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Increasing groundwater recharge through intregrated approach in black soil region

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Abstract
An integrated watershed development programme for soil and water conservation was undertaken in 424 hectare at Hingonia-Pipliyatapha watershed. The present study was carried out to assess the impact of soil and water conservation structures on ground water recharge. Analyses of water table data collected from six open wells located in the watershed reflect average annual rise of 10 m in water table due to recharge. Annual rise in water table is highly correlated to annual rainfall. Increase in availability of irrigation water in wells has resulted in 44 percent increase in rabi cropped area and almost doubled the productivity of rabi and kharif crops.

INTRODUCTION

In the year 1989-90, a watershed area called Hingonia-Pipliyatapha watershed near Indore city was considered for demonstration, dissemination, evaluation and monitoring of the appropriate technologies developed at AICRP on Dryland Agriculture, Indore. The study was carried out by a team of scientists viz., agronomists, soil and water conservation Engineers. Various soil and water conservation measures were constructed for the control of control soil erosion and runoff were constructed in this area during a period of 5 years (1989-1993). An integrated approach was adopted for the improvement in the overall productivity of the area. Suitable agronomical practices, demonstrations were laid in the area that was simultaneously treated with the soil erosion control measures. Thus, reduction in runoff and soil loss and improvement in production have been achieved through proper land use, construction of erosion control structures, selection of suitable crops and varieties, crop rotation and cultural practices. Singh et al. (1989) reported that soil conservation practices have net effect on increase in recharge by rainfall to an extent of 14.02 to 19.52 percent of rainfall in Udaipur region. Various structures and cropping systems have been also found to increase in water table on downstream side (Gouda et al., 1992). Similarly average annual rise of 8m in water table due to recharge has been reported in the open wells located in Navamota watershed area where an integrated watershed development programme for soil and water conservation was taken up (Goel and Singh, 1996). The present study was, therefore, initiated with a view to assess the impact of integrated approach of agronomical package of practices and soil and water conservation measures on overall development of the watershed area in Hingonia watershed area in the Malwa region of Madhya Pradesh.

MATERIALS AND METHODS

The ORP at Hingonia-Pipliyatapha ($76^0 4^{'}$ E and $22^0\ 7^{'}$ N) is located in N-W of Indore (549 MSL). This project is in operation since 1986 in the said villages in the lower reaches of river Gambhir. This area typically represents soil, climate and socio-economic condition of Malwa region. The mean annual rainfall is about 980 mm. The soils of the area are typical Vertisols synthesized from basaltic parent material. The soils though fertile and rich in $CaCO_3$ nodules are vulnerable to runoff and erosion as per LCC belongs to II, III, IV and V. Uninterrupted slopes of the large field develop erodible velocities of runoff, resulting in severe splash, sheet, rill and gully erosion. The dry spell in the flowering, dough stages of kharif adversely affect the yields even though the total rainfall is quite high. With a view to overcome few of these problems, adopting integrated approach treated the area.

Soil and water conservation

An integrated watershed management plan for soil conservation works was made in 1989 after a detailed topographical, soil and socio-economical surveys of the area during the year 1987-1988. This plan involved construction details of bunding, various engineering measures and strategy to develop other resources. As a result of these measures, runoff has been controlled and diverted safely. The waterways were stabilized and gully head advancement phenomenon has been controlled. The silt is being trapped in the field along-with bunds, waste weirs, loose boulder and gabion structures and diversion drains.

Field bunding has been done in an area of about 250 hectare. Considering the soil type, topographical and climatic condition, 1.0 sq.m. Cross-section of 0.75 m high bunds have been constructed. Minor levelling has also been carried out in few locations. In all, 33 waste weirs, 8 loose boulder structures and 3 gabion structures have been constructed at suitable sites. Waterways of about 1800 m (Table 1) have been provided in the area for safe disposal of excess water.

Table 1. Soil and water conservation measures followed in watershed.

Particulars	nos./m length/ hectare
Graded bunding	1500 m
Levelling	8 hectare
Gabion structures	3 nos.
Loose boulder structures	8 nos.
Waste weirs	33 nos.
Water ways	1800 m
Diversion drains	1375 m
Terracing	5 hectare
Spurs	2 nos.
Water harvesting tanks	2 nos.

Two water-harvesting tanks have been constructed in the area to collect the excess runoff from the large chunk of the watershed. The storage capacities of the tanks are 10,000 cu.m and 17,000 cu.m. with the catchment area of 50 hectare and 55 hectare respectively. The earlier cropping systems was substituted by soybean + arhar, soybean-wheat, soybean-linseed, soybean-chickpea and soybean-safflower. A complete package of conservation agronomic practices with improved/high yielding varieties, fertility and plant protection management techniques for different crops has been demonstrated in the watershed.

DATA COLLECTION

The daily rainfall data from 1993 to 1996 were collected. Total 6 nos. of open wells has been selected for recording the ground water level in the wells. Water table depth was measured from the top of the well at a fixed point. The data on water table have been collected after the completion of major soil and water conservation structures viz. water harvesting tanks, gabion structures and loose boulder structures i.e. during 1993-94.

