Economic Affairs 2014, 59(3) : 389-402

New Delhi Publishers

Economic Affairs

RESEARCH PAPER

59(3): 2014: DOI 10.5958/0976-4666.2014.00007.2

Secondary Storage Reservoir: A Potential Option for Rainwater Harvesting in Irrigated Command for Improved Irrigation and Agricultural Performance

A. Mishra[1], S.Ghosh[2], R.K.Mohanty[3], P.S.Brahmanand[4] and H.C.Verma[5]

[1]International Water Management Institute, Southern Africa Office, Pretoria, South Africa.
[2]Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal-731236, India.
[3 &4] Directorate of Water Management (ICAR), Bhubaneswar -751023, India.
[5]Central Institute for Sub Tropical Horticulture (ICAR), Lucknow-227107, India.

✉Correspoding author: souvik.ghosh@visva-bharati.ac.in

Paper No. 147 Received: 22th April, 2014 Accepted: 20 September, 2014

Abstract

Present study recommends an option to overcome the limited water availability in surface irrigation system through provision of secondary reservoirs in the command. The harvested water can be utilized for irrigation in the dry season, short duration fish culture, etc. Approximately 10% of the command area is required for the secondary reservoir with assumption of 50% capacity of the main reservoir will be available for irrigating dry season crops. The demonstration of use of water from the secondary reservoir in addition to the water from main reservoir has resulted in substantial crop and fish yield. The gross and net returns from various cropping patterns considered using irrigation water from main reservoir (MR) and from main and secondary reservoir (MR+SR). Among the cropping patterns considered, rice-tomato cropping pattern resulted in highest net return of INR 29,457/ha followed by rice-brinjal cropping pattern (INR 22,430/ha) with benefit cost ratio of 2.07 and 1.79, respectively. Highest benefit-cost ratio of 2.09 was obtained for rice-sunflower cropping system due to relatively lower cost of cultivation of sunflower. The highest incremental value of net returns of 3710 ₹/ha was obtained with rice-tomato cropping system. The low input-based scientific fish culture in the secondary reservoir has enhanced the fish yield by three fold over traditional practice increasing the gross return from the system. The economic analysis also revealed that the intervention is economically viable.

Keywords: Secondary reservoir, surface irrigation, cropping pattern, fish culture, net return

Introduction

Over last few decades, rapid expansion of irrigation facilities has taken place globally as well as in India. The demand for creation of water resources is increasing along with the need to enhance agricultural production to fulfil the requirement of the growing population. In India, irrigated agriculture in about 42% of net sown area contributes to 60% of the country's total food grain production. Created irrigated potential of the country has gone up from 22.6 M ha in 1950-51 to about 123 M ha at present including 42 M ha under major and medium irrigation project, 14 and 67 M ha under minor surface and minor lift project, respectively. At the same time, the gap (32 M ha) between the potential created (123 M ha) and utilized (91 M ha) has been increasing. This necessitates to identify and prioritise the problems in irrigated agriculture and to provide integrated action plan addressing such challenge. The problems in irrigation sector in India are low irrigation efficiency (30-35%), deteriorating physical structures, inadequate maintenance, low cost recovery, under-utilization (74%) of created potential, uncontrolled water delivery, tail-end water deprivation, seepage loss, siltation, waterlogging and soil salinity.Therefore, the thrust is now focused on growth, efficient management and sustainability of irrigated agriculture.

Owing to inadequate availability of irrigation water in the reservoir, many of the flow based irrigation projects suffer from poor irrigation intensity and cropping intensity. There is no proper crop planning especially during dry season taking into account the availability of irrigation water in the reservoir. Higher crop coverage sometimes leads to severe scarcity of irrigation water in the advanced crop growth stages thereby restricting the productivity of the crop significantly less than the yield potential. Therefore, the challenges of food security in irrigation sector calls for development of suitable ways and means to bring improvement in the performance level. One of the ways to improve the performance of the irrigated agriculture is by augmenting the water resource status, thereby overcoming the inadequate irrigation water availability.

The Concept

The overall objective of this article is to illustrate the concept and methodology of augmenting the water resource scenario of surface irrigation projects which suffer badly from inadequate irrigation water availability during dry season. The possibility of increasing the capacity of the main reservoir in these irrigation projects is extremely remote. Therefore, the concept of creating secondary storage reservoir in the command of each outlet can be a potential option in enhancing the water resource status. These reservoirs will harvest the rainwater during monsoon as well as capture excess irrigation water, if any, at the time of each irrigation. The harvested water in the secondary reservoir will be utilized for raising crops in the dry season along with the left out water available in the main reservoir after meeting the requirement of rainy season crops. The augmented water resource can be utilized in more effective and productive manner through multiple use management. The definition sketch of the proposed secondary storage reservoir is shown in Figure 1.

