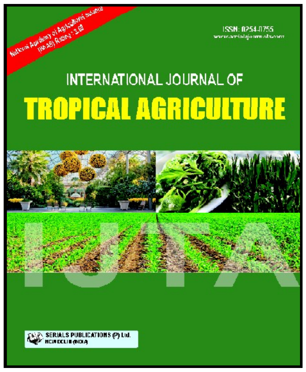

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Evaluation of Various Irrigation Methods and Improved Water Conservation Practices in Hills of Uttarakhand in India

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Abstract: Irrigation is globally critical to quality of life, providing at least 40% of the total worldwide food and fiber supply. The paradox is that agriculture needs to increase production to meet societal needs; but the productive irrigated land base and available water is declining. The present study was conducted in hills of Uttarakhand State in India. A sample of 112 farm families was selected who were using poly-tanks for vegetable crops production. An *ex-post-facto* (Before and after) research design was used to study the impact. Results shown that about 4.04 ha area was brought under irrigation in selected villages after constructing LDPE film lined water tank. It was also found that a significantly high production (686.80 Qt.) of vegetables was added as compared to the before intervention situation (184.12 Qt.). Highest cost of cultivation was found in protected manual irrigation condition (Rs. 96600/- per ha) followed by Protected with MIS (Rs. 93470/- per ha), open with MIS (Rs. 83160/- per ha), open manual irrigated (Rs. 78700/- per ha) and open rainfed (Rs. 67640/- per ha). B:C Ratio also was highest for protected with MIS (3.22) followed by protected manual irrigation condition (2.82), open with MIS (2.25), open manual irrigated (1.93) and open rainfed (1.67). For fish tank B:C Ratio was 1.80 which was higher than vegetable production in open rainfed condition. After adoption of water conservation technique, the distance for fetching water was found to be reduced to less than 1 km for 70.54% people of the village population which was otherwise 1-2 km earlier.

Key words: Impact Evaluation, water conservation, vegetable cultivation, protected cultivation.

INTRODUCTION

As the major consumer of this global asset, irrigation accounts for about four fifths of the total freshwater consumed and about two thirds of the total diverted for human uses. It is estimated that 60% of the global population may suffer from water scarcity by 2025 [*Qadir et al.*, 2007]. India presently supports world's 18% human population and 15% livestock population on world's 2.4% land mass and 4.2% fresh water (NAAS, 2009), and the pressure on these finite resources is swelling due to ever increasing population.

The United Nations [*U.N. Educational, Scientific, and Cultural Organization*, 2006] estimated that increased cropping intensity to meet world demands will require an increase of 40% in the area of harvest crops by 2030, and that the amount of water allocated to irrigation must increase correspondingly by 14%. However, it is unlikely that the needed water will be available. This is creating a major paradox and a looming crisis. Rise in human population is linked to rise in demand for water, with agriculture being the major consumer. Per capita utilizable water for various purposes would decline, while the per capita water demand in different sectors will increase in due course. Consequently, share of agriculture sector in the total water use may reduce from 78% at present to 65-68% in 2050 (Dhingra and Ramaswamy, 2011).

Crop productivity has often been increased by adding inputs, including water, fertilizers and pest control. However, these activities usually increase rather than reduce water use. It is therefore more logical to consider increasing crop productivity per unit water, which is generally termed water use efficiency (WUE) or crop water productivity. Rainfed areas in India, which constitute about 60% of the net cultivated area, contribute only 42% to the total food production, while 39% of the irrigated area accounts for 58% of total output (GOI, 2011) to the national food basket.

As per a FAO study, food consumption levels in India are projected to increase from current level of 2400 kcal/per capita/day to about 3000 kcal/per capita/day and demand for cereals to 243 Mt in 2050, an increase of 0.9% per year. Over the same period, cropping intensity in India is also projected to increase from 101% to 104% in rainfed areas and from 127% to 129% in irrigated areas. Rainfed crop yields are expected to increase to 2.0 t/ha and irrigated cereal yields from 3.5 to 4.6 t/ha in 2050 (Singh, 2009).