RESULTS AND DISCUSSION

The water availability in the area also encouraged the farmers of the area to adopt animal rearing and dairying as secondary occupation. The tanks and wells meet the drinking water requirement of animals. Thus, the number of animals increased from 114 to 312 in watershed (Table 7).

Table 2. Annual rainfall, rise in ground water and percentage change due to recharge.

Year	Rainfall (mm) R_1	Average fluctu-Ation in water level in well (m) W_1	Percentage change over previous year (%)		Percentage change over average value (%)	
			Rainfall R_2	Water level W_2	Rainfall R_3	Water level W_3
1989	624.0	2.30	-	-	-36.15	-66.12
1990	1046.0	4.92	+6.70	+113.05	+7.0	-27.83
1991	779.8	3.70	-25.41	-24.46	-20.2	-45.51
1992	583.7	3.45	-25.10	-6.75	-40.2	-49.18
1993	1062.5	7.82	+82.02	+126.62	+8.7	+15.17
1994	1445.4	13.57	+36.04	+73.52	+47.8	+99.85
1995	946.7	6.29	-34.49	-53.64	-3.1	-7.36
1996	1331.6	12.31	+40.66	+95.70	+36.2	+81.29
Average	977.4	6.79	-	-		-

Data collected from 1993 to 1996 were analyzed. All the wells exhibit the natural phenomenon of water level variations. Water level in wells starts receding after the monsoon and reaches to lowest level just before the monsoon. During the monsoon, water level rises due to well recharge. The difference between maximum and minimum depth of water level in wells recorded just before the monsoon and after monsoon, respectively. This difference reflects the total rise in ground water as a result of recharge. In cases when water table goes down even below the bottom of wells, rise in ground water table was calculated considering maximum water table depth at bottom of well. Close look of data reveals that even in the year of scanty rainfall, water remains available in most of the wells throughout the year.

Regression analysis was carried out to find correlation between rainfall and rise in water table due to recharge. Analysis indicates that annual rainfall and annual rise in water table are highly correlated (R^2 = 0.9981). Efforts were made to find out correlation between percentage change in comparison to previous year values of rainfall and rise in water levels.

Table 3. Monthly rainfall (mm) in watershed during study period.

Month	1993	1994	1995	1996
January	0.00	31.00	11.70	9.80
February	0.00	2.80	0.00	0.00
March	0.60	0.00	2.80	2.00
April	0.00	0.00	2.35	1.40
May	6.30	5.50	0.75	9.30
June	134.30	315.40	145.28	54.70
July	394.40	314.80	385.50	676.90
August	277.00	470.40	224.40	269.00
September	201.40	302.60	121.30	227.90
October	46.70	2.40	51.50	79.32
November	0.00	0.50	0.00	0.80
December	1.80	0.00	1.20	0.00
Total	1062.50	1445.40	946.78	1331.62
Rainy days	53	53	40	53

Details of these changes are given in Table 3. It was found that percentage change over the average value are highly correlated (R^2 = 0.9961). Regression equations developed describing the relationship between various factors are given below:

$$W_1 = 0.0151 (R_1) - 8.036 \quad (R^2 = 0.9981) \qquad (1)$$

$$W_2 = 2.0900 (R_2) - 2.370 \quad (R^2 = 0.9556) \qquad (2)$$

$$W_3 = 1.4600 (R_3) + 6.070 \quad (R^2 = 0.9961) \qquad (3)$$

Where,

R_1 - annual rainfall (mm),

W_1 - average increase in water levels in well (m),

R_2 - percentage change in rainfall over previous year (%),

W_2 - percentage change in water levels in wells over previous year (%),

R_3 - percentage change in rainfall over average values (%), and

W_3 - percentage change in water level in wells over average value (%).

High rainfall year 1994 and 1996 exhibits a wide difference in percentage change in rainfall and rise in water level over previous year values. In 1994, the change in rainfall and rise in water level were 36.04 and 73.52 % over previous year values while in 1996, these were 40.66 and 95.70 percent respectively. This reflects lesser percentage recharge in 1995 (Table 2). This phenomenon can be well understood by close scrutiny of rainfall distribution during the year. Uneven distribution of rainfall contributed very little towards ground water and more surface runoff in 1995 while in the year 1994 and 1996, more uniform distribution of rainfall resulted higher recharge and rise in water table (Table 3).

As a result of soil and water conservation programs, moisture availability in soil profile and water availability in well increased. A significant improvement in water potential was recorded in this area. During pre-project period, the life span of shallow wells used to be only 2-3 months after the cessation of monsoon rains. However, in the post-project era, wells do not dry up till as late as March in the subsequent year. There was increased water availability in the watershed due to impounding and recharging of water. As such, the irrigated area has increased from 28 hectare during 1987-88 to 168 hectare during 1994-95 (Table 4). This increase in irrigation potential in wells due to water recharge resulted an increase in area under Rabi (Table 5). Before project, only 166 hectare were under rabi crops while in 1996-97, it increased to 300 hectares. An increase in area under wheat by 44 percent clearly reflects the impact of programme as increase in water availability in wells. Introduction of new varieties, improved management practices coupled with more available water in wells resulted in increase in land productivity of kharif and rabi crops (Table 6).

