

Effect of harvested rainwater in farm ponds of a saline area on soil properties

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Summary

Harvesting rainwater through surface storage is one of the options to combat the frequently occurring drought condition in rainfed agriculture. The quality of irrigation water plays a very important role in improving crop productivity and maintaining soil health, especially in the saline area. The information on the water quality of harvested rainwater in farm ponds of the saline area needs to be made available. Hence, an attempt has been made to study the water quality in farm ponds and its effect on soil health and crop productivity after irrigation using different energy sources for lifting the water. The study was carried out on 11 dugout-type farm ponds from the Ghusar village in Akola taluka of Akola district. The harvested rainwater in farm ponds was only used as protective irrigation for rabi crops through a sprinkler irrigation system operated by either an electric pump or diesel pump or tractor-operated pump. The values of EC (0.16 to 0.36) dSm⁻¹, pH (7.54 to 8.66), SAR (1.02 to 1.78) me l⁻¹ and RSC (0.2 to 0.4) me l⁻¹ in harvested rainwater indicated that the cations and anions were in acceptable limits of safe quality water for protective irrigation. The use of harvested rainwater in farm ponds in Ghusar village of the saline area was also found to be within safe limits from a soil health point of view and it maintains soil fertility.

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Introduction

Water is one of the most critical natural resources and all life forms depend on it. Therefore, it is essential to properly conserve and manage this resource and regulate its use to obtain maximum benefits. Precipitation is the most important source of fresh water and there is a need to manage the rainwater so as to reduce the impact of moisture stress during prolonged dry spells and obtain sustainability in agricultural production. Out of 400 million ha-m precipitation in the country, 70 million ha-m is consumed as evapotranspiration, 215 million ha-m infiltrates the soil, and 115 million ha-m is lost as run-off. Harvesting of one-fourth of this 115 million ha-m run-off water in farm ponds can provide three irrigations to the entire rainfed area, which constitutes two third of the cultivated land of the country. Harvesting rainwater through surface storage is one option to combat the situation. Construction of farm ponds in individual farmer's fields or on a community basis for harvesting run-off water when it is in excess and recycling of stored water for irrigation and other purposes when water is deficient is a very effective and efficient method of facing the challenge of water scarcity in rainfed areas ⁷.

In India total cultivable land is 139.36 M ha, out of this 37.64 M ha is under irrigation (27 per cent). In

Maharashtra, the total cultivable land is 18.5 M ha and the gross cropped area is 22.66 M ha out of which 4.04 M ha is the gross irrigated area and the percentage of gross irrigated area to gross cropped area comes to 17.8 ², which is quite below the national average. In Maharashtra, 87 percent of rainfall is received during the southwest monsoon season and it is unevenly distributed, which greatly affects agricultural production, hence improvement in irrigation facilities is necessary. The total cultivable land of the Akola district is 0.47 M ha, out of which 0.026 M ha is under irrigation (5.53 percent) ¹.

Enhancing productivity and production from the rainfed areas is crucial for increasing food production and reducing regional imbalance in agricultural development. As rainfall is the only water source, its utilization and management hold the key to success in dryland agriculture. The socio-economic status of the farmers in the rainfed condition is very poor due to very low crop productivity. They do not make a large investment in creating irrigation facilities, such as the excavation of ponds, lifting devices and irrigation units, etc. The farm ponds are small tanks or reservoirs constructed to store runoff generated from the catchment and supply this water to fulfil the farm needs like irrigation, livestock, and domestic and fish production. Farm ponds also play a key role in firefighting and as a natural habitat for wildlife, also in flood control or flood retardance when constructed in large numbers in an area.

To tide over the drought-prone situation in drought-affected districts of Vidarbha, the construction of several dugout-type ponds for harvesting excess rainwater on

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farmers' fields is the best option available and is being implemented for the last six to seven years. The Purna Valley of Vidarbha region is an east-west elongated basin with slight convexity to the south, occupying the part of Amravati, Akola and Buldana districts of Vidarbha region, and extends from 20°45' to 21°15'N latitude and 75°15' to 77°45' E longitude with an east-west length of about 100-150 km having a width of about 10 to 60 km, covering an area of about 2.74 lakhs hectare in 547 villages. Purna river originates at an elevation of 900 m in the Gawilgarh hills of Satpura in the Baitul district of Madhya Pradesh and drains for about 240 km before meeting the Tapi river. The total catchment area is about 18,929 km². The important tributaries of Purna are Pedhi, Chandrabhaga, Shahnur, Wan, Katepurna, Nalganga, Gyanganga, Morna, and Man (Pal 2004)¹². Ghusar village falls in this saline area of Purna valley in Akola taluka of Akola district.