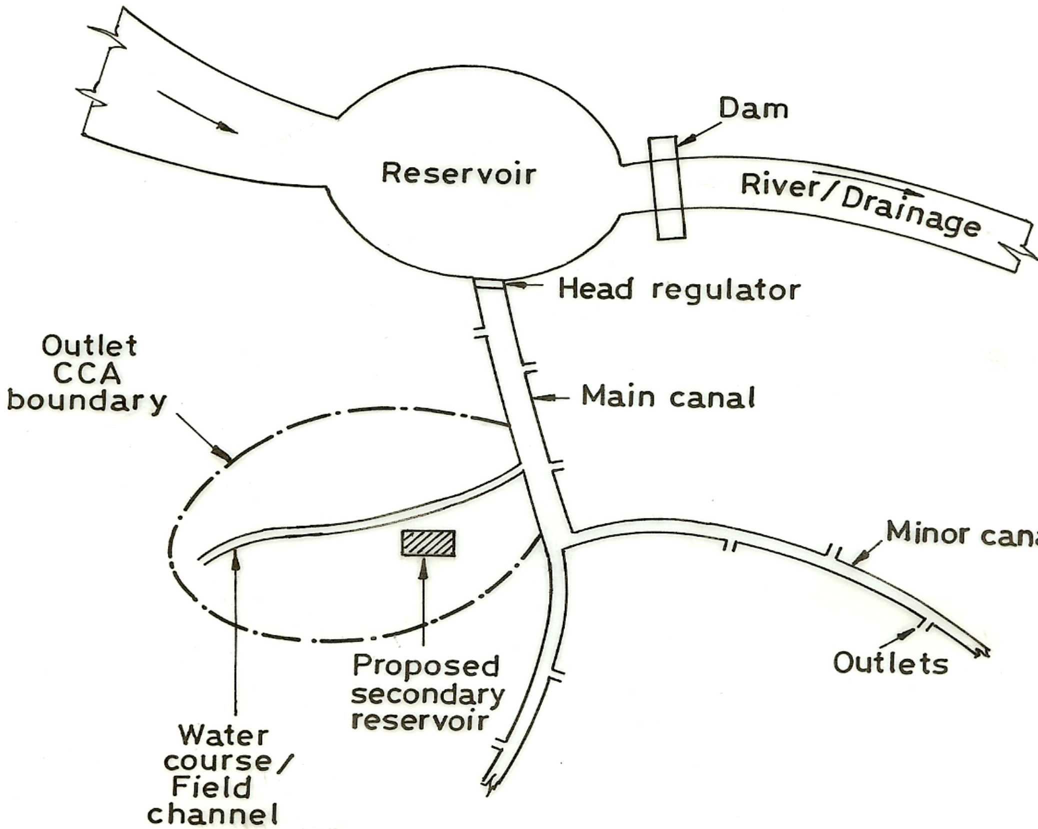

Fig. 1 Definition sketch of the proposed secondary reservoir in the surface irrigation project

In the past, several researchers have studied different aspects of secondary storage reservoir concept in the command of major irrigation projects. It is recommended that for effective and efficient use of water, it is essential for every farm entity to have a service reservoir so that the farmer can use his allocation at his convenience, both in regard to time of irrigation and size of the stream (Zimmerman, 1966). The main function of auxiliary reservoir is to supplement and absorb the spill of main reservoir (Sharma and Sharma, 1990). The need for provision of auxiliary storage reservoirs at strategic points within the canal system to buffer the mismatch between water supply and demand was explained by Gowing *et al.* (2004). This would also improve service delivery and better recovery of return flows. It was also mentioned that these secondary reservoirs may provide opportunities for multiple-use management and increased productivity of irrigation water. A large number of secondary reservoirs to reduce the management problems and enhance non-irrigation usage of water in a large scale irrigation project is also recommended. Methods have been worked out to specify the optimal sizes and locations of farm service reservoirs within an irrigation project (Khanjani and Busch, 1983). The role of irrigation water authorities in maintenance of secondary reservoir and importance of crop and hydrological models in optimum irrigation management decision support system have been emphasized (Lorite *et al.*, 2005). The effective performance of irrigation water delivery with introduction of auxiliary storage reservoir at the farm outlet level has been observed (Mishra and Tyagi, 1988).

Mishra *et al.* (2009) explored the scope and feasibility of auxiliary storage reservoir in the outlet command of a flow based minor irrigation project to overcome the inadequate irrigation water availability during the dry season. Assuming that about 50% main reservoir capacity water will be available for irrigating dry season crops and fixing the first priority level of the objective function as maximization of net seasonal benefit and maximization of cropped area, the optimal surface area for auxiliary storage reservoir as the percentage of the command area has been obtained as 17.40% and 10.92%, respectively.

The performance of the minor irrigation project significantly increased due to provision of auxiliary storage reservoir. Utilization of the harvested water in the secondary reservoir for irrigating dry season crop in addition to the irrigation water from the main reservoir has resulted in increasing the yield of crops (Mishra *et al.*, 2013). The economic analysis also revealed that the intervention is economically viable. The importance of water harvesting and supplemental irrigation to crops was also emphasized by Oweis and Hachum, 2003 and Molden *et al.*, 2010.

