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Economic evaluation of rain water harvesting systems

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■ **ABSTRACT :** A growing fraction of the human population will face water scarcity in the coming decades and this will be more acute in the rural areas of the arid and semi arid regions of the world. In this context the role of rain water harvesting systems which includes collection and storage of rain water that runs off a natural or human made surface has greatly increased. It has been observed that during rains the surface water is wasted as runoff and the groundwater table is fast declining as years go by. The water demand in the Tamilnadu Agricultural University main campus was assessed and technically feasible and economically viable agricultural and non-agricultural rainwater harvesting systems were suggested. The economic feasibility of water harvesting structures were evaluated on the basis of expected net return method, benefit-cost ratio and internal rate of return.

■ **KEY WORDS :** Economic evaluation, Rain water harvesting

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Appropriate planning in the utilization of available water sources has become essential for maximizing returns from farms. How much risk to take with respect to rainfall during the season, selection of optimal designs of rainwater harvesting structures based on cost and benefit and allocation of the available water resources in the most cost effective manner are some of the decisions that must be made.

The benefit cost ratio of an earthen embankment reservoir was worked out by Pandy and Hiran (1992). The cost of cultivation of the crops which are grown during *Rabi* and *Kharif* in the area along with the net returns with and without the implementation of the reservoir was worked out. Taking into consideration a lifespan of 10 years, the present worth of total cost and present worth of net incremental income the benefit cost ratio was worked out, which came as 1.38:1. Thus the planning was justified economically.

Sivanappan (1992) states that the investment opportunities suited to an area should be carefully evaluated in terms of costs and benefits before an investment is made. He describes all the tools of analysis that can be used to make such an evaluation. The merits and de-merits of different methods like B/C ratio, net present value and internal rate of returns (IRR) are presented. The IRR method is said to be superior compared to others.

Studies carried out in Jhanwar model watershed by Goyal *et al.* (1995) reveal that water harvesting by means of farm pond of 271 m^3 capacity coupled with ber trees in the adjoining area could sustain the system even in low rainfall situations. The benefit cost ratio of the system worked out to be 1.672 which indicates that, in order to impart stability to agricultural production on rainfed lands in arid and semi arid areas farm ponds seems to hold the key.

The Tamil Nadu Agricultural University main campus in Coimbatore spreads over an area of 324 ha with 175 ha under agricultural use depending mainly on ground water for its varied needs. It has been observed that during rains the surface water is wasted as runoff and the groundwater table is fast declining as years go by. To evolve suitable remedial measures based on a sound and scientific methodology this study was undertaken. The water demand in the campus was assessed and technically feasible and economically viable agricultural and non-agricultural rainwater harvesting systems were suggested.

■ METHODOLOGY

The economic feasibility of water harvesting structures were evaluated on the basis of expected net return method and benefit-cost ratio and internal rate of return.

Expected net return method:

Water supply reliability was used to describe the chance of attaining a given amount of water, which included initial storage and expected rainfall. As the initial storage at the start of a particular period was known, its reliability is equal to 1. The reliability of the total water supply over a period was expressed by the following equation :

$$R_y = Sv_0/W + Pr((W - Sv_0)/W)$$

where,

SV0 = Initial storage, m^3

W = Total expected water supply, m^3

Pr = Rainfall probability (fraction)

R_y will have a value between 0 and 1.

The expected net return

$$E_r = R_yT_r + ((1 - R_y)(T_r - T_c)/2)$$

where,

T_r = Target net return

T_c = Total cost

For a specific water supply amount W, the chance of attaining a target net return T_r is given by R_y. The chance of not attaining T_r is therefore, (1- R_y). If T_r is not obtained, its value will range between – T_c and a positive value less than T_r . For this condition, a mean value between – T_c and T_r was taken. For different probability values, the corresponding expected net return and reliability values were calculated and compared.

Benefit-cost ratio and internal rate of return :

The economic feasibility of the water harvesting structures was evaluated based on the following two criteria.

$$\text{Benefit-cost ratio (BCR)} = \frac{\sum_{t=1}^{T} B_t/(1+i)^t}{\sum_{t=1}^{T} C_t/(1+i)^t}$$

when the BCR is 1 or above the project is said to be worthy of consideration.

$$\text{Net present worth (NPW)} = \frac{\sum_{t=1}^{T} B_t - C_t}{(1+i)^t}$$

where,

B_t = Benefit at time t

C_t = Cost at time t

i = Interest (or discount) rate

t = Life of the project.

The internal rate of return (IRR) is that discount rate at which NPW = 0. IRR represents the average earning power of the money in the project over its life. The incremental costs and benefits resulting from the project were computed first. A discount rate was chosen and the annual incremental net flow was multiplied by it. The algebraic sum of the net flow will be either positive or negative or will be equal to zero. If the sum is zero, the chosen discount rate will be the project IRR. If the sum is positive, it is necessary to repeat the exercise with a higher discount rate. The positive value shows that the present worth of the project benefits is greater than the present worth of costs. The project could pay a higher rate of interest and still recover the capital invested.