The unique feature of the salt-affected soils of Purna valley is that though the salinity and sodicity are widely reported in this tract the presence of salt efflorescence on the surface is hardly seen. The groundwater, which could be better in quality (highly saline) makes the situation more problematic. The groundwater is saline about 2760 km² area with an electrical conductivity of greater than 2 dSm⁻¹ to 17 dSm⁻¹ at 25 °C [12].

Large numbers of dug-out type farm ponds were constructed in Ghusar village of Akola taluka by the State Agriculture Department, which varies in design, dimensions and size (Mahalle 2011). Both lined and unlined dug-out farm ponds are available in the study area. Most of the water in the farm pond is brought in during the rainy season however, only a small portion of the pond water is obtained from direct precipitation (Sudaria et al. 2020; Kaur L & Bala 2020)^{13&14}. The bulk of it comes from the catchment area. Water flows into the pond and brings dissolved materials during the runoff process by contacting soil, rock and other inorganic and organic substances. Irrigated agriculture is dependent on

an adequate water supply of usable quality. Thus, the information on the water quality of harvested rainwater during its storage period in farm ponds is not available which is essential to decide the utilization of this stored water in a saline tract of Purna Vally. Considering the above points, the present study on "Utility of harvested rainwater in farm ponds of saline area" was planned and undertaken in the farmer's field.

Materials and Methods

The Ghusar village in Akola taluka was selected as an experimental site for the present study since a large number of farm ponds were constructed in 2008 and onwards under Prime Minister's Package Programme for drought-affected districts in the Vidarbha region under National Horticulture Mission. The village is located at 20° 7'N latitudes, 77° 07' E longitude and at an altitude of 282 m above mean sea level. The Ghusar village comes under the saline area of western Vidarbha. The soils are mainly black cotton soils with depths varying from 4 m to 6 m having a clayey texture. Soils are poorly drained and have moderately high runoff potential. The climate is characterized by a relatively hot summer and cold winter. In Akola taluka average annual temperature ranges from a high of 45° C to a low of 10° C. The overall climate can be classified as semi-arid tropical. The total average annual rainfall in Akola taluka is 825.62mm. During the monsoon season, most of the ponds were filled fully. The study area comes under the assured rainfall zone of the Vidarbha region.

Data Acquisition

More than 120 dug-out-type farm ponds were constructed under the different government programs in Ghusar village of Akola taluka during 2008-11. The farm ponds constructed during 2008-11 were considered for the present study, out of which 11 dug-out type ponds were randomly selected. The details of selected dug-out type farm ponds and sizes of the pond along with the owner's name are given in Table 1.

Table 1. Details of selected farm ponds in the saline area of Ghusar village

S. No	Name of farmer	Size of farm pond (mxmxm)	Types of water lifting power source	Volume
1	Godabai Lahariya	30 × 30 × 2.60	Tractor operated Pump	1957.83
2	Rajesh S. Laharia	30 × 30 × 2.45	Tractor operated Pump	1864.45
3	Gunwantrao Wakode	82 × 26 × 2.65	Electric pump (5 Hp)	4916.17
4	Nilesh Raut (1)	30 × 30 × 2.60	Diesel pump (5 Hp)	1957.83
5	Dipak Prakash Raut	30 × 30 × 2.64	Electric pump (5 Hp)	1982.35
6	Sardar S. Laharia	30 × 30 × 2.63	Electric pump (5 Hp)	1980.41
7	Rajendra Pagrut	30 × 30 × 2.50	Diesel pump (5 Hp)	1895.83
8	Laxman W. Behare	30 × 30 × 2.61	Electric pump (5 Hp)	1963.97
9	Minakshi Karle	82 × 26 × 2.67	Electric pump (5 Hp)	4947.86
10	Damodar Pagrut	30 × 30 × 2.61	Electric pump (5 Hp)	1980.41
11	Nilesh Raut (2)	30 × 30 × 2.63	Diesel pump (5 Hp)	1957.83