Field Testing Feasibility Study of Secondary Reservoir

The scope and feasibility of introducing secondary storage reservoir in the outlets command of Devijhar Minor (flow) Irrigation Project's command area in Khalikote block of Ganjam district in Odisha was field demonstrated. The objective was to augment the water resource scenario of Devijhar minor irrigation project (command area of 500 ha) which suffers badly from inadequate irrigation water availability during dry season. The possibility of increasing the capacity of the main reservoir is remote. Therefore, the concept of secondary storage reservoir in the command of each outlet was hypothesized for harvesting the rainwater during monsoon as well as capturing excess irrigation water, if any during each irrigation supply period. About 54 existing water bodies (both individually owned and community owned) in the command of the study system were delineated covering water spread area of about 55 ha. These water bodies could act as secondary reservoir with required minor modifications (desilting, providing inlet, outlet, etc). Hence, in the chosen study system, secondary reservoirs are proposed to be created by renovation of existing defunct water bodies in irrigation command which will result in no loss of cultivated land and no loss of value of production.

Among the 54 identified water bodies, a community owned water body located in Kamarsingh village in the command of outlet 8R of the main canal system (having water spread area of 700 m^2 and depth of 3.6 m) was selected for field demonstration and treated as secondary storage reservoir. The canal outlet 8R has a design discharge of 19.6 lit/sec and command area of 17.98 ha with 34 beneficiary farmers. Effective utilization of stored water from this secondary reservoir was field demonstrated in two successive years (2006–2008) by irrigating the dry season crops and growing fish in the secondary reservoir. Farmers having their lands in the vicinity of the secondary reservoir were encouraged to grow vegetables and oilseed crops in the dry season utilizing the water from it through a 3.5 HP pump set. The secondary reservoir stores the excess irrigation water supplied through the canal system from the main reservoir besides harvesting rainwater during rainy season. The depth of water in the secondary reservoir fluctuated between 1.5 m (month of May) in summer season to 3.3 m (month of September) in rainy season. Sunflower (*Helianthus annuus*), tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*) and groundnut (*Arachis hypogaea*) were grown in winter season of both the years. In addition to irrigation water from main reservoir, additional 2–3 irrigations were supplied from secondary reservoir for irrigating these crops. The additional irrigations have resulted in increasing the yield by 14.3, 15, 16.8 and 20% in sunflower, tomato, brinjal and groundnut, respectively (Figure 2).

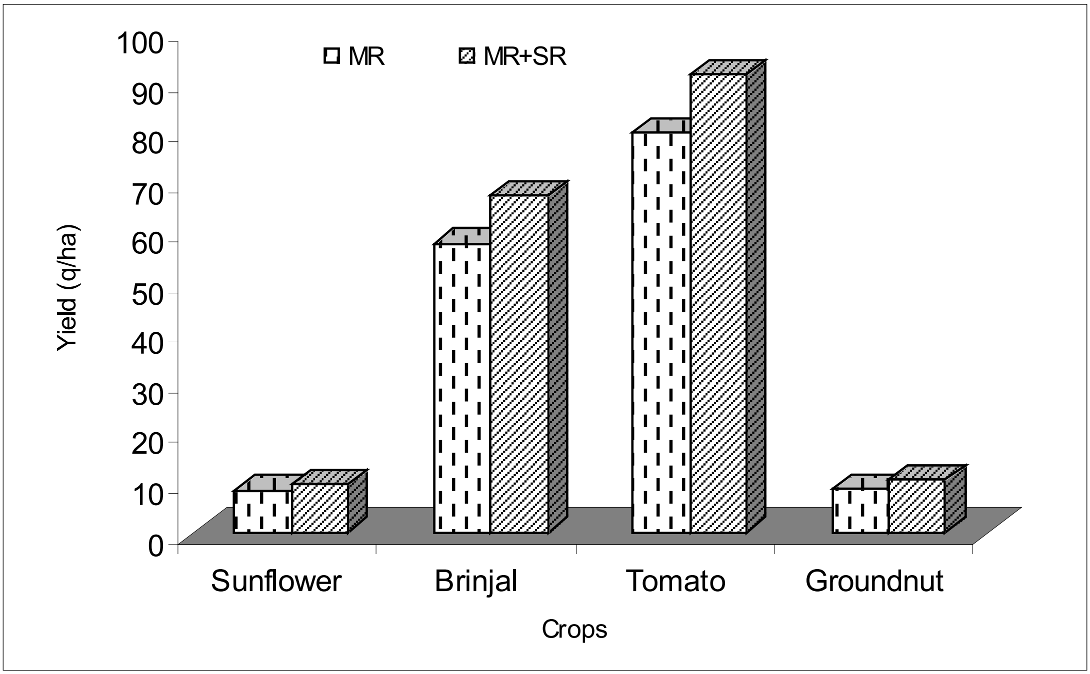

Fig. 2 Yield of winter crops receiving water from main reservoir (MR) as well as from main and secondary reservoir (MR+SR)