Table 4. Improvement in water potential.

Particulars	1987-88	1991-92	1994-94
Surface water storage (cum)	nil	27,000	27,000
Dug wells (Nos.)	19	29	29
Shallow /deep wells (Nos.)	3	12	27
Total irrigated area (hectare)	28	77	168
Irrigated area (%)	6	17	40

Table 5. Cropping pattern in the watershed.

Crops	Area (hectare)	
	Before project (1987-88)	After project(1996-97)
Kharif		
Sorghum	48.0 (18.4)	3.5 (1.1)
Maize	4.5 (1.7)	--
Pigeon pea	4.5 (1.7)	7.0 (2.2)
Soybean	132.0 (50.6)	243.0 (78.0)
Mixed crop	9.0 (3.4)	--
Fodder	24.5 (9.4)	40.0 (12.80
Inter cropping	3.0 (1.1)	9.0 (2.8)
Vegetables	7.0 (2.6)	6.0 (1.9)
Miscellaneous	28.0 (10.7)	3.0 (0.9)
Total kharif	260.5 (83.7)	311.5 (97.9)
Rabi		
Wheat	56.0 (33.7)	233.5 (77.8)
Gram	77.0 (46.3)	33.0 (11.0)
Fodder	1.5 (0.6)	9.5 (3.1)
Linseed	11.0 (6.6)	4.0 (1.3)
Vegetables	8.0 (4.8)	3.0 (1.0)
Total rabi	166.0 (53.3)	300.0 (94.3)

Figures in parenthesis are percent to total area.

The present study infers that various soil conservation measures in the watershed enhance ground water recharge and ultimately increase crop intensity and crop productivity. Although, annual ground water recharge in a particular year depends upon numerous factors but a close estimate for the year can be drawn by the average annual recharge in water table in the past years.

Table 6. Productivity of major crops in the watershed.

Crop	Local variety	Grain yield (kg/ha)			Improved varieties	Grain yield (kg/ha)		
		87-88	93-94	96-97		87-88	93-94	96-97
Sorghum	Vidisha 60-1	680	1430	-	CSH-5, SPV-475	1210	3780	3480
Maize	Satha	390	1250	-	Ganga 5	410	2900	-
Soybean	Kali tuar	320	-	-	JS 71-05, JS 335	480	1940	2048
Wheat rainfed	Pissi	280	-	-	Sujata	560	700	560
Wheat Partially irrigated	Lok -1	-	-	-	Sujata, Lok-1	960	2200	2420
Wheat irrigated	Wh 147	-	-	-	WH 147, Raj 1555	2200	4260	4350
Gram rainfed	U 21	320	-	670	U-21	380	1340	670
Gram irrigated	U - 24	470	1130	1340	Annagiri 218	560	1840	1756
Linseed	-	-	-	-	ILS 73-25	-	920	830

As a result of soil and water conservation programmes, moisture availability in soil profile and water availability in well increased. A significant improvement in water potential was recorded in the watershed. During pre - project period, the life span of shallow wells used to be only 2-3 months after the cessation of monsoon rains. However, in the post-project era, wells do not dry up till as late as March in the subsequent year. There was increased water availability in the watershed due to impounding and recharging of water. As such, the irrigated area has increased from 28 hectare in 1987-88 to 168 hectare in 1994-95. This increase in irrigation potential of wells due to water recharge resulted an increase in area under Rabi. Before project, only 166 hectare were under rabi crops while in 1996-97, it increased to 300 ha. An increase in area under wheat by 44 percent clearly reflects the impact of programme due to increase in water availability in wells. Introduction of new varieties, improved management practices coupled with more available water in wells resulted in increase in land productivity.

The indirect advantage of the development of water bodies in the watershed can be assessed from the increase in no. of animals in the watershed, thus an appreciable increase in the milk production. The number of buffaloes, cows (Jersi) and goats increased from 88, 2 and 35 in 1987-88 to 260,43 and 120 respectively in 1995-96 mainly due to availability of drinking water (surface as well as ground water) and fodder.

Table 7. Animal population in watershed.

Particulars	No. of animals			Mean Milk Production (lit/day)		
	87-88	93-94	96-97	87-88	93-94	96-97
Buffaloes	88	240	260	4.8	6.2	6.8
Cows	153	103	92	2.5	3.3	3.4
Cows (Jersy) cross	2	26	43	8.0	10.8	12.8
Goat	35	108	120	-	-	-

The present study infers that various soil conservation measures in the watershed enhance ground water recharge and ultimately increased crop intensity and crop productivity. Although, annual ground water recharge in a particular year depends upon other factors but a close estimate for the year can be drawn by the average annual recharge in water table in the past years.

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