Chemical Analysis of Water and Soil Samples

Water samples from the pond were collected at different time intervals after the farm pond filling and analyzed for different chemical parameters. The samples were collected from August to January 2014-15. Soil samples were collected before sowing and after harvesting rabi crops in October 2014 and March 2015, respectively,

from the selected experimental fields to which harvested pond water was applied. The soil sample was analyzed for the soil chemical parameter such as pH, EC, cations (Ca²⁺, Mg²⁺, Na⁺, K⁺), anions (CO₃²⁻, HCO₃⁻ and Cl⁻), macronutrients (N, P and K) and bulk density.

Water Sample Analysis

The pH of water samples was measured using a glass electrode pH meter, according to the method outlined by Jackson in 1973⁶. The water sample's electrical conductivity (EC) was measured using a Conductivity Bridge, as described by Jackson in the same reference. Carbonates and bicarbonates were determined using the rapid titration method outlined by Richards in 1954.¹² Chlorides were determined by titration with standard AgNO₃, following the procedure described by Richards in the same reference. Calcium and magnesium were determined using the Versenate titration method, as given by Richards in 1954.¹² Sodium and potassium were determined using a flame photometer, as described by Page et al. in 1989⁸.

Soil Sample Analysis

Saturated soil pastes and saturation extracts were prepared following the procedure described by Richards in 1954. The saturation extract's pH and electrical conductivity (EC) were determined using a pH meter and a conductivity bridge, respectively. The composition of cations and anions in the saturation extracts was

analyzed using the methods outlined by Richards in the same reference. Soil reaction (pH) was determined in a soil suspension (1:2 soil: water) by a glass electrode pH meter after allowing the soil to equilibrate with water for 30 minutes, with occasional stirring, as outlined by Jackson in 1973⁶. The same soil water suspension prepared for measuring pH was also used for measuring EC from the supernatant, and EC was measured using the ELICO conductivity bridge, as described by Jackson in the same reference

Result and Discussion

Quality of Harvested Water

The harvested water samples from 11 dug-out type farm ponds of Ghusar village were collected at different intervals. Water quality was analyzed for different chemical parameters in Soil Science and Agricultural Chemistry Laboratory. The results of the analysis of water samples at the time of protective irrigation are given in Table 2.

Table 2. Quality of harvested water in different farm ponds on 24 December 2014 (at the time of protective irrigation)

Farm pond number	pH	EC (dSm ⁻¹)	HCO ₃ ⁻ (me l ⁻¹)	Cl ⁻ (me l ⁻¹)	Ca ⁺² +Mg ⁺² (me l ⁻¹)	Na ⁺ (me l ⁻¹)	K ⁺ (me l ⁻¹)	SAR	RSC
1	8.57	0.23	1.6	0.90	1.30	1.8	0.2	1.61	0.30
2	8.58	0.36	2.0	0.80	1.77	1.2	0.2	1.27	0.23
3	8.66	0.24	1.9	1.05	1.60	1.3	0.1	1.45	0.30
4	8.66	0.21	2.5	1.70	2.30	1.9	0.2	1.77	0.20
5	8.60	0.30	2.2	1.20	1.90	1.3	0.1	1.33	0.30
6	8.52	0.27	2.1	1.20	1.73	1.6	0.2	1.72	0.37
7	8.65	0.31	2.4	1.80	2.15	1.4	0.1	1.35	0.25
8	8.60	0.36	2.1	1.70	1.80	1.5	0.1	1.58	0.30
9	8.56	0.23	2.4	1.80	2.20	1.8	0.1	1.64	0.20
10	8.46	0.28	2.6	1.20	2.35	1.9	0.2	1.75	0.25
11	8.65	0.26	2.1	1.20	1.80	1.5	0.2	1.58	0.30
Mean	8.59	0.27	2.17	1.32	1.90	1.56	0.15	1.55	0.27
Median	8.60	0.27	2.10	1.20	1.80	1.50	0.20	1.58	0.30
CV %	0.69	18.51	13.36	27.27	16.84	16.02	33.33	10.96	18.51