The harvested water in the secondary reservoir has been primarily utilized for raising crops in the dry season along with the available water in the main reservoir after meeting the requirement of wet season crops. The augmented water resource has been utilized in more effective and productive manner through multiple use management. Utilization of the harvested water of secondary reservoir for irrigating dry season crop in addition to the irrigation from the main reservoir have resulted in increasing the yield of cops. In the present study, the quantity of water use is not uniform i.e. higher volume of irrigation water was supplied to the field plots those received water from main reservoir and secondary reservoir compared to that of field plots received water from only main reservoir. All other agricultural inputs were supplied uniformly to both the treatments (i.e., field plots receiving irrigation water from main and secondary reservoir and field plots receiving water from only main reservoir). As a result of this differential irrigation application, different levels of return per unit of land were noticed between the irrigation treatments. Figure 3 presents the gross and net returns from various cropping patterns considered using irrigation water from main reservoir (MR) and from main and secondary reservoir (MR+SR). Among the cropping patterns considered, rice-tomato cropping pattern resulted in highest net return of INR 29,457/ha followed by rice-brinjal cropping pattern (INR 22,430/ha). The benefit cost ratio of 2.07 was

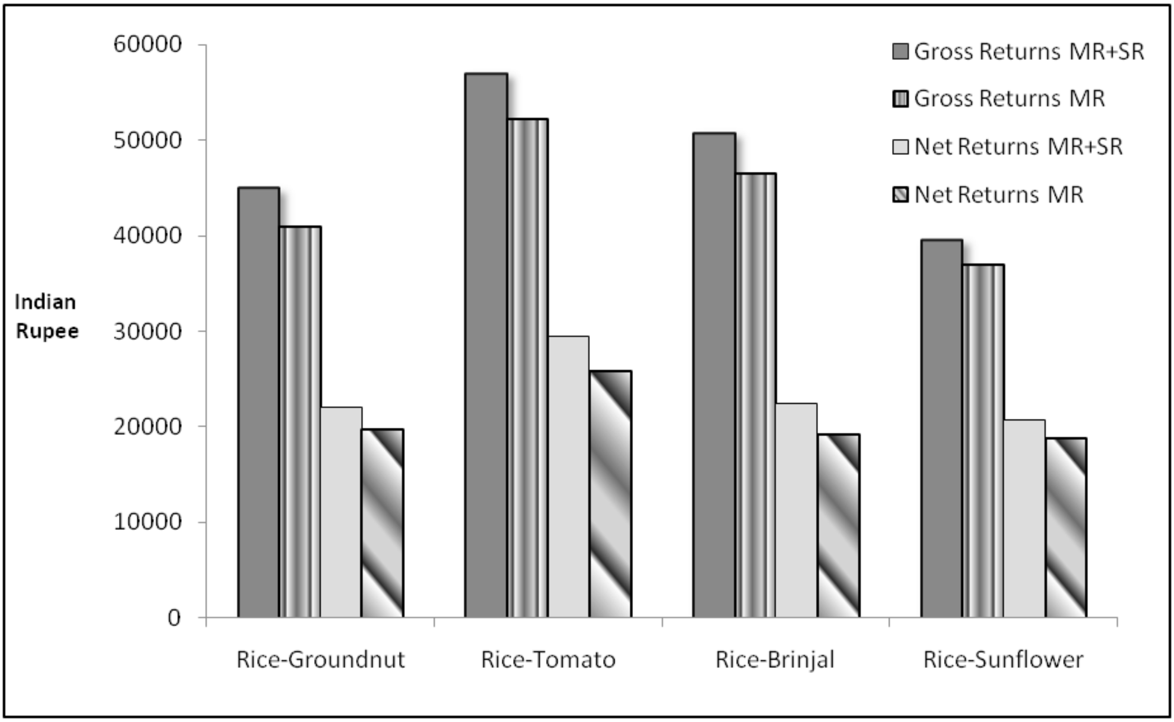

Fig. 3 Gross and net return from various cropping pattern using water from main reservoir (MR) as well as main and secondary reservoir (MR+SR)

computed for rice-tomato cropping pattern followed by 1.79 for rice-brinjal. Highest benefit-cost ratio of 2.09 was obtained for rice-sunflower cropping system due to relatively lower cost of cultivation of sunflower. Further, the difference between the value of production (gross returns) and costs of cultivation of crops per unit of land respectively in the sample farms under two different irrigation scenarios was estimated to represent the incremental values of net returns per unit of land due to additional irrigation in various cropping patterns (Fig 4). The highest incremental value of net returns was obtained with rice-tomato cropping system and hence, the farmers are recommended to grow tomato during winter season after harvest of monsoon paddy.

Low input-based fish culture was carried out for two consecutive years (2006–2008) in the secondary reservoir by the User group. After 226 days of rearing, the 1st crop harvesting was carried out in the month of April, 2007. The average mean body weight (MBW) was 1246.5 g, 219 g, 243.4 g and 379.3 g for *Catla, Rohu, Mrigal* and *C. Carpio,* respectively. Total yield was 186 kg and productivity was 2.65 t/ha/226 days as against the previous year yield of 60 kg (0.85 t/ha/year) i.e., farmer's practice. The apparent feed conversion ratio was 1.34. Biomass contribution was maximum by *C. catla* (46%) followed by *C. mrigala* (24.7%). Higher and lower Performance Index (PI) was recorded incase of (185.9) and (41.8), respectively (Table 1). Similarly, after 273 days of rearing, the 2nd crop harvesting was carried out in the month of May, 2008. In the 2nd crop, the average MBW was 1050 g, 269 g, 252 g and 302 g for *Catla, Rohu, Mrigal* and *C. carpio*, respectively. Total yield was 191.8 kg and productivity was 2.74 t/ha/273 days. The apparent feed conversion ratio was 1.48. Biomass contribution was maximum by *C. catla* (44.1%) followed by *L. rohita* (25.6%). Higher and lower PI was recorded incase of *C. catla* (116.3) and *L. rohita* (26.7), respectively (Table 1). Higher PI, and specific growth rate (SGR) in case of surface feeder was probably due to the stocking composition and minimal inter specific competition with column feeders, while moderate growth performance of both column and