Farmers still need to maintain crop yields at the same or improved levels to satisfy production needs while actually consuming less total water over the season. The discussion really needs to be defined in terms of the economic optimum and maximizing economic productivity per unit of water applied to that area. One option for raising the productivity of water is to manage soil water through improved irrigation timing to minimize negative effects of water deficits on yields and quality. This will require changes to the physical and managerial aspects of the water delivery and farm irrigation system designs that will enable farmers to apply the right amount of water at the right place for all irrigations. Optimal use of available precipitation will obviously be required.

Worldwide, irrigation has been practiced for more than 6000 years [*Postel*, 1999], but more innovation has occurred in this arena in the last 100 years than in all of the preceding centuries combined. Improving irrigation efficiencies will require substantial investments by farmers in infrastructure and new equipment. Micro-irrigation offers the potential for high levels of water savings because of precise, high-level management and is an extremely flexible irrigation method. Micro-irrigation can be used over a wide range of terrain, and it has allowed expansion of irrigated crop production into areas with problem soils (either very low or very high infiltration rates), salt affected soils, and poor water quality that could not be utilized with other irrigation methods. It can be installed as either a surface [*Schwankl and Hanson*, 2007] or subsurface [*Camp*, 1998; *Lamm and Camp*, 2007] water application system.

It is estimated that by 2050, about 22% of the total geographic area and 17% of the population will face water scarcity. Per capita water availability, which was about 1704 m^3 in 2010, is projected to be 1235 m^3 in 2050 (GOI, 2011). This would classify the country as a water stressed region with less than 1700 m^3 water available per person (Falkenmark, 1994). Availability of water remained a serious issue and its severity is increasing day by day with changing climatic regime. The situation is further being deteriorating in earthquake prone, hilly, and rural areas in North western Himalaya. In these areas most vulnerable segment of population is farm women who cultivate crops and vegetables in their fields. In order to resolve the water crisis, different approaches, techniques, and practices are being adopted among which, one is water harvesting through LDPE tank. ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (*aka* ICAR-Vivekananda Institute of Hill Agriculture) is a pioneer institution devoted to development of hill agriculture and has developed cheaper water conservation technologies suitable for hill conditions using LDPE film and micro-irrigation systems. These technologies have been demonstrated on the farmers' fields in a large scale and most of the farmers have adopted the technology. Present study is an attempt to assess the impact of these technologies in farming conditions.

METHODOLOGY

The present study was conducted in Kumaun hills of Uttarakhand by randomly selecting 112 farm families of Almora, Nainital and Pithoragarh districts who were already using poly-tanks for vegetable crops production. An *ex-post-facto* (Before and after) research design was used to study the impact. Evaluation of various irrigation methods used by the hill farmers was done through comparison on the basis of their performance on vegetable production, productivity, profitability and water use efficiency. Impact of improved water conservation practice was measured in terms of increase in vegetable area, production and productivity parameters before and after adoption of water conservation tanks. Reduction of drudgery amongst farm families was measured in terms of reduced distance of water source. Data was collected through a pre-structured and pre-tested interview schedule. Following five treatment groups were formed for the study.

T1: Farmers having poly tanks without micro-irrigation system.

T2: Farmers having poly tanks with micro-irrigation systems.

T3: Farmers having poly tanks and poly houses without micro-irrigation systems.

T4: Farmers having poly tanks and poly houses with micro-irrigation systems.

T5: Farmers cultivating under rain-fed condition (control)

RESULTS AND DISCUSSION

The area under different irrigation condition and total land holding of the respondent farmers is presented in following table 1.

Table 1
Landholding scenario in selected villages.

Village	*Rain-fed area (ha)*	*Open irrigated area (ha)*	*Protected cultivation (ha)*	*Total cultivated landholding (ha)*
Bhagartola	1.59	4.79	2.51	8.89
Darim Dubkhar	1.55	2.87	0.00	4.42
Dunagiri	0.76	2.83	1.93	5.52
Pithoragarh	0.39	0.43	0.24	1.06
Total Area (ha)	4.29	10.92	4.67	19.88

Below is presented the percent area of vegetable cultivation under rainfed and irrigated condition.

