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Enhancing Rainwater Productivity and Economic Viability of Rainfed Crops through Tank Silt Application

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ABSTRACT: A study was carried for treated and untreated silt application at four centers namely Nalgonda (Telangana), Warangal, (Telangana) Anantapur (Andhra Pradesh) and Kolar (Karnataka) under farmers participatory action research programme (FPARP) conducted in 2008-09 and 2009-10. The data were collected from these centers and analyzed. The results showed that the contribution of silt application during second year (2009-10) was more pronounced although 2009 was a mega drought year. Rainwater productivity in terms of yields without and with silt application during 2009-10 (2^{nd} year) varied from 0.29 and 0.33 kg/ha/mm in case of mulberry in Kolar to 2.07 and 3.34 kg/ha/mm in groundnut in Anantapur, respectively. Significantly higher yield increase in treated with silt over untreated registered in case of castor (229% or 2.52 q/ha) in Nalgonda and groundnut (153% or 4.07 q/ha) in Anantapur while it was non-significant in case of cotton in Warangal and mulberry in Kolar during 2008-09. Across the crops and between the treated *versus* untreated trials and years, cotton in Warangal district registered the highest benefit-cost ratio in treated (3.75) and untreated (3.14) trials. Water productivity of crops in terms of income accrued per millimeter of water was found to be higher with silt application than without in both the years in all the centers, however, year 2009-10 was better than 2008-09. The additional benefits to cost ratio (BCR) ranged between 5.16 in case of cotton in Warangal and 0.25 in case of mulberry in Kolar. The pay back period (PBP) and BCR at 12% discount rate of silt application in castor cultivation was found to be 6 years and 1.70, respectively while internal rate of return (IRR) worked out to 30%.

Key words: Tank silt, recycling, rainwater productivity and economic viability

In India, higher water productivity and income from rainfed agriculture is constrained by erratic rainfall, low moisture status of soils, poor *in-situ* moisture conservation practices and poor groundwater resources (for supplemental irrigation), besides lack of balanced fertilization and addition of organic matter through different sources. Productivity and profitability from rainfed agriculture can be enhanced along with conservation of natural resources like soil, rainwater and efficient use of nutrients. Under high risk, low productivity and fragile rainfed farming situation, 'water bodies' are found to be the way out after watersheds. Among various water harvesting structures at landscape level, tanks are the most viable, socially acceptable and time tested option to mitigate drought and floods. Of late, their restoration and rejuvenation are being taken through renewed efforts of desilting and recycling like in "Mission Kakatiya" of Telangana State, Sujala-III in Karnataka and National Project for Repair, Renovation and Restoration of Water Bodies (RRR) of Ministry of Water Resources, Government of India. These programs will not only enhance crop yields, mitigate drought and floods but also improve soil health. Tank silt is a rich mine containing all the needed macro and micro nutrients essential for plant growth and also a good source of organic matter.

Droughts and floods are common to rainfed areas and tanks act as drought mitigators and flood moderators. Tanks are eco-friendly and farmers'-friendly. As such, multi-functionality of tanks is well documented (CRIDA, 2006; DHAN, 2004 and Osman *et al*., 2001). The strategy of desilting and its recycling will not only rejuvenate tanks but also improve recharge of groundwater besides improving the soil properties in a cost-effective manner. Small storages like tanks are much more appropriate and effective for groundwater recharge (Mc Cully, 2006) and will also arrest siltation of large reservoirs built at huge cost. The programs for tank management in recent decades have been inadequate in scale, misconceived in design, poor implementation and dubious in their impact (Vaidyanathan, 2001). Thus, there is need of renewed focus on research, new and innovative approaches in development and support services matching with resource allocation and augmentation. There is also possibility of substituting inorganic fertilizers with silt as an organic amendment for improving soil quality, increasing crop productivity, rainwater productivity and economic viability of crop production in rainfed areas. The present study is an attempt in this direction.