Table 1. Species-wise production performance of Indian Major Carps in polyculture system

SPECIES	2006-2007			2007-2008		
	SGR % d^{-1}	PI	Biomass contribution (%)	SGR % d^{-1}	PI	Biomass contribution (%)
Catla catla	1.41	185.9	46.0	1.44	116.3	44.1
Labeo rohita	1.1	41.8	21.8	1.17	26.7	25.6
Cirhinus mrigala	1.22	54.1	24.7	1.24	67.2	18.0
Cyprinous carpio	1.26	96.3	5.9	1.26	36.3	12.3

SGR- specific growth rate, SR- survival rate, PI- performance index bottom feeders were due to stronger competition for food and space among each other. The low input-based scientific fish culture in the secondary reservoir has enhanced the fish yield by three fold over traditional practice; it has also enhanced the water productivity.

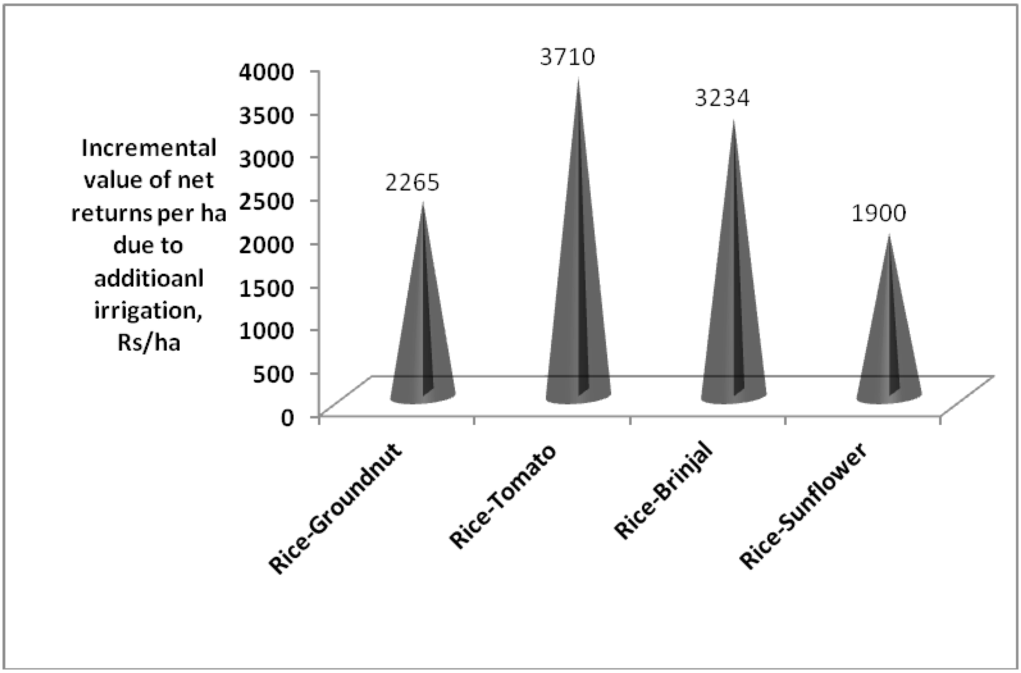

Fig. 4 Incremental value of net returns per ha due to additional irrigation (₹/ha) for different cropping patterns

Secondary reservoir based micro-level water user groups mobilized for participatory creation, utilization and maintenance ensuring sustainability of the innovation (Mishra *et al.*, 2010). Users group was formed for maintenance and management of the secondary reservoir.

Two persons were chosen as their group leaders by the User group. The decision related to crop diversification activities, irrigation application schedule, fish culture in the secondary reservoir, selling of fish, operation of bank account, etc. were carried out by the group leaders. Group meetings were often held during evening hours to take decision on above mentioned activities. The group opened its saving account in the nearby bank by depositing INR 5000 which was obtained from sale produce of harvested fish in the year 2007. Subsequently, the revolving fund was utilized for procurement of inputs like fish seeds, feed, fuel for the pump set, etc.

With more than 1 m water available in the existing 54 water bodies (spreading over 55 ha area), if converted to secondary reservoirs in the selected minor irrigation command (500 ha command area), which otherwise was not used earlier for irrigating crops in dry season, could bring substantial area under cultivation with assured irrigation especially during dry season enhancing the productivity of crops. This innovation also creates approximately about 550000 m^3 of water in the chosen irrigated command which could be utilized for irrigating dry season crops and rearing fish for short duration.