If it turns out to be negative, a lower discount rate is adopted, until the sum value nearest to zero is reached. When the discounted present worth of cash flow is negative, it is inferred that the present worth of costs is greater than the present worth of benefits and the project cannot pay such a high rate of interest and still recover the capital investment. Now there is a need for discount rate which is on the lower side. When the IRR lies between a discount rate, too high on one side and too low on the other, IRR could be interpolated by applying the following rule:

IRR = (Lower discount rate + difference between the discount rates) - (Present worth of incremental net benefit stream at lower discount rate / sum of the present worth of incremental net benefit stream of the two discounted rates)

The IRR so derived was compared with the market rate of interest. When the IRR is higher than the cut off rate the project was considered worthy.

RESULTS AND DISCUSSION

The water supply reliability depends on the initial storage and total expected water supply over a period. The water budgeting studies revealed that almost all the weeks in a year experience a water deficit with respect to harvested water. The very small volume of surplus water in a few weeks is sufficient to meet the demands in a few successive weeks. The net availability is always a deficit and, therefore, in an annual scenario the initial storage is always zero. Hence, the reliability Ry will always be equal to the corresponding rainfall probability fraction in the present case study. The estimation of expected returns at different probability levels are shown in Table 1.

The returns and costs for the life period of the harvesting system were taken into account. The return was calculated on the basis of the total annual depth of rainfall at different probability levels. The expected returns show a decreasing trend with increase in probability. The probability at which maximum return is to be expected is selected for design and planning. 33.33 per cent probability at which annual depth of rainfall coincides with the mean annual depth of rain gives the maximum returns. The maximum volume that can be harvested is 808 m^3 and the expected return in 25 years is Rs. 47659/-.

But as planning is done on a weekly basis, in this study, a storage tank to hold this huge volume is not necessary. As already observed, the maximum mean weekly depth of rainfall coincides with the maximum weekly depth at 50 per

Table 1 : Expected net returns at different rainfall probabilities

Total returns										
PR	Total depth, mm	Roof area, m^2	Vol., m^3	Drinking water, m^3	Balance, m^3	Rate, Rs. m^{-3}		Return, Rs.		Total return, Rs.
						Drinking	Pumped	Drinking	Pumped	
33.33	709.7	1138	807.64	71.34	736.3	30	3.6	2140	2651	4791
40	508.3	1138	578.45	71.34	507.1	30	3.6	2140	1826	3966
50	341	1138	388.06	71.34	316.7	30	3.6	2140	1140	3280
60	202.6	1138	230.56	71.34	159.2	30	3.6	2140	573	2713
70	83.6	1138	95.14	71.34	23.8	30	3.6	2140	86	2226

Expected returns						
Probability, %	Yearly return	Total return (25y)	Initial cost	Maintenance cost	Total cost	Expected return
33.33	4791	119775	37881	18183	56064	61159
40	3966	99150	34253	16441	50694	54197
50	3280	82000	32907	15795	48702	49325
60	2713	67825	29892	14348	44240	45412
70	2226	55650	25353	12169	37522	41674

Table 2 : Benefit cost analysis at 33.33 per cent rainfall probability

Year	Cost	Benefit	Discount factor	Discounted cost	Discounted benefit
1	37881	3981.00	1.00	37881	3981
2	758	4180.05	0.86	650	3584
3	758	4389.05	0.79	602	3484
4	758	4608.51	0.74	557	3387
5	758	4838.93	0.68	516	3293
6	758	5080.88	0.63	478	3202
7	758	5334.92	0.58	442	3113
8	758	5601.67	0.54	410	3027
9	758	5881.75	0.50	379	2942
10	758	6175.84	0.46	351	2861
11	758	6484.63	0.43	325	2781
12	758	6808.86	0.40	301	2704
13	758	7149.30	0.37	279	2629
14	758	7506.77	0.34	258	2556
15	758	7882.11	0.32	239	2484
16	758	8276.21	0.29	221	2416
17	758	8690.02	0.27	205	2349
18	758	9124.52	0.25	190	2283
19	758	9580.75	0.23	176	2220
20	758	10059.79	0.21	163	2158
21	758	10562.78	0.20	151	2099
22	758	11090.92	0.18	139	2040
23	758	11645.46	0.17	129	1983
24	758	12227.74	0.16	120	1928
25	758	12839.12	0.15	111	1875
			Total	45273	67379
				BC	1.49

cent probability. Hence, this probability value was selected as the optimal probability level. The maximum volume that can be harvested at this level is 388 m^3 and the expected return comes to Rs. 42,800/- which is not very less than that at 33.33 per cent. Therefore, design of all rain water harvesting structures in the campus can be done based on the 50 per cent probable rainfall.