Materials and Methods

The study is part of Farmers' Participatory Action Research Program (FPARP) of Ministry of Water Resource, Government of India entitled "Tank Silt as an Organic Amendment for Improving Soil and Water Productivity" implemented by CRIDA in four centers namely, Nalgonda (Telangana) Warangal (Telangana), Anantapur (Andhra Pradesh) and Kolar (Karnataka) during 2008-09 & 2009-10 in collaboration with All India Coordinated Research Project for Dryland Agriculture (AICRPDA) of SAUs and NGOs namely, PEACE (NGO, Nalgonda), MARI (NGO, Warangal), Anantapur (AICRPDA, ORP) and MEOS, NGO) and Kolar (AICRPDA, ORP Bangalore and AME, NGO). The sample farmers (beneficiaries) identified were 20, 22, 20 and 20, respectively across these four centers. Castor, cotton, groundnut and mulberry are the dominant crops focused in this study as they were the main crops in these centres. "Untreated (without tank silt application) and treated (with tank silt application)" approach was followed for two years for this study. The trials were conducted in farmers' fields in 'participatory mode' and data were collected and analyzed for two cropping seasons. The rate of silt application to farmers' fields was based on textural property of tank sediment and field soil. A user-friendly MS - Excel based tank silt applicator was developed and is available on CRIDA website for deciding number of tractor trolley loads based on either physical or chemical characteristics of tank silt (Figure 1). In this study, tank silt applicator was employed using textural property of both tank sediment and field soil and aimed at improving the clay content of field soil surface (0-15 cm) up to 10%. Textural analysis (sand, silt and clay content) of tank sediment and field soil was carried out by employing standard procedure using hydrometer. The number of tractor trolleys varied between 100 to 120 loads per hectare depending on clay content of tank silt, which amounted to 2.5 cm depth of application.

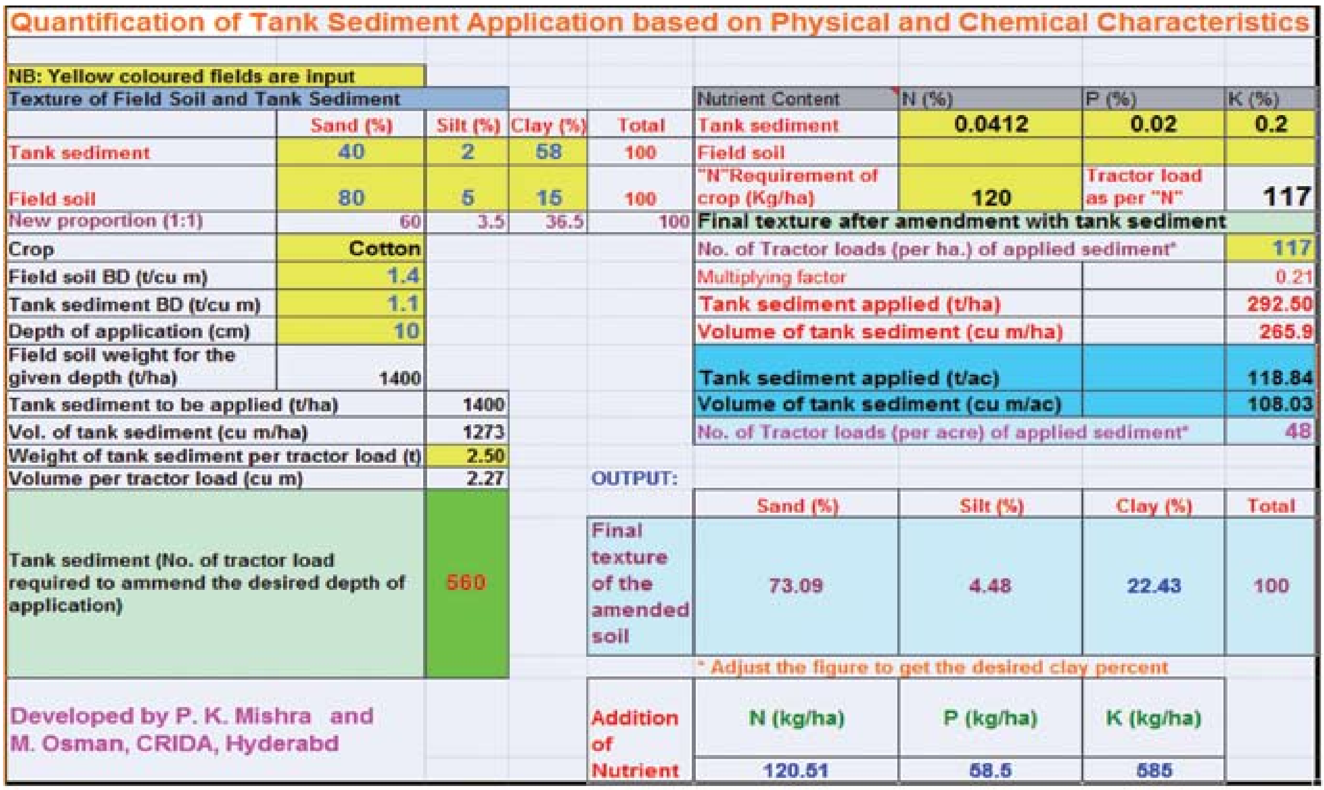

Fig. 1 : Graphic user interface indicating rate of application of tank silt based on textural property of tank silt and field soil and also based on N content of tank silt (www.crida.in/services/tanksilt applicator)