The pH of harvested water samples in the farm ponds was analysed at the time of protective irrigation. It is observed that the pH of the farm pond water at the time of protective irrigation was in the range of 8.46 to 8.66, indicating that the water in dugout-type farm ponds was slightly alkaline. The high pH of irrigation water is a function of high carbonate and bicarbonate concentrations. However, pH of irrigation water is generally given less importance in assessing water quality parameters because of poor buffering capacity of water. According to Alexander and Mahalingam (2011)³, the normal pH range is 6.5 to 8.4 and hence can be used for protective irrigation.

Electrical Conductivity (EC)

The electrical conductivity of harvested water samples in farm ponds was assessed. The value of EC ranges from 0.21 to 0.36, which was normal as far as the saline area is concerned. EC values of water samples in different farm ponds are lower than these are of harvested rainwater. The electrical conductivity of harvested runoff water at the time of protective irrigation in almost all ponds is within limits except ponds No. 2 and 8, which was slightly higher (0.36 dSm). According to Alexander

and Mahalingam (2011)³, the EC less than 0.7 dSm⁻¹ falls into the "none" degree of restriction to the use of irrigation. The maximum value of EC observed in harvested water was 0.36 dSm⁻¹; hence, the water can be safely used for protective irrigation.

Cations

The cationic concentration of harvested water in farm ponds was analyzed for measuring the calcium + magnesium, sodium and potassium ions. It is observed that the value of Ca⁺² + Mg⁺², Na⁺ and K⁺ were in the range of 1.30 to 2.35, 1.20 to 1.90 and 0.10 to 0.20 me l⁻¹ respectively. These can be categorized as normal as far as saline area is concerned. The cations in the harvested rainwater were found in a safe limit. According to Alexander and Mahalingam (2011)³, the Na⁺ less than 3 me l⁻¹ falls into "none" degree of restriction to use sprinkler irrigation. The maximum value of Na⁺ observed in harvested water was 1.9 me l⁻¹. Hence, it can be concluded that the harvested water is safe for use with sprinkler irrigation.

Anions

The anions concentration of harvested water in farm ponds was assessed for measuring the bicarbonate and

chloride. The value of HCO_3^- and Cl^- was observed in the range of 1.60 to 2.60 and 0.80 to 1.80 me l^{-1} , respectively, which was found to be normal as far as saline area is concerned. According to Alexander and Mahalingam (2011)³, bicarbonate less than 5 me l^{-1} and chloride less than 3 me l^{-1} is safe and it falls into the “none” degree of restriction to use with overhead sprinkling. This limit of chloride concentration does not produce ion toxicity for plant growth.

Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio (SAR) is derived from Ca^{+2} , Mg^{+2} and Na^{+} as per the criteria given by Richards, (1954)¹¹. It is revealed that sodium adsorption ratio in harvested water sample was in the range of 1.27 to 1.77 me l^{-1} . According to Alexander and Mahalingam, SAR less

than 3 is safe and it falls into “none” degree of restriction to use for protective irrigation.

Residual Sodium Carbonate (RSC)

The residual sodium carbonate (RSC) level of harvested water in farm ponds was in the range of 0.2 to 0.27 me l^{-1} and it is within the permissible limit as per the criteria for suitability of irrigation water (Richards, 1954)¹¹.

Effect of Protective Irrigation on Physiochemical Properties of Soil

The chemical analysis of soil was carried out before sowing of the crop and after harvesting of the crop to find out the effect of protective irrigation by using harvested rainwater in the farm ponds on soil properties. The harvested water in pond 10 number was not utilized

