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Rainwater Harvesting and Recycling for Sustainable Agriculture in Assured Rainfall Zone of Marathwada Region, Maharashtra

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ABSTRACT: The study was conducted with dug out farm pond at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during 2010-11 to 2013-14. Reutilization study on protective irrigation to soybean was conducted during *kharif* 2013. On an average, runoff of 12.43% and harvesting potential of 11.10% of rainfall was observed from the catchment area of 1.60 ha during experimentation period. An average total storage loss of 1718.10 m^3 was observed during the period from July to December comprising an evaporation and seepage losses of 150.59 m^3 (8.67%) and 1567.51 m^3 (90.29%), respectively. One protective irrigation of 5 cm to soybean at maturity stage during prevailing critical dryspell, increased soybean grain yield by 30.87%. An average irrigation potential, on the basis of monthly storage volume of farm pond during 2010 and 2013, was observed as 0.87 ha.

Key words: dugout farm pond, protective irrigation, critical dryspell, storage loss, grain yield

Rainwater scarcity is not limited to the arid climate regions, but in areas with good supply, the access to safe water is becoming a critical problem. In major parts of the country, despite accumulated flooding in high risk areas, it remains dry leading to drought or drought like situations during major part of the year. Even after good monsoon, water shortage for agriculture occurs due to lack of proper rainwater management, *in-situ* water storage, low water holding capacity of soils, low infiltration, larger intra/inter rainfall fluctuations and high evaporation demand (Suraj Bhan, 2009). In-situ harvesting of every drop of rain water is very essential for promoting sustainable agriculture in semi-arid regions (Goyal, *et al.*, 1995). The successful production of rainfed crops largely depends on efficient soil moisture conservation, surplus runoff harvesting and its utilization for supplemental or protective irrigation. There are divergent views on the actual potential and scope of farm ponds for water harvesting and its likely impact on enhancing food production. This is because of the uncertainty on availability of surface water for harvesting due to varied geographical features, soil types, slopes, rainfall and high capital investment (Sastry & Singh, 1993). Considering this, the present study was taken up to assess the surface runoff potential of Vertisols, harvesting efficiency of farm pond and storage losses of harvested water in assured rainfall zone of Marathwada region of Maharashtra state.

Materials and Methods

Climate

Marathwada region falls under semi-arid tropic with highest maximum temperature of 43^{0}C during the month of May, while the lowest minimum temperature of 11^{0}C during the month of December. Considering agro-climatic zones, mostly 80% area of the region come under assured rainfall zone with mostly *kharif* cropping and 20% moderately high rainfall and scarcity zone. Soils of the region comprise 60 to 70% medum to deep Vertisols. Under rainfed farming in *kharif* season cotton, soybean, pigeonpea, sorghum and in *rabi* season sorghum, chick pea, safflower are grown. South-west monsoon is the major source of rainfall in the region with average annual rainfall of Parbhani as 890 mm with 48 rainy days.

Location

The present study was conducted with dug out farm pond, developed from murum quarry at Demonstration-cum-Mega Seed Production Farm, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The soils in the catchment of farm pond are medium deep to deep black and mostly clayey in texture with pH 7.5. The soil strata at the farm pond site comprised top clay soil layer 1.0 to 1.25 m, followed by 1.5 to 1.8 m soft murum and then hard murum.

Components of farm pond

From topographic map of the area, catchment of farm pond was determined as 1.60 ha. Farm pond is rectangular in shape with an average size of 23.0 x 27.0 m at top and 16.0 x 19.5 m at bottom with an average depth of 2.95 m. Area under farm pond worked out as 5.88% of catchment area. Farm pond comprised with approach channel, silt trap, rectangular cement concrete inlet-outlet, storage area and clay lining with sodic soil layer

Storage capacity of farm pond

From grid survey of farm pond storage area at 0.25 m vertical interval, incremental storage capacity was calculated. Average elevation and water spread area were also determined at the embankment top, pond bottom and outlet crest. The storage capacity of the farm pond was calculated using Trapezoidal formula (Sastry & Mittal, 1987),

$$V = \left\{ \frac{A_1 + A_2}{2} \right\} \times D \quad \ldots\ldots \quad (1)$$

in which, V = Volume of water stored between contours 1 & 2, m^3

A_1 = Water spread area corresponding to contour 1, m^2

A_2 = Water spread area corresponding to contour 2, m^2 and

D = Contour interval, m

Stage-storage and stage-water spread area curves were drawn and subsequently used for daily water balance component analysis of farm pond. Storage capacity of farm pond at outlet crest (2.20 m average depth) was observed as 1080 m^3.