Economic Analysis

The economic analysis of the proposed secondary reservoir was carried out considering that after end of the kharif season there will be 50 % water availability in the main reservoir for irrigating the rabi crop. The remaining irrigation water requirement of the entire command needs to be met from the secondary storage reservoir. A multi objective optimization routine was developed for determining the optimal surface area required for the proposed secondary reservoir. Considering two scenarios of prioritising the objective function i.e., maximization of net seasonal benefit (case 1) and maximization of cropped area (case 2), the optimal surface area for secondary storage reservoir as the percentage of the command area has been obtained as 17.40% and 10.92%, respectively (Mishra *et al.*, 2009). The economic analysis was carried out for the entire command of Devijhar minor irrigation system.

The initial investments, annual costs and annual returns from irrigation were calculated for the total command for 25 years as because the life span for the secondary storage reservoir was considered here as 25 years (Panigraghi and Panda, 2003). The initial investment is associated to first year of the project. The yearly maintenance cost for the secondary reservoir and pump set was taken as 1% and 2.5% of the initial cost, respectively (Mishra and Tyagi, 1988). To have a more generalized analysis, few more crops were considered which are normally grown in the command than the four crops used for field demonstration. The percentage change in cultivation cost for groundnut, sunflower, green gram, black gram and vegetables were taken as 3.12, 6.37, 3.43, 3 and 3.12 respectively. The percentage change in returns for groundnut, sunflower, green gram, black gram and vegetables were as 9.058, 15.108, 9.304, 9.612 and 9.058 respectively (Sen and Bhatia, 2004). For calculating the Net Present Value (NPV) and Benefit Cost ratio, discount rate at 9% was considered.

The present worth value of the annual costs and returns were calculated for all 25 years of simulation and presented in Table 2 and Table 3. The benefit cost ratio for Case 1 and Case 2 were obtained as 1.68 and 1.86, respectively. The net present value (NPV) and internal rate of returns (IRR) for Case 1 were ₹162701247 and 22.52 %, respectively. Similarly for Case 2, the NPV and IRR were ₹ 135865000 and 24.43 %, respectively. In both the cases (Case 1 & 2), the benefit cost ratio of more than one, positive value of NPV and higher value of IRR than the bank interest rate indicates that the proposition of secondary storage reservoir in the command of the MI system is economically viable. Economic feasibility of the intervention reinforces the proposal. Thus, to increase the productivity, cropping intensity and overall production in a minor flow irrigation system there is a need for creation of additional water resource through rainwater harvesting in secondary storage reservoir.

Table 2. Economic analysis of the proposed secondary storage reservoir (Case 1)

Year	Added return (₹)	Added cost (₹)	Net return (₹)	Discount return (₹)	Discount Cost (₹)	Discount Net benefit (₹)
1	20961007	100435229.1	-79474222.11	20961007.00	100435229.11	-79474222.11
2	22237780.62	10286574.49	11951206.13	20401633.60	9437224.31	10964409.29
3	23597727.7	10620544.75	12977182.95	19861735.29	8939100.03	10922635.25
4	25048453.52	10974655.93	14073797.59	19342002.01	8474448.01	10867554.00
5	26598260.9	11350523.26	15247737.64	18842878.59	8040996.84	10801881.75
6	28256214.4	11749918.99	16506295.41	18364600.60	7636641.14	10727959.46
7	30032210.6	12174789.45	17857421.15	17907225.93	7259429.16	10647796.77
8	31937054.85	12627274.12	19309780.72	17470662.68	6907551.36	10563111.32
9	33982545.17	13109726.95	20872818.23	17054693.52	6579329.89	10475363.63
10	36181564.01	13624740.09	22556823.92	16658997.18	6273208.83	10385788.35
11	38548178.49	14175170.51	24373007.98	16283167.18	5987745.21	10295421.97
12	41097750.02	14764169.64	26333580.38	15926728.21	5721600.74	10205127.46
13	43847054.25	15395216.63	28451837.62	15589150.38	5473534.11	10115616.27
14	46814412.11	16072155.43	30742256.68	15269861.60	5242393.91	10027467.69
15	50019833.24	16799236.4	33220596.84	14968258.28	5027112.11	9941146.17
16	53485172.86	17581162.78	35904010.08	14683714.59	4826697.99	9857016.60
17	57234303.31	18423142.78	38811160.53	14415590.39	4640232.60	9775357.79
18	61293301.89	19330947.91	41962353.98	14163237.98	4466863.54	9696374.44
19	65690656.3	20310978.32	45379677.98	13926007.92	4305800.26	9620207.66
20	70457489.52	21370335.98	49087153.54	13703253.88	4156309.59	9546944.29
21	75627805.99	22516906.78	53110899.21	13494336.72	4017711.71	9476625.00
22	81238761.19	23759452.58	57479308.61	13298627.93	3889376.39	9409251.54
23	87330956.72	25107714.34	62223242.37	13115512.43	3770719.48	9344792.95
24	93948763.61	26572527.93	67376235.67	12944390.81	3661199.71	9283191.10
25	101141176.4	28165954.02	72975222.41	12784744.41	3560315.75	9224428.67
Total				401432019.10	238730771.79	162701247.32
			IRR = 22.52	B/C ratio = 1.68		NPV = 162701247.32

Table 3. Economic analysis of the proposed secondary storage reservoir (Case 2)