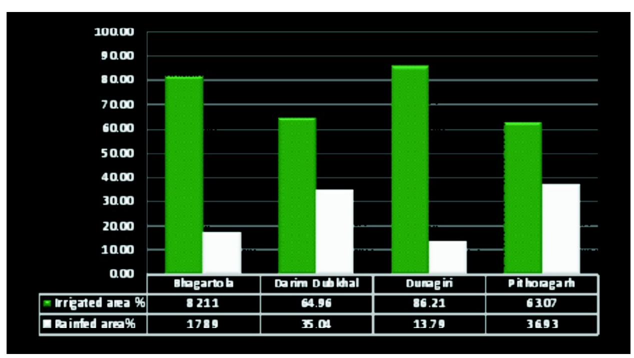

Figure 1: Per cent area of vegetable cultivation under ren-fed and irrigated situation

Following Table 2 presents the area under different vegetables in selected villages.

Table 2
Area under different vegetable crops in selected villages (ha)

Vegetable Crops	*Area under different vegetable crops in selected villages (ha)*				
	Bhagartola	*Darim Dubkhar*	*Dunagiri*	*Pithoragarh*	*Total*
Tomato	2.71	0.96	1.75	1.42	6.84
Capsicum	1.26	1.55	0.47	0.83	4.11
F. Bean	1.06	0.47	0.61	1.06	3.19
Cauliflower	1.24	0.47	0.80	1.13	3.64
Cabbage	1.60	0.53	1.17	0.83	4.13
Cucumber	1.01	0.45	0.73	0.88	3.06
Total	8.89	4.42	5.52	6.15	24.97

Table 3 presents the area under irrigation under various vegetable crops before and after adoption of poly-tanks for water conservation and irrigation. It is evident that a significantly large area (4.04 ha) has been brought under irrigation which was otherwise rainfed.

Table 4 presents production of various vegetables in selected areas before and after the adoption of poly-tanks for water conservation and irrigation. It was found that a significantly high production (686.80 Qt.) of vegetables was added as compared to the before intervention (184.12 Qt.). Similar results are also presented in Figure 2.

Table 3
Area under irrigation before and after intervention and total area under various vegetable crops

Crops	*Tomato*	*Capsicum*	*F. B.*	*Cauliflower*	*Cabbage*	*Cucumber*	*Total*
Area before intervention (ha)	0.71	0.19	0.15	0.26	0.28	0.13	1.71
Additional area after intervention (ha)	1.16	0.62	0.61	0.66	0.68	0.32	4.04
Total area after intervention (ha)	1.86	0.80	0.76	0.91	0.95	0.45	5.74

Table 4
Vegetable production before and after intervention (Qt.)

Crops	*Tomato*	*Capsicum*	*F. B*	*Cauliflower*	*Cabbage*	*Cucumber*	*Total*
Production before intervention (Qt.)	72.90	16.46	16.36	30.98	32.97	14.45	184.12
Additional production after intervention (Qt.)	233.83	91.61	77.03	109.45	127.73	47.15	686.80
Total production after intervention (Qt.)	306.73	108.07	93.38	140.43	160.70	61.60	870.91

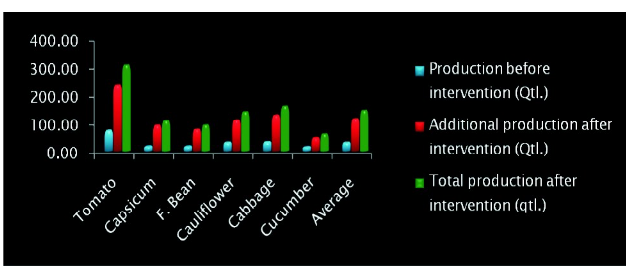

Figure 2: Vegetable production before and after intervention (Qt.)