Farm Pond Water Balance Analysis

The parameters of farm pond water balance, such as precipitation, evaporation, inflow-outflow and change in storage depth were monitored on daily basis during monsoon season and analyzed to determine storage losses from harvested water. Precipitation and evaporation data were recorded at same location in Meteorological Observatory, VNMKV, Parbhani. Daily loss of stored water due to evaporation was determined from daily pan evaporation and average water surface area in the farm pond. Evaporation loss was subtracted from change in storage volume over the period to determine surface/subsurface inflow or outflow.

Measurement of Inflow/Outflow

Inflow and outflow were measured manually by recording the flow depth at inlet and outlet with respect to time and stormwise inflow and outflow were determined using rectangular weir formula (Wasi Ullah *et al.,* 1972),

$Q = 3.34\ L\ H^{1.47}$ ……. (2)

in which, Q = Discharge, cft/sec

L = Effective length of weir, feet and H = Head, feet

Runoff samples from inflow were also collected and analyzed to determine soil loss.

Assessment of storage losses

Major losses from harvested water in farm pond were evaporation and seepage losses. The daily evaporation loss through farm pond was calculated using the following formula,

$$\text{Evaporation loss, } m^3/\text{day} = \frac{\text{Daily pan evaporation (mm)} \times 0.7 \times \text{Average water surface area, } m^2}{1000}$$

Silt deposition

Silt deposited in water storage area of farm pond was determined during 2010 by measuring the area of silt deposition and the depth of silt with respect to side slope and bottom, at grid interval of 4 m. Water content of the silt samples was also measured to determine dry density of silt and its corresponding weight.

Reutilization of harvested water

Water harvested in the farm pond was utilized for applying protective irrigation to soybean crop (MAUS-162) at maturity stage during the critical dryspell observed from 19th August to 9th September, during *kharif* season of 2013. The study was planned in R. B. D. design with plot size of 5.0 x 10.0 m and treatments of one protective irrigation of 5 cm depth and treatment of without protective irrigation (control). The irrigation was provided on 8th September 2013 with 1.5 hp, portable Monoblock 'petrol start-diesel run' pump set.

Results and Discussion

Rainfall

On the basis of an average from 2010 to 2013, 937.63 mm rainfall was received at Parbhani during June to December in 52 rainy days, whereas long term average is 968.13 mm and 55 rainy days. July was found as the wettest month with average monthly rainfall of 329.08 mm, in 15 rainy days followed by the month of August and September with an average monthly rainfall of about 206 mm in 12 rainy days (Table 1).

Runoff

Inflow to the farm pond was determined from storm-wise volume of water harvested during 2010 and actual measurement at inlet during 2013 (Table 2). From the catchment area of 2.04 ha in 2010 & 2011 and 1.60 ha in 2013 a total runoff of 80.41 mm was generated due to a total runoff producing rainfall of 646.80 mm during three years, which accounted as 12.43% of rainfall and effective in producing equivalent average runoff volume of 749.48 m^3 per year.

Development of stage- storage and stage-water spread area curves

Stage-storage and stage-water spread area relationship of the farm pond was developed in the form of curve using data on storage capacity and water spread area with respect to stage of water above pond bottom (Figure 1). The developed curve was further used in daily analysis of components of water balance.