Benefit cost ratio and internal rate of return :

The benefit cost ratio of the roof water harvesting system of PPC hostel was estimated and it presented in Table 2 and 3. The BCR's at 50 per cent and 33.33 per cent probable rainfalls were calculated. Maintenance cost was taken as 2 per cent of the initial investment and the rate of increase in benefit was taken as 5 per cent of the previous year. The discount rate was considered as 8 per cent as the current interest for agricultural loans are around 8 per cent. The ratio of the sum of discounted benefits and costs for the life of 25 years gave the BC ratio as 1.33 for 50 per cent probable rainfall and 1.48 for 33.33 per cent. Since both these values are above one, both of them are feasible projects. In accordance with the earlier discussion the project based on 50 per cent probable rainfall can be selected for implementation.

The internal rate of return which shows how much the new investment of capital will earn in terms of the present value was computed and is depicted in Table 4. The present lending rate of 8 per cent was chosen as the discount rate first and the present worth was found out. It showed a positive discounted cash flow. This shows that the present worth of the project benefits is greater than the present worth of costs and the project can pay a higher rate of interest and still recover the capital invested.

This exercise was repeated with higher discount rates and the algebraic sum of the discounted cash flow becomes negative at 12 per cent discount rate. This shows that the present worth of cost is greater than the present worth of benefits and the project can not pay such a high rate of interest and recover the capital. Therefore, the internal rate of return was interpolated as follows.

Table 3 : Benefit cost analysis at 50 per cent rainfall probability

Year	Cost	Benefit	Discount factor	Discounted cost	Discounted benefit
1	32907	2932.00	0.93	30469	2715
2	658	3078.60	0.86	564	2639
3	658	3232.53	0.79	522	2566
4	658	3394.16	0.74	484	2495
5	658	3563.86	0.68	448	2426
6	658	3742.06	0.63	415	2358
7	658	3929.16	0.58	384	2293
8	658	4125.62	0.54	356	2229
9	658	4331.90	0.50	329	2167
10	658	4548.49	0.46	305	2107
11	658	4775.92	0.43	282	2048
12	658	5014.71	0.40	261	1991
13	658	5265.45	0.37	242	1936
14	658	5528.72	0.34	224	1883
15	658	5805.16	0.32	207	1830
16	658	6095.42	0.29	192	1779
17	658	6400.19	0.27	178	1730
18	658	6720.20	0.25	165	1681
19	658	7056.21	0.23	152	1635
20	658	7409.02	0.21	141	1589
21	658	7779.47	0.20	131	1546
22	658	8168.44	0.18	121	1502
23	658	8576.86	0.17	112	1461
24	658	9005.71	0.16	104	1420
25	658	9455.99	0.15	96	1381
			Total	36884	49407
				BC	1.34

Table 4 : Internal rate of return

Year	Cost	Benefit	Cash flow	Disc. fact at 8%	Present worth	Disc fact at 12%	Present worth
1	32907	2932.00	-29975.00	0.93	-27753.85	0.89	-26764.68
2	658	3078.60	2420.60	0.86	2075.18	0.80	1929.70
3	658	3232.53	2574.53	0.79	2043.66	0.71	1832.55
4	658	3394.16	2736.16	0.74	2011.08	0.64	1738.83
5	658	3563.86	2905.86	0.68	1977.73	0.57	1648.79
6	658	3742.06	3084.06	0.63	1943.57	0.51	1562.38
7	658	3929.16	3271.16	0.58	1908.72	0.45	1479.55
8	658	4125.62	3467.62	0.54	1873.55	0.40	1400.57
9	658	4331.90	3673.90	0.50	1837.68	0.36	1324.81
10	658	4548.49	3890.49	0.46	1802.08	0.32	1252.74
11	658	4775.92	4117.92	0.43	1766.18	0.29	1183.90
12	658	5014.71	4356.71	0.40	1730.05	0.26	1118.37
13	658	5265.45	4607.45	0.37	1694.16	0.23	1056.03
14	658	5528.72	4870.72	0.34	1658.48	0.20	996.55
15	658	5805.16	5147.16	0.32	1622.38	0.18	940.39
16	658	6095.42	5437.42	0.29	1587.18	0.16	886.84
17	658	6400.19	5742.19	0.27	1552.11	0.15	836.06
18	658	6720.20	6062.20	0.25	1516.76	0.13	788.09
19	658	7056.21	6398.21	0.23	1482.46	0.12	742.83
20	658	7409.02	6751.02	0.21	1448.09	0.10	700.08
21	658	7779.47	7121.47	0.20	1415.04	0.09	659.45
22	658	8168.44	7510.44	0.18	1381.17	0.08	620.36
23	658	8576.86	7918.86	0.17	1348.58	0.07	584.41
24	658	9005.71	8347.71	0.16	1316.43	0.07	550.11
25	658	9455.99	8797.99	0.15	1284.51	0.06	517.32
					12523		-413.97

$$\textbf{Internal rate of return} = 8 + \mathbf{4}\left[\frac{\mathbf{12523}}{\mathbf{12937}}\right]$$

$= 8 + 4\,(0.96)$

$= 11.87$ per cent

Hence, the rate of interest up to which this project will be profitable is 11.87 per cent which is not much higher than the current lending rate of the banks.

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