Table 5 presents increase of area and production in percentage with respect to different vegetable crops. It was found that there was more than 60% increase in area and production of all vegetable crops. Figure 3 is the pictorial depiction of similar results.

Comparison of Vegetable Yields Under Different Irrigation Conditions

It is evident from the following Table 6 that MIS (Micro-irrigation system) along with protected cultivation is the most-efficient system with highest productivity. If we compare this with the open rain-

Table 5
Percent increase in area and production after intervention

Crops	*Tomato*	*Capsicum*	*F. B*	*Cauliflower*	*Cabbage*	*Cucumber*	*Av.*
Area increased (%)	62.02	76.85	80.51	71.98	70.96	70.48	72.14
Production increased (%)	76.23	84.77	82.49	77.94	79.48	76.54	79.57

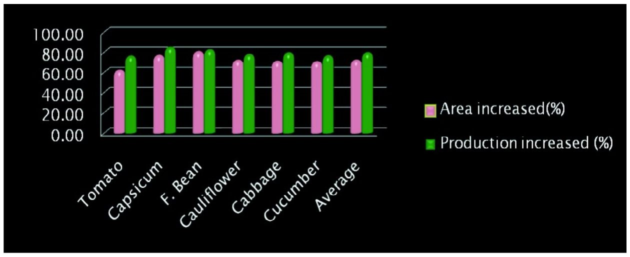

Figure 3: Percent increase in area and production after intervention.

fed condition (control) then we can see that the yield levels are almost double in case of improved water conservation system (protected with MIS).

Yield Advantage Over Rain-fed Condition in Different Crops

Yield advantages in different treatment groups as compared to the control (rain-fed condition) are presented in Table 7. The highest returns from vegetable cultivation were found in treatment group 4 (Protected cultivation with MIS) for all the vegetable crops. Second best was the protected cultivation with manual irrigation. The same results are also presented in Figure 4.

Table 6
Comparison of vegetable yields under different irrigation conditions (Qt./ha)

Conditions	*Tomato*	*Capsicum*	*F. B*	*Cauliflower*	*Cucumber*	*Total*
Open rain-fed	117.87	112.20	110.06	114.08	93.80	548.01
Open Manual Irrigated	152.57	127.69	125.63	128.74	109.76	644.39
Open with MIS	173.74	154.47	151.42	157.24	128.30	765.17
Protected Manual Irrigated	213.85	169.79	165.17	181.52	144.92	875.25
Protected with MIS	264.44	201.43	186.69	208.50	171.86	1032.92

Table 7
Yield advantage over rain-fed condition in different crops.

Treatments	*Cucumber*	*Tomato*	*Cauliflower*	*Capsicum*	*French bean*
T1	10.14	8.3	21.8	53.7	50.8
T2	44.20	19.5	33.8	75.0	88.1
T3	75.40	118.0	63.2	41.7	140.3
T4	89.90	145.9	127.8	99.1	276.1

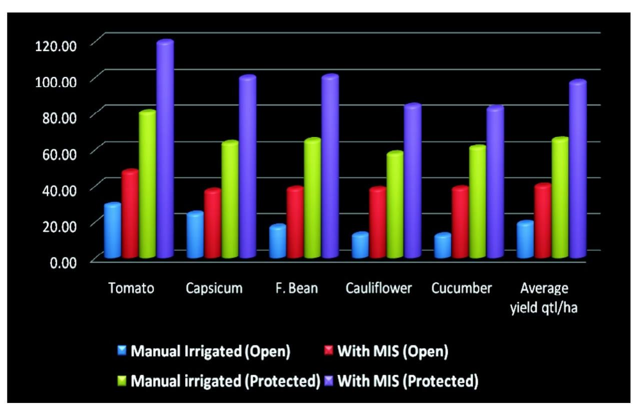

Figure 4: Percent increase in vegetable yield over rain-fed condition.

