean fertilizer expenses have decreased by 13%. There is an increase in the yield of crops by 49%. Hence, the adaptation of drip irrigation has created more opportunities for earning higher returns from the crops sown in this area. Besides, out of farmers who have not adopted drip irrigation, 42% are casual about conserving and recharging groundwater, and 14% are less aware.

Moreover, 19% of farmers feel there is a risk in investing in drip irrigation since they have not seen anyone in their village adopting the technology—specifically in Salaki village. The present research also shows that demand-side interventions such as drip irrigation and supply-side interventions such as recharge and filling of lakes have led to positive results in addressing the groundwater overexploitation in Sampa village. Implementing both strategies shows an increase in the groundwater level from 91 to 73 m from 1997 to 2017 in private bore wells. Finally, while supply-side management focuses on increasing water supply through groundwater recharge and related measures, demand-side management aims to minimize irrigation water demand through increased efficiency. These measures should be suitably adapted according to the local conditions in the villages and the need for various relevant strategies. Thus, the local conditions at the village level are essential in dealing with groundwater overexploitation/depletion. Lastly, the observations from this research may help further study policy measures to implement water-saving strategies and devise awareness programs for farmers.

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