Economic analysis for silt application once in a life time of 25 years using discount factor method

Economic analysis for silt application using discount factor method is exclusively applicable to the low income generating crops like castor, finger millet, etc. ranging from 25 to 30% of the investment made or one time cost incurred on cultivation of the annual arable crops or orchards/tree crops that takes 5 to 6 years to generate income. In this study, an attempt was made for castor crop (I year, as an example) in Nalgonda district. The per ha cost of 100 tractor loads of tank silt incurred for cultivation of castor was worked out to be ₹ 10,000. This is nothing but per ha average additional cost of cultivation of castor incurred only once in a life time of 25 years. However, the improvement in texture of soil is a permanent feature. The average annual additional income accrued per ha of the crop registered ₹ 2570, however, for economic analysis, 5% annual inflation was considered for both the cost and returns using discount factor over a period of 25 years. The methodology adopted by Gittinger (1972) was followed for determining pay back period (PBP), benefit-cost ratio (BCR) and internal rate of return (IRR) without considering intangible benefits of the treatment.

$$PBP = \sum_{t=1}^{n} \frac{B_n}{(1+i)^n} = \sum_{t=1}^{n} \frac{C_n}{(1+i)^n} \text{ --------------- } (1)$$

$$BCR = \sum_{t=1}^{n} \frac{B_n}{(1+i)^n} \Big/ \sum_{t=1}^{n} \frac{C_n}{(1+i)^n} \text{ --------------- } (2)$$

$$IRR = \sum_{t=1}^{n} \frac{B_n - C_n}{(1+i)^n} = 0 \text{ --------------------- } (3)$$

Where, B_n = present value of benefits accrued in each year (n = 1,2,3…….............................….25)

C_n = present value of costs involved in each year (n = 1,2,3…….............................….25)

n = number of years, i.e 25

i = interest (discount) rate

If the value of BCR is greater than unity, it is considered as economically viable and profitable and *vice versa.* Benefit-cost ratios (BCRs) and incremental/ additional BCRs were worked out for treated and untreated trials to know the economic viability of crops for the two trials and years in the four centers. Student t-test was applied to test the hypothesis of improvement in productivity of crops with recycling of silt. Osman *et al.*, (2006) attempted BCRs for treated and untreated treatments with silt in production of cotton and chillies. To arrive at IRR, discounted cash flow (incremental benefit) was worked out for measuring the worth of silt application in the cultivation of castor at which (discount rate) just made the net present value of cash flow to zero.

Results and Discussion

Productivity Enhancement

Across the crops and centres in 2008-09, castor in Nalgonda and groundnut in Anantapur were found to be highly significant while cotton in Warangal and mulberry in Kolar were non-significant. Castor and groundnut registered significantly higher yield increase (229% and 153%) in Nalgonda and Anantapur, respectively while lower yield increase registered in case of cotton (19%) in Warangal and as low as four per cent in case of mulberry crop in Kolar (Table 1). Lower yield increase of mulberry crop is indicative of the fact that silt application had minimal effect on established perennial plant, however, farmers noticed improvement in quality of mulberry leaves and higher intake by silk worms.

Table 1 : Comparative yields of crops without and with silt application during 2008-09 and 2009-10 (q/ha)

District (state)	Crop	2008-09				2009-10			
		Treated with silt	Un treated	p value**	% increase	Treated with silt	Un treated	p value**	% increase
Nalgonda (Telangana)	Castor*	3.62 ± 0.919	1.10 ± 0.880	0.04	229.1	11.75 ± 0.060	5.25 ± 0.040	0.00	124.0
Warangal (Telangana)	Cotton	21.14 ± 1.075	19.43 ± 1.030	0.26	18.5	25.15 ± 1.068	16.02 ± 0792	0.00	57.0
Anantapur (Andhra Pradesh)	Groundnut	6.88 ± 0.531	2.81 ± 0.248	0.00	152.6	11.69 ± 0.974	7.23 ± 0.700	0.00	61.7
Kolar (Karnataka)	Mulberry	28.8 ± 3.13	27.5 ± 3.17	0.78	4.3	11.2 ± 1.07	9.9 ± 0.90	0.37	13.1