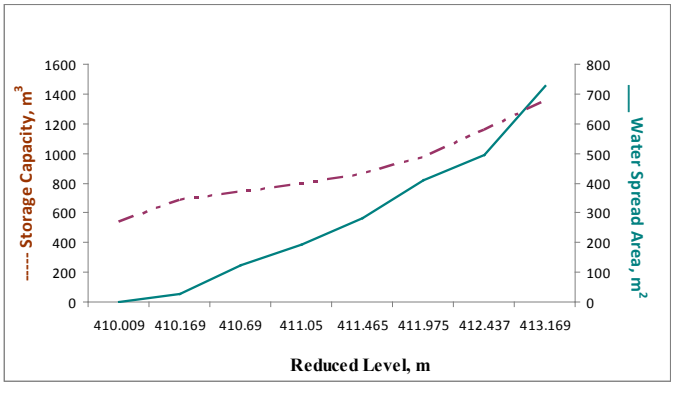

Fig. 1 : Stage – storage and stage – water spread area curves of farm pond, VNMKV, Parbhani

Rainwater harvesting and assessment of storage losses

Data on rainwater harvesting during 2010 to 2013 (Table 3) indicated that on an average, a total of 1816.82 m^3 rainwater was harvested during July to December, due to runoff generating successive rain events in wet rainfall years against average seasonal (June-December) rainfall of 1022.77 mm. Considering the catchment area of 1.60 ha, the harvesting potential of farm pond was worked out as 11.10% of rainfall, indicating approximately 1.33% loss during runoff conveyance from catchment to farm pond through channel of length 95 m. On the basis of data of 2010 and 2013, average monthly storage in

Table 1 : Rainfall observed at VNMKV, Parbhani during 2010 to 2013

Month	June	July	Aug	Sept	Oct	Nov	Dec
2010							
Rainfall, mm	106.1	426.8	380.7	221.1	31.2	93.3	0.5
(Rainy Days)	(5)	(14)	(15)	(14)	(5)	(5)	(0)
June-December	1259.7 (58)						
January-December	1295.2 (60)						
2011							
Rainfall, mm	36.3	259.9	189.30	131.3	19.2	--	--
(Rainy Days)	(6)	(16)	(15)	(7)	(2)		
June-December	636 (46)						
January-December	677 (50)						
2012							
Rainfall, mm	82.5	220.4	105.6	220.5	49.0	4.2	--
(Rainy Days)	(5)	(15)	(9)	(11)	(2)	(0)	
June-December	682.2 (42)						
January-December	688.2 (43)						
2013							
Rainfall, mm	202.5	409.2	138.1	264.9	117.3	14.0	26.6
(Rainy Days)	(10)	(16)	(10)	(11)	(11)	(2)	(1)
June-December	1172.6 (61)						
January-December	1216.1 (65)						
Average of 2010-2013							
Rainfall, mm	106.85	329.08	203.43	209.45	54.18	27.88	6.77
(Rainy Days)	(7)	(15)	(12)	(11)	(5)	(2)	(0)
June-December	937.63 (52)						
January-December	968.13 (55)						

Table 2 : Runoff and total depth of runoff producing rainfall during 2010 to 2013, VNMKV, Parbhani

Year	Rainfall (mm)	Runoff volume, m^3	Runoff, mm	Runoff as a per cent of rainfall, %
2010	468.80	1273.26	62.41	13.31
2011	44.20	745.00	3.65	8.25
2012	--	--	--	--
2013	133.80	230.19	14.35	10.72
Total	646.80	2248.45	80.41	12.43

farm pond was observed as 517.66 m^3. Rainwater harvested and stored in the farm pond was analyzed for partitioning the storage losses. However, 0.09% i.e. 13.50 m^3 and 4.50 m^3 rainwater harvested was utilized for protective irrigation under research projects during 2010 and 2013, respectively. From harvested water, an average total evaporation loss of 150.59 m^3 (8.67%) and seepage loss of 1567.51 m^3 (90.29%) was observed during the period from July to December. Similarly, on the basis of data during wet years 2010 and 2013, an average daily evaporation and seepage loss for the months from July to December, were worked out (Table 4).

Reutilization of harvested water

Protective irrigation from harvested water was provided to soybean at maturity stage during the prevailing critical dryspell of 21 days from 19th August to 8th September, 2013. Treatment of protective irrigation recorded significantly higher soybean grain yield (2179 kg/ha) than control (1665kg/ha) and recorded 30.87% higher soybean grain yield over control i.e. without protective irrigation (Table 5).