Table 3. Soil chemical analysis before sowing of crop

Farm Pond no	pHs	ECe dSm^{-1}	Cations				Anions		Macronutrient			O.C g Kg^{-1}	Derived		
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^-	Cl^-	N	P	K		SAR	RSC	BD Mg m^{-3}
			me l^{-1}				me l^{-1}		Kg ha^{-1}						
1	8.1	1.15	2.3	3.37	4.87	0.12	8.27	1.6	210	17.1	320	6.8	2.89	2.6	1.51
2	8.09	1.20	3.4	4.6	4.07	0.10	8.02	1.1	194	16.1	290	5.6	2.03	0.2	1.49
3	8.2	1.10	2.8	4.07	3.93	0.20	9.87	0.87	220	22.1	335	6.4	2.12	2.23	1.54
4	7.9	1.19	3.1	3.93	4.2	0.10	8.93	1.1	215	18.4	333	6.8	2.24	1.9	1.46
5	8.1	1.14	3.33	4.1	4.1	0.10	9.83	1.03	217	16.8	345	5.6	2.12	2.4	1.56
6	8.0	1.13	3.6	4.22	3.98	0.09	8.23	1.12	186	19.6	385	6.7	2.01	0.41	1.51
7	8.2	1.12	3.5	4.27	4.65	0.13	9.75	0.95	212	21.2	297	5.8	2.35	1.98	1.52
8	8.1	1.10	2.9	4.08	4.82	0.15	8.98	1.15	192	22.2	368	5.9	2.58	2.00	1.55
9	8.2	1.12	3.5	3.97	3.97	0.14	9.72	1.08	213	19.2	389	6.3	2.05	2.25	1.48
11	8.2	1.19	3.6	4.17	4.78	0.17	9.45	1.09	215	18.6	348	6.0	2.47	1.68	1.55

Table 4. Soil chemical analysis after harvesting of a crop

Pond No	pHs	ECe dSm^{-1}	Cations				Anions		Macronutrient			O.C g Kg^{-1}	Derived		
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	HCO_3^-	Cl^-	N	P	K		SAR	RSC	BD Mg m^{-3}
			me l^{-1}				me l^{-1}		Kg ha^{-1}						
1	8.2	1.17	2.38	3.48	4.89	0.12	8.36	1.62	219	17.3	321	6.8	2.85	2.5	1.51
2	8.1	1.22	3.52	4.65	4.10	0.13	8.20	1.15	193	16.2	295	5.6	2.02	0.03	1.50
3	8.3	1.13	2.91	4.2	3.95	0.19	9.10	0.92	215	22.18	317	6.3	2.09	1.99	1.54
4	8.1	1.22	3.22	4.1	4.25	0.14	8.97	1.14	223	21.52	330	6.6	2.22	0.8	1.47
5	8.3	1.16	3.41	4.2	4.14	0.13	9.97	1.08	212	16.85	332	5.6	2.12	2.36	1.56
6	8.2	1.16	3.72	4.1	4.02	0.07	8.29	1.18	196	19.74	381	6.6	2.03	0.27	1.50
7	8.4	1.14	3.52	4.29	4.68	0.14	9.79	0.97	219	21.4	302	5.8	2.36	1.98	1.53
8	8.2	1.12	2.93	4.11	4.85	0.15	9.02	1.17	197	22.3	371	5.9	2.58	1.98	1.55
9	8.2	1.14	3.53	4.02	3.99	0.16	9.77	1.10	218	19.4	391	6.3	2.05	2.22	1.49
11	8.3	1.21	3.62	4.22	4.81	0.18	9.49	1.10	217	18.8	349	6.0	2.42	1.65	1.56

pH

It is observed that the pHs of soil irrigated with harvested water were in the ranges of 7.9 to 8.4 before the sowing of crop, while it slightly increased with a range of 8.1 to 8.4 after the harvest of the crop, which was due to one protective irrigation through sprinkler irrigation.

Electrical Conductivity (EC)

The electrical conductivity of soil varied in the range of 1.10 to 1.20 dSm^{-1} before the crop sowing, while it was slightly increased in the range of 1.13 to 1.22 dSm^{-1} after crop harvest.