*indicates substitution of castor with cotton during second year in the same plot; ** probability corresponding to t-test

Rainwater Productivity

Efficient utilization in terms of yield(s) per millimeter of rainwater (kg/ha) use was noticed in treated trials in the second year (2009-10) than the first year (2008-09) in all the crops except mulberry in Kolar (Table 2(a)). The response was high even in severe drought year (2009) indicating higher impact of silt application in realizing higher rainwater use in Nalgonda, Warangal and Anantapur districts. The impact of silt application on mulberry was not high as it was an established perennial plant. Higher water use efficiency registered in case of cotton in place of castor, cotton and groundnut in Nalgonda, Warangal and Anantapur districts were attributed mainly to the better soil mixing (aggregation) in the second year, respectively.

The yields without and with silt application during 2008-09 (I year) varied from 0.14 and 0.48 kg/ha/mm in case of castor in Nalgonda to 2.17 and 2.57 kg/ha/mm in case of cotton in Warangal, respectively. While the yields with silt application during 2009-10 (2nd year) ranged between 0.33 kg/ha/mm in case of mulberry in Kolar and 3.89 kg/ha/mm in case of cotton (the farmers preferred cotton to castor in the same plot in 2nd year) in Nalgonda but, the yields without silt application varied from as low as 0.29 kg/ha/mm in case of mulberry in Kolar to 2.07 kg/ha/mm in case of groundnut in Anantapur. The lower yield of castor in 2008-09 was due to the highly erratic and uneven distribution of rainfall i.e., rainfall started late in mid July and ended in September in 2008. Thus, the application of silt has resulted in resilience to moisture stress in terms of more or less normal crops yield.

Table 2(a) : Rainwater use in different crops w.r.t yield

District	Crop	Rainwater use (kg/ha/mm)			
		2008-09 (year I)		2009-10 (year II)	
		With silt	Without silt	With silt	Without silt
Nalgonda	Castor*	0.48	0.14	3.89	1.74
Warangal	Cotton	2.57	2.17	3.35	2.00
Anantapur	Groundnut	1.86	0.74	3.34	2.07
Kolar	Mulberry	0.52	0.50	0.33	0.29

* The farmers preferred cotton in the same plot during second year

Table 2(b): Water productivity in terms of ₹/ha/mm (Constant at 2008)

District	Crop	Water productivity (₹/ha/mm)			
		2008-09 (year I)		2009-10 (year II)	
		With silt	Without silt	With silt	Without silt
Nalgonda	Castor*	10.9	3.3	116.7	52.2
Warangal	Cotton	72.6	61.3	100.5	60.0
Anantapur	Groundnut	46.0	14.8	84.5	47.0
Kolar	Mulberry	83.7	80.5	63.3	54.1

*indicates substitution of castor with cotton during second year in the same plot

Income per unit of water (₹/ha/mm)

Table 2(b) shows higher rainwater use in terms of income per millimeter of water in the second year than in the first year. As expected, the rainwater use was higher with silt application than without silt in all the crops in the four selected districts in both the years. The income accrued with silt application in the second year varied from 63.3 (₹/ha/mm) in case of mulberry in Kolar to 116.7 (₹/ha/mm) in cotton in Nalgonda. Similarly, the income accrued without silt application in the II year ranged between 47.0 and 60.0 ₹/ha/mm in case of groundnut and cotton in Anantapur and Warangal, respectively (Table 2(b)). The reasons attributed for these variations is similar as cited in the case of yield per millimeter of water.

While in first year, the higher income accrued with silt application ranged between 10.9 (₹/ha/mm) in castor in Nalgonda and 83.7 (₹/ha/mm) in mulberry in Kolar. However, the income derived without silt application varied from 3.3 (₹/ha/mm) in case of castor in Nalgonda to 80.5 (₹/ha/mm) in mulberry in Kolar. Thus, it is evident from the above that water productivity in terms of yield and income accrued per millimeter of water was found to be higher with silt application than without silt application indicating the positive impact of silt application irrespective of erratic behaviour of monsoon.

Economics of crops

Across the crops cultivated in the four districts in 2008-09 (I year), the per ha cost of cultivation involved in treated trials ranged between ₹ 29403 in case of cotton in Warangal and ₹ 14929 in case of castor in Nalgonda while the returns accrued varied from ₹ 60276 to ₹ 8211 in Warangal and Nalgonda districts, respectively. As such, BCR ranged between 2.05 and 0.55 for cotton and castor in Warangal and Nalgonda, respectively (Table 3(a)).