Year	Added return (₹)	Added cost (₹)	Net return (₹)	Discount return (₹)	Discount Cost (₹)	Discount Net benefit (₹)
1	13668895	63433588.7	-49764693.7	13668895.00	63433588.70	-49764693.70
2	14583973.66	6894388.79	7689584.872	13379792.35	6325127.33	7054665.02
3	15571050.28	7131915.15	8439135.133	13105841.50	6002790.30	7103051.20
4	16638062.24	7383827.57	9254234.669	12847636.80	5701669.67	7145967.13
5	17793872.47	7651248.66	10142623.81	12605627.86	5420337.45	7185290.41
6	19048383.88	7935406.4	11112977.48	12380142.54	5157469.68	7222672.86
7	20412668.55	8237645.24	12175023.31	12171407.31	4911838.71	7259568.60
8	21899113.96	8559438.58	13339675.38	11979565.27	4682306.02	7297259.25
9	23521588.46	8902402.56	14619185.9	11804692.09	4467815.65	7336876.44
10	25295628.57	9268311.54	16027317.02	11646810.09	4267388.10	7379421.99
11	27238651.25	9659115.29	17579535.96	11505900.65	4080114.68	7425785.97
12	29370194.55	10076958.2	19293236.35	11381915.21	3905152.34	7476762.87
13	31712190.48	10524200.8	21187989.69	11274784.93	3741718.84	7533066.09
14	34289274.76	11003443.6	23285831.17	11184429.24	3589088.34	7595340.90
15	37129138.45	11517554	25611584.49	11110763.43	3446587.31	7664176.12
16	40262927.51	12069696	28193231.46	11053705.25	3313590.71	7740114.54
17	43725696.81	12663364.2	31062332.63	11013180.88	3189518.53	7823662.35
18	47556926.52	13302420.4	34254506.13	10989130.09	3073832.54	7915297.55
19	51801109.51	13991136.2	37809973.29	10981510.95	2966033.30	8015477.65
20	56508419.95	14734239.7	41774180.27	10990303.94	2865657.41	8124646.53
21	61735474.72	15536967.7	46198506.99	11015515.69	2772274.98	8243240.71
22	67546200.69	16405125.1	51141075.61	11057182.28	2685487.22	8371695.07
23	74012823.24	17345150.1	56667673.12	11115372.36	2604924.31	8510448.06
24	81216993.3	18364188.7	62852804.56	11190189.86	2530243.37	8659946.49
25	94983522.79	19470177.2	75513345.62	12006386.57	2461126.59	9545259.98
Total				293460682.15	157595682.05	135865000.10
			IRR = 24.43	B/C ratio = 1.86		NPV = 135865000.10

Participatory Creation, Utilization and Maintenance of Secondary Reservoir

Based on the experience gained while conducting the study and interacting with the farmers at Devijhar Minor irrigation project, Odisha, India, the following micro-level institutional arrangements are suggested for participatory creation, utilization and maintenance of secondary storage reservoir in the command of each outlet.

Creation of secondary reservoir

Place of creation: It is ideal to have it on community land in the command of a given outlet. If common land is not available, individual farmer is to be motivated to construct the reservoir on his land and accordingly benefit will be shared among the users.

Users' group formation: The farmers having land in command area of a given outlet as well as getting water from the secondary reservoir would be members of users group. The formation of users group would be on the basis of utilization of water by the farmers from specific secondary reservoir. The number of users groups depends on number of secondary reservoirs created under a given outlet of the canal system. Thus, each secondary reservoir will have a user group.

Process of creation: The construction of secondary reservoir may be under taken following participatory approach in which users will bear the expenditure. This may be realized through self or hired labour or proportionate contribution of the fund required for construction.

Utilization of secondary reservoir

Mode of utilization: The utilization of secondary reservoir includes irrigation to the crops raised in its command, horticultural crops cultivation on the embankment, fish farming, duckery in the reservoir etc. The user group needs to decide on cropping pattern, irrigation schedule and intricacies of fish and duck farming.

Fund generation: User group need to decide the water rates and collect from each users depending upon the types of crop grown and number of irrigations received from the reservoir. Similarly, a percentage of accrued income from fish farming and / or duckery as decided by the group would be saved in group's account as revolving fund.

Method of benefit sharing: Benefit sharing becomes simple and easy, if the secondary reservoir is located in the common land. When the reservoir is constructed in individual's land, benefit sharing needs to be worked out through agreement between the individual farmer on whose land the reservoir is created and the other user members. A percentage of accrued income from fish farming and / or crop cultivation may be given to the farmer who has provided the land for reservoir. It may also happen that individual farmer given land may enjoy entire right of fish farming in the reservoir while others get water for irrigation to the crops by paying water tax. There could be a number of ways of benefit sharing and the best suited one to the farmer on whose land reservoir is constructed and other user members should be finally agreed upon.