Cost of Cultivation and Net-Return Under Different Irrigation Conditions of Production

Economics of vegetable cultivation was worked out, the results of which are presented in Table 8. Highest cost of cultivation was found in protected manual irrigation condition (Rs. 96600/- per ha) followed by Protected with MIS (Rs. 93470/- per ha), open with MIS (Rs. 83160/- per ha), open manual irrigated (Rs. 78700/- per ha) and open rainfed (Rs. 67640/- per ha). B:C Ratio was also found highest for protected with MIS (3.22) followed by protected manual irrigation condition (2.82), open with MIS (2.25), open manual irrigated (1.93) and open rainfed (1.67). For fish tank B:C Ratio was 1.80 which was higher than vegetable production in open rainfed condition.

Table 8
Cost of Cultivation and Net Return Under Different Irrigation Conditions (Rs. in ,000)

Treatments	*Cost of Cultivationper ha.*	*Price per quital*	*Gross Return per ha*	*Net Return per ha*	*B:C Ratio*
Open rain-fed	67.64	4.02	108.55	40.91	1.67
Open manualirrigated	78.70	3.81	148.71	70.03	1.93
Open with MIS	83.16	5.09	186.12	102.95	2.25
Protected Manualirrigated	96.60	10.72	270.86	174.26	2.82
Protected with MIS	93.47	7.58	281.15	187.68	3.22
Fish production/tank	6.33	140	14.00	7.67	1.80

Percentage Increase in Net-Return in Different Irrigation Conditions of Vegetable Production over Rainfed Condition

Following Table 9 presents the increase in net-returns over control (rainfed condition). It was found that in case of 'protected cultivation with MIS' returns were 246.82% higher followed by protected manual irrigation condition (111.37%), open with MIS (97.83%) and open manual irrigated (79.64%). In case of fish production per LDPE tank returns were 100% higher.

Table 9
Percentage increase in Net-Return in Different Irrigation Conditions of Vegetable Production over Rainfed Condition

Conditions	*Net return (Rs)*	*NR increased over rain-fed condition (%)*	*NR increased over rain-fed condition (Rs.)*
Open- rain-fed	11643		
Open manual irrigated	20916	9273	79.64
Open with MIS	23033	11390	97.83
Protected manual irrigated	26504	12967	111.37
Protected with MIS	40338	28737	246.82
Fish production per LDPE tank	7670	7670	100.00

Drudgery Before and After Adoption of Improved Water Conservation Technique

In hills, farmers undergo tremendous drudgery every day due to long distance to walk to fetch water. In selected villages before adoption of water conservation technique majority of the farmers (63.39%) were forced to travel daily about 1-2 km, but after adoption of water conservation technique only 29.46% had to walk1-2 km. After adoption of water conservation technique, the distance for fetching water was found to be reduced to less than 1 km for 70.54% people of the village population which was otherwise 1-2 km earlier. (Table 10).

Table 10
Analysis of drudgery before and after adoption of the water conservation technique

	Before adoption of water conservation technique	*After adoption of water conservation technique*
Distance of water source	*Farm families (%)*	*Farm families (%)*
Less than 1 km.	10.71	70.54
1-2 km.	63.39	29.46
More than 2 km.	25.89	0
Average Distance of water source (km.)	2.08	1.17

Treatment-wise Performance of Profitability Index

Economic indicators like profitability index and net present value showed positive impact of water conservation technology on occupation of farmers. It is evident from the above Figure 5 that protected cultivation with MIS gave the maximum profitability index followed by protected manual irrigated, MIS in open, open manual and open rain-fed with profitability index of 1.69, 1.22, 0.94 and 0.65 respectively.

CONCLUSION

Vegetable productivity has significantly increased through use of water conservation practices. Among all different practices protected cultivation with micro-irrigation system has been proven as the best method followed by protected manually irrigated, open micro irrigated, and open manually irrigated. Increase in water use efficiency by 30-40% is seen using LDPE water tank for irrigation. Increase in yield in different vegetable crops by 30-50% has been recorded. With the help of LDPE water tank an additional income of Rs. 7670/- from fisheries can be generated.