Table 3(a) : Economics of crops with and without silt application for different centers, 2008-09 (Constant at 2008)

District	Crop	With (treated)			Without (untreated)		
		Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	BCR	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	BCR
Nalgonda	Castor*	14929	8211	0.55	11175	5641	0.50
Warangal	Cotton	29403	60276	2.05	23287	55423	2.38
Anantapur	Groundnut	15850	20288	1.28	8025	6741	0.84
Kolar	Mulberry	25932	43311	1.67	13728	41603	3.03

*indicates substitution of castor with cotton during second year in the same plot

In untreated trials, the per ha cost of cultivation incurred varied from ₹ 23287 in case of cotton in Warangal to ₹ 8025 in case of groundnut in Anantapur while the returns accrued ranged between ₹ 55423 in case of cotton in Warangal and ₹ 5641 in case of castor in Nalgonda district. The BCRs varied from 3.03 in case of mulberry in Kolar to 0.50 in case of castor in Nalgonda district in 2008-09. In 2009-10, as expected the per ha costs and returns of crops registered higher in treated trials than untreated in each of the four districts (Table 3(b)).

Table 3(b) : Economics of crops with and without silt application for different centers, 2009-10(Constant at 2008)

District	Crop	With (treated)			Without (untreated)		
		Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	BCR	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	BCR
Nalgonda	Castor*	12189	30230	2.48	8435	12820	1.52
Warangal	Cotton	20280	76050	3.75	14164	44475	3.14
Anantapur	Groundnut	18085	29660	1.64	10537	15595	1.48
Kolar	Mulberry	18086	21520	1.19	5882	18470	3.14

*indicates substitution of castor with cotton during second year in the same plot

It may be seen that in treated trials, the per ha cost of cultivation involved ranged between ₹ 20280 in case of cotton in Warangal and ₹ 12189 in case of cotton in Nalgonda (the farmers preferred cotton to castor in the same plot in the second year) while returns accrued varied from ₹ 76050 in case of cotton in Warangal to ₹ 21520 in case of mulberry in Kolar. BCR ranged between 3.75 and 1.19 in Warangal and Kolar, respectively. In untreated plots, the BCR ranged between 3.14 and 1.48 in case of cotton and groundnut in Kolar and Anantapur, respectively.

Economics of technology (impact of silt application)

Economics of silt application as a potential technology for crop improvement was analyzed at two levels. Firstly using the figures of yield and income at current prices. Then the data were analyzed in the investment analysis mode. For the first approach, the incremental costs and returns analysis was used, while for the investment analysis, discounting factor method was employed.

Impact of silt application reveals that the additional returns accrued per ha due to silt application registered higher in the second year (2009-10) compared to the first year (2008-09) in all the crops across the four districts. While marginal difference in additional cost incurred (cost of silt application) was found in Anantapur between the two years but, no difference in additional cost was noticed in Nalgonda, Warangal and Kolar. Evidently, higher additional BCRs registered in the second year than in the first year (Table 4). In the second year among the different crops grown in the four districts, additional BCRs were found to be higher in cotton (5.16) in Warangal indicating that for every one rupee per ha of additional investment made on production of cotton resulted to accrue additional gross returns of over ₹ 5.00 followed by cotton (4.46) in Nalgonda, groundnut (1.86) in Anantapur and as low as 0.25 in case of mulberry in Kolar indicating that the silt application was of no use for already established plants in moderately good soils.

Table 4 : Economics of technology (impact of silt application)

District /State	Crop	I-year			II-year		
		Additional cost (₹/ha)	Additional returns (₹/ha)	BCR	Additional cost (₹/ha)	Additional returns (₹/ha)	BCR
Nalgonda (T)	Castor*	3754	2570	0.68	3754	17410	4.64
Warangal (T)	Cotton	6116	4853	0.79	6116	31575	5.16
Anantapur (AP)	Groundnut	7825	13541	1.73	7548	14065	1.86
Kolar (K)	Mulberry	12204	1708	0.14	12204	3050	0.25

*indicates substitution of castor with cotton during second year in the same plot
AP = Andhra Pradesh T = Telangana K = Karnataka

Table 5 : Economic analysis for silt application in cultivation of castor in Nalgonda, 2008-09