Table 3 : Rainwater harvesting and assessment of storage losses through the farm pond during 2010-2013 at VNMKV, Parbhani

Year	Surface inflow, m^3	Precipitation and sub surface inflow, m^3	Total inflow, m^3	Average monthly storage, m^3	Evapo-ration loss, m^3	Seepage loss, m^3	Total storage losses*, m^3
2010 (July-December)	--	--	3022.60	571.83	228.66	2525.75	2754.41
2011 (27 July-20 August)	--	--	745.0	--	29.00	681	710.00
2012	--	--	--	--	--	--	--
2013 (July-December)	230.18	1453.28	1683.46	463.49	194.11	1495.77	1689.88
Average	230.18	1453.28	1817.02	517.66	150.59 (8.67 %)	1567.51 (90.29 %)	1718.10

* Harvested water was used for protective irrigation as 13.50 m^3 in 2010 and 4.50 m^3 in 2013

Table 4 : Average daily evaporation and seepage loss observed during 2010 and 2013, VNMKV, Parbhani

Month	Av. daily evaporation loss, m^3		Av. daily seepage loss, m^3	
	2010	2013	2010	2013
July	1.351	1.69	--	--
August	1.182	1.19	29.308	1.36
September	1.461	1.43	19.142	6.94
October	1.148	1.50	13.106	3.66
November	1.241	1.33	5.197	9.04
December	0.943	1.14	8.423	6.71

Table 5 : Soybean grain yield as affected by protective irrigation during *kharif* -2013, VNMKV, Parbhani

Treatments	Soybean grain yield, kg/ha	Gross monetary returns, ₹/ha	Net monetary returns, ₹/ha	B-C ratio	Increase in grain yield over control, %
T1 - One Protective irrigation of 5 cm depth	2179	76265	56515	2.86	30.87
T2 - Control i.e. without any protective irrigation	1665	58275	42525	2.70	--
SEm+	14				
CD (P=0.05)	53				
Mean	1922				
C.V%	3.0				

Irrigation Potential of farm pond

Quantity of harvested rainwater available in farm pond during monsoon season and probable irrigation potential for applying 5 cm of depth of irrigation (Table 6) indicated that on an average 544.20 m^3 water was available during the period from July to December and could be utilized for protective irrigation to 0.87 ha area. Volume of harvested water during September and October was in the range of 1/2 to 3/4th of storage capacity and can be utilized for protective irrigation to about one hectare area.

Table 6 : Water availability in farm pond and irrigation potential with irrigation conveyance efficiency of 80% during 2010 and 2013

Date	Water available in the farm pond, m^3			Probable Irrigation Potential, ha		
	2010	2013	Average	2010	2013	Average
15, July	610.00	--	610.00	0.976	--	0.976
31, July	277.50	598.41	437.96	0.444	0.96	0.70
15, August	1060.00	676.90	868.45	1.696	1.08	1.39
31, August	1050.00	508.33	779.17	1.680	0.81	1.25
15, September	840.00	445.75	642.88	1.344	0.71	1.03
30, September	775.00	748.40	761.70	1.240	1.20	1.22
15, October	572.50	787.83	680.17	0.916	1.26	1.09
31, October	447.50	493.69	470.60	0.716	0.79	0.75
15, November	422.50	282.33	352.42	0.676	0.45	0.56
30, November	350.00	215.14	282.57	0.560	0.34	0.45
15, December	230.00	95.36	162.68	0.368	0.15	0.26
Annual average	603.18	485.21	544.20	0.96	0.78	0.87

References

Goyal RK, Ojasvi PR and Bhati TK. 1995. Economic evaluation of water harvesting pond under arid condition, Indian Journal of Soil Conservation, 23(1): 74-76.

Narayanan HC, Itnal CJ, Krishna GB and Patil VS. 1987. An evaluation of supplemental irrigation through farm ponds on drylands, Indian Journal of Soil Conservation, 15(1): 1-6.

Sastry G and Gurmel Singh. 1993. Water harvesting and recycling engineering aspects, Indian Journal of Soil Conservation, 21(2): 40-45.

Sastry G and Mittal SP. 1987. Water harvesting and recycling engineering aspects, Indian Journal of Soil Conservation, 15(3): 17-22.

Suraj Bhan. 2009. Rainwater management, Journal of Soil & Water Conservation, 8(1): 42-48.

Wasi Ullah, Gupta SK and Dalal SS. 1972. Hydrological Measurements for Watershed Research. Jugal Kishore and Co. (Pub. Div.), Dehradun. pp 52-65.

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