Maintenance of secondary reservoir

Major shortcomings of any operation research project are speedy withdrawal of technology and poor maintenance of assets created after completion of the project. This makes the project unsustainable after withdrawal of the project functionaries. Therefore, maintenance of secondary reservoir by the users is of paramount importance. The important aspects in this regard are as follows:

- ❐ Responsibility of maintenance of assets should be taken care by the users group.
- ❐ Financial support to manage and maintain the assets by farmers' groups should be given through group's own generated fund.
- ❐ Contribution of own labour and resource for repair and maintenance of reservoir.
- ❐ Irrigation and other line departments (agriculture, fisheries etc.) officials should act as facilitator and provide technical support to farmers' participation in water management.

Follow up action through farmers training on scientific water management and providing technical guidance, advice and support to properly maintain the created water resource for effective utilization would ensure sustainability of technological innovation.

It is essential to develop a sustainable water management strategy compatible to the socio-economic conditions and aspiration of the farming community. Concerted efforts by the user group for achieving common goals and sharing of benefits are essential.

Conclusion

The limited water availability in surface irrigation system can be overcome through provision of secondary reservoirs in the command. These reservoirs harvest rainwater during monsoon in addition to collecting the unutilized irrigation water. The harvested water is utilized for irrigation in the dry season, short duration fish culture etc. The existence of large number of existing water bodies in the command can be utilized as secondary reservoirs with suitable modifications and maintenance. Case study reveals that secondary storage reservoir in the outlet command is found feasible to augment the water resource scenario of flow based minor irrigation project which suffers badly from inadequate irrigation water availability during dry season and spatial inequity of water distribution even after rehabilitation and irrigation management transfer. Approximately 10% of the command area is required for the secondary reservoir with assumption of 50% capacity of the main reservoir will be available for irrigating dry season crop. As noticed in case of the selected minor irrigation project about 54 water bodies are in existence which could be converted in to secondary reservoirs with suitable modifications. Besides irrigating dry season crop, the water stored in these reservoirs can be utilized for short duration fish culture, embankment horticulture, duckery etc. through participatory institutional mechanisms. In order to make irrigated agriculture more productive and efficient, harvesting of rainwater in the irrigated command needs to be given emphasis through provision of secondary reservoirs either by requisite modification of existing water bodies or creation of new storage units. Use of improved irrigation application methods such as drip and sprinkler in conjunction with the secondary storage reservoir would significantly enhance the irrigation and crop performance. The demonstration of use of water from the secondary reservoir in addition to the water from main reservoir has resulted in substantial crop and fish yield. There is a need for more such demonstrations to make realize the farmers about its benefits and help in horizontal expansion of the promising technology.

References

Gowing, J.W., LI, Q. and Gunawardhana, T., (2004). Multiple-use management in a large irrigation system: Benefits of distributed secondary storage. *Irrigation and Drainage Systems,* **18**:57-71.

Khanjani, M.J. and Busch, J.R., (1983). Optimal irrigation distribution systems with internal storage. *Transactions of ASAE*, **26**(3): 743-747.

Lorite, I.J., Mateos, L. and Fereres, E. (2005). Impact of spatial and temporal aggregation of input parameters on the assessment of irrigation scheme performance. *Journal of Hydrology,* **300**(1-4): 286-299.

Mishra, A. and Tyagi, N.K., (1988). Improving canal water deliveries with secondary storage. *Journal of Irrigation and Drainage Engineering (ASCE)*, **114**(3), 535-545.

Mishra, A., Adhikary, A.K., Panda, S.N., (2009). Optimal size of secondary storage reservoir for rain water harvesting and better crop planning in a minor irrigation project. *Water Resources Management,* **23**: 265–288.

Mishra, A.,Ghosh, S.,Mohanty, R.K. and Brahmanand P.S. (2013). Performance evaluation of a rehabilitated minor irrigation project and augmentation of its water resource through secondary storage: A case study. *Agricultural Water Management*, **128**: 32-45.

Mishra, A; Adhikary, A.K.; Mohanty, R.K.; Anand, P.S.B.; Ghosh, S.; Panda, S.N. and Kumar, A. (2010). Performance enhancement of minor irrigation system through secondary storage and multiple use management. Research Bulletin No. 49. Directorate of Water Management (ICAR), Bhubaneswar, Orissa. 38p.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M.A. and Kijne, J. (2010). Improving agricultural water productivity: Between optimism and caution. *Agricultural Water Management*, **97**(4): 528-535.

Oweis, T.Y. and Hachum, A.Y., (2003). Improving water productivity in the dry areas of west Asia and North Africa. In: Kijne, J.W., Barker, R., Molden, D. (Eds.), Water Productivity in Agriculture: Limits and Opportunities for Improvement.. CABI Publishing and International Water Management Institute, Wallingford, UK/ Colombo, Sri Lanka.

Panigrahi, B., and Panda, S.N., (2003). Optimal sizing of on-farm reservoir for supplemental irrigation. *Journal of Irrigation and Drainage Engineering* (ASCE), **129**(2):1-12.

Sen. A. and Bhatia, M.S., (2004). State of the Indian Farmer: Cost of Cultivation and Farm Income. Ministry of Agriculture, Government of India, New Delhi.

Sharma, R.K. and Sharma, T.K. (1990). Irrigation Engineering (including hydrology). S, Chand & Company Private Limited, New Delhi. 437p.

Zimmerman, J.D., (1966). Irrigation. John Wiley and Sons, Inc., New York, N.Y.