Year	Average cost (₹/ha)	DF 12%	Present worth 12% (₹/ha)	Income (₹/ha)	Present worth 12% (₹/ha)	Incremental benefit (cash flow) (₹/ha)	Present worth 12% (₹/ha)	DF 25%	Present worth (₹/ha)	DF 30%	Present worth (₹/ha)
1	10000	0.893	8930	2570	2295	-7430	-6635	0.800	-5944	0.769	-5714
2	500	0.797	399	2699	2151	2199	1752	0.640	1407	0.592	1302
3	500	0.712	356	2699	1922	2199	1566	0.512	1126	0.455	1001
4	500	0.636	318	2699	1717	2199	1399	0.410	902	0.350	770
5	500	0.567	284	2699	1530	2199	1246	0.328	721	0.269	592
6	500	0.507	254	2699	1368	2199	1115	0.262	576	0.207	455
7	500	0.452	226	2699	1220	2199	994	0.210	462	0.159	350
8	500	0.404	202	2699	1090	2199	888	0.168	369	0.123	270
9	500	0.361	181	2699	974	2199	794	0.134	295	0.094	207
10	500	0.322	161	2699	869	2199	708	0.107	235	0.073	161
11	500	0.287	144	2699	775	2199	631	0.086	189	0.056	123
12	500	0.257	129	2699	694	2199	565	0.069	152	0.043	95
13	500	0.229	115	2699	618	2199	504	0.055	121	0.033	73
14	500	0.205	103	2699	553	2199	451	0.044	97	0.025	55
15	500	0.183	92	2699	494	2199	402	0.035	77	0.020	44
16	500	0.163	82	2699	440	2199	358	0.028	62	0.015	33
17	500	0.146	73	2699	394	2199	321	0.023	51	0.012	26
18	500	0.130	65	2699	351	2199	286	0.018	40	0.009	20
19	500	0.116	58	2699	313	2199	255	0.014	31	0.007	15
20	500	0.104	52	2699	281	2199	229	0.012	26	0.005	11
21	500	0.093	47	2699	251	2199	205	0.009	20	0.004	9
22	500	0.083	42	2699	224	2199	183	0.007	15	0.003	7
23	500	0.074	37	2699	200	2199	163	0.006	13	0.002	4
24	500	0.066	33	2699	178	2199	145	0.005	11	0.002	4
25	500	0.059	30	2699	159	2199	130	0.004	9	0.001	2
	22000	7.846	12413	67346	21061	45346	8655		1063		-85

$$\text{Benefit -cost ratio at 12\%} = \frac{21061}{12413} = 1.70$$

$$\text{Internal rate of return} = 25 + 5\left(\frac{1063}{1063+85}\right) = 30\%$$

Pay back period = 6 years

In the first year, the higher additional BCRs were recorded in case of groundnut (1.73) in Anantapur followed by cotton (0.79) in Warangal, castor (0.68) in Nalgonda while it was lower in mulberry (0.14) in Kolar. Thus, the additional costs and returns analysis gives an extent of profitability and viability of crops for sound agro-climatic regional planning.

Economic analysis for silt application (discount factor method)

It was found that the pay back period was 6 years at which the present value of returns (income) accrued crossed the present value of costs incurred (Table 5). The BCR for silt application in castor growing fields registered 1.70 which was more than unity at 12% discount rate. The present value of benefits accrued was more than the present value of costs incurred implying that the growers of castor crop were recovering the entire amount (@ ₹ 10,000 per ha) spent by the implementing agency in 6 years.

IRR of silt application in cultivation of castor worked out to be higher (30%) indicating that at a discount rate of 30%, the silt application in castor bean cultivation just breaks even, i.e., that growers would earn back the entire investment (@ ₹ 10,000 per ha by implementing agency) and in addition to the amount of 5% annual inflation as operating cost incurred by the farmers in silt application of castor farms and by receiving 30% for the use of money in the meantime. Thus, the study indicates that recycling of tank silt not only will be economically viable but also eco-friendly. Another dimension of tank silt use for agriculture is employment generation and related economic activity in the process besides creation of an additional water storage capacity in tanks. Earlier studies documented the additional benefits like increased soil microbial bio-diversity and improved soil quality (Osman *et al*., 2009).

Conclusions

Silt application technology not only helped the farmers in making their soil rich and get "More Crop and Income Per Drop of Water" but also motivated farmers to diversify to other crops for realizing higher returns. Recycling of silt in rainfed areas not only improves yield and income but also makes use of rainwater efficiently and mitigate dry spells. It is in this backdrop that certain public funded schemes like MGNREGS has included tank desilting as one of the priority works. This common traditional practice that was given up must be revived to benefit not only the cause of natural resources build up but also for enhancing farm productivity and income.

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