Cation

The Ca^{+2} before sowing of the crop was in the range of 2.3 to 3.6 me l^{-1} and after harvest of the crop in the range

of 2.38 to 3.72 me l^{-1} . In the case of Mg^{+2} cations, the values range from 3.37 to 4.60 me l^{-1} before the sowing of crop, while it ranges from 3.48 to 4.65 me l^{-1} after the crop harvest. Similarly, the Na^{+} cations were found in the range of 3.93 to 4.87 me l^{-1} before the sowing of crop and 3.95 to 4.89 me l^{-1} after crop harvest. Whereas, the K^{+} cations range from 0.09 to 0.20 me l^{-1} and 0.07 to 0.19 me l^{-1} before sowing and after the harvest of crop, respectively. The above result indicates that there were slight changes in Ca^{+2} , Mg^{+2} , Na^{+} and K^{+} cations after harvest of crop *i.e.*, after the application of protective irrigation by using of harvested rainwater in the farm ponds and the change was in acceptable limits of soil reaction.

Anions

It is observed, the HCO_3^- anions in the soil range from 8.02 to 9.87 me l^{-1} before the sowing of crop and from 8.2 to 9.97 me l^{-1} after harvest of crop. In the case of Cl^- anions, it is observed that it ranges from 0.87 to 1.6 me l^{-1} before sowing and from 0.92 to 1.62 me l^{-1} after the crop harvest.

Macronutrients

The status of available macronutrients before sowing and after harvest of the crop is observed that the available nitrogen ranges from 186 to 220 kg ha^{-1} before sowing while it was decreased to some extent after crop harvest. The declining pattern of available nitrogen in some fields must be due to management practices while in general, the protective irrigation through harvested rainwater helps to release the nutrients because of enhanced percolation. A similar trend was also noted regarding available phosphorus and potassium.

The available phosphorus was in the range of 16.1 to 22.2 kg ha^{-1} before sowing while it was in the range of 16.20 to 22.3 kg ha^{-1} after the harvest of crop. The slight increase of P may be due to higher P fixation capacity of soil. It is observed that the available potassium was in the range of 290 to 385 kg ha^{-1} before sowing, while it was in the range of 295 to 395 kg ha^{-1} after harvest of crop.

Organic Carbon

The organic carbon in the soil ranges from 5.6 to 6.8 g ha^{-1} before as well as after the harvest of the crop. No significant change was observed in the soil's organic carbon after applying protective irrigation from the harvested water in farm ponds.

Sodium Adsorption Ratio (SAR)

The SAR ranges from 2.01 to 2.89 me l^{-1} before sowing as well as after the harvest of the crop. There was no change observed in SAR after the application of protective irrigation from the harvested water in farm ponds.

Residual Sodium Carbonate (RSC)

The residual sodium carbonate (RSC) was found between 0.2 to 2.6 me l^{-1} and 0.03 to 2.36 me l^{-1} before sowing and after harvest of crop, respectively. There was a decrease in RSC at almost all the fields under study after protective irrigation from the harvested water in farm ponds.

Bulk Density

The bulk density of soil ranges from 1.46 to 1.56 Mg m^{-3} before sowing, while it was in the range of 1.47 to 1.56 Mg m^{-3} after the harvest of crops, in different fields. No change in bulk density was observed after the application of protective irrigation from the harvested water in farm ponds.

Conclusions

From the above result of effect of use of harvested rainwater in farm ponds as protective irrigation through sprinkler irrigation on physiochemical properties of soil in saline area, it can be inferred that the changes in different chemical properties of soil were within the safe limit of good soil health and fertility point of view, following conclusions are obtained in the present study. The harvested rainwater in farm ponds was utilized for the protective irrigation of rabi crops through a sprinkler

irrigation system, preferably operated by an electrical pump followed by a diesel pump or tractor-operated pump. The values of electrical conductivity (EC) ranging from 0.16 to 0.36 dSm^{-1} , pH ranging from 7.54 to 8.66, sodium adsorption ratio (SAR) ranging from 1.02 to 1.78, and residual sodium carbonate (RSC) ranging from 0.2 to 0.4 indicated that the cations and anions in the harvested rainwater in different farm ponds fell within acceptable limits of safe quality water for protective irrigation. The utilization of harvested rainwater in farm ponds in Ghusar village of a saline area was found to be within safe limits from a soil health perspective and contributed to maintaining soil fertility.

Declarations of interests

All authors of this manuscript declare that they have no conflict of interest.

Data sharing

All relevant data are within the manuscript.

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