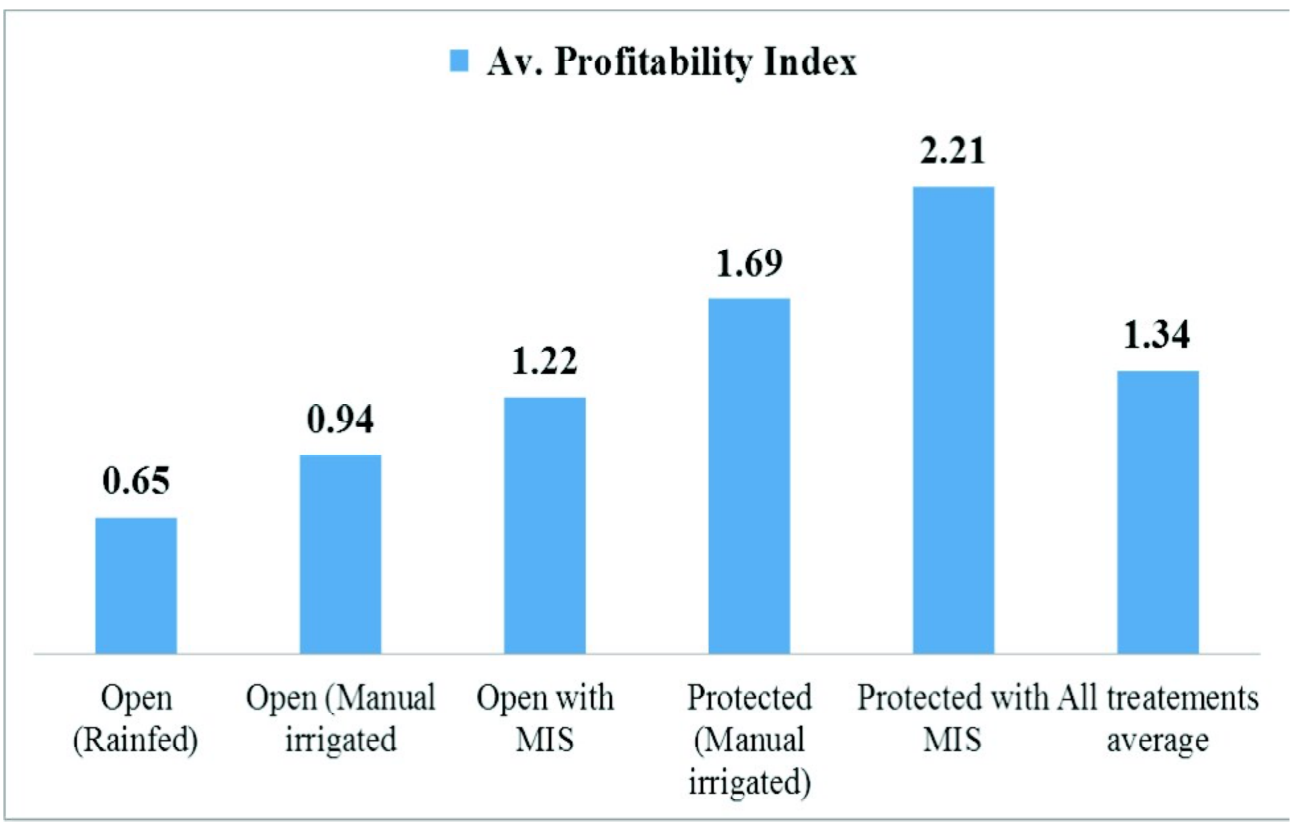

Figure 5: Treatment-wise Performance of Profitability Index

Overall benefits of adoption of water conservation technology by farmers are evident from the present study *viz.*, increased area under irrigation, increased production and productivity of vegetables, increased income and overall livelihood of farmers, reduced scarcity of water for agriculture and household requirements, increased off-season cultivation of vegetables.

Technical and financial support as well as trainings for maintenance and management of adopted technology was identified as an important factor for sustainable adoption of water conservation practices in long run.

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