Research Article

Cost-Benefit Analysis and Adoption Prospects of Selected Moisture Conservation Technologies in Pothwar, Punjab

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Abstract | Economic analyses of moisture conservation for groundnut and wheat crops through gypsum application, and adoption of micro-catchments for olive orchards and fruit trees in rain-fed Pothwar have been carried out. Socioeconomic characteristics of the adopter farmers have also been studied. The study is based on primary data that was collected from 110 sample farmers in the year 2018. It is found that adopters of the gypsum technology are more educated, having large family size, operational land and livestock holdings. Gypsum application at a rate of 0.26 ton per acre doubled the productivity (26.80 mounds/ 40kg) of groundnut crop than without its use. Benefit-cost ratios (BCRs) for groundnut crop with and without gypsum application are 4.47 and 3.23, respectively. Similarly, productivity of wheat crop with application of 0.66 ton gypsum per acre is higher (32.25 mounds) than normal practice by 84.3 percent. Benefit-cost ratios with and without gypsum application for wheat crop are 1.38 and 1.16, respectively. Micro-catchment technology is mostly adopted by women (60%) for fruit trees in house courtyards, and by large farmers for olive orchards. Most of the adopters of the technology reported to have membership in community-based organizations. Adoption of the technology in olive and mixed fruits orchards resulted in BCRs of 1.63 and 30.91, respectively. Thus, in rain-fed ecology of Pothwar Punjab, moisture conservation through gypsum application for major crops, and water harvesting through micro-catchments for fruit trees are promising productivity and profitability enhancing farming technologies. Access to market and enabling institutions are critical for adoption of these technologies. Characteristics of adopters of these technologies as delineated above should also be given due consideration in promotion of the technologies.

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Introduction

Maximum public sector investment in Pakistan is mainly made in irrigated agriculture, resultantly rain-fed areas are mostly neglected. In these areas, crop productivity remains low due to low annual precipitation and its poor distribution throughout the year. Furthermore, in the patches with run-off generating rain fall loss of precious rainwater results into soil erosion, nutrient loss and moisture stress for crops (SAWCRI, 2018). In this perspective, application of gypsum/ Calcium Sulfate ($CaSO_4 2H_2O$) in field crops and making micro-catchments for fruit plants have been proved promising soil moisture conservation technologies. Gypsum is mainly used to reclaim sodic soils (Oster, 1993). Application of gypsum improves physical conditions and hydrological properties of clayey or sodic soils. Its use also helps to control soil and water erosion. Gypsum used for agriculture purposes contain 23.28 percent calcium, 2.34 percent hydrogen, 18.62 percent sulfur, and 55.76 percent oxygen (Oweis and Ashraf, 2012). The use of gypsum has also shown good results in conservation of soil moisture in rain-fed conditions and its use increases moisture infiltration rates and the crops yields (Chartres *et al*., 1985; Farina *et al*., 2000; Yu *et al*., 2003; Hamza and Anderson, 2004; Rashid *et al*., 2008; Mahmood *et al*., 2012). Although the solubility of gypsum is very low generally less than one percent, yet it benefits in conserving soil moisture can last for longer period of time (SAWCRI, 2018).

Gypsum should be applied at the rate of one ton/ acre for wheat crop, through broadcasting before the onset of the monsoon and sowing of the crop should be completed by mid-November (Rashid *et al*., 2008). Similarly, for groundnut, the same amount of gypsum should be applied in mid-February, two months prior to sowing. Before applying gypsum, the field should be ploughed with moldboard plough. After applying, it should be mixed in the soil with cultivator (Ashraf, 2015). Groundnut is main cash crop in rain-fed areas of Pothwar. In the year 2014-15, area under the crop in the country was 0.0986 million hectare with production of 0.093 million tons (GOP, 2019). Wheat is major food crop of Pakistan, in year the 2020-21 it was sown on 9.178 million hectare with total production of 27.293 million tons (GOP, 2021). The gypsum technology has been promoted in rain-fed Pothwar by Soil and Water Conservation Research Institute (SAWCRI, 2018), Chakwal since 2012-13 through a project entitled 'Pakistan water dialogue diffusion and adoption through partnerships and action of the best watershed rehabilitation and irrigation practices and technologies to help rural farmers', which was funded by International Center for Agricultural Research in the Dry Areas (ICARDA)-Pakistan/United States Department of Agriculture (USDA). Since then, a great success has been achieved in adoption of the technology by improving supply of gypsum in the area. In this regard, project technical partner i.e. SAWCRI, Chakwal and socioeconomic partner i.e. Social Sciences Research Institute (SSRI), PARC-National Agricultural Research Centre (NARC), Islamabad developed linkages of farmers with gypsum supplier/ dealers through SMS service to promote adoption of gypsum application for moisture conservation in the study area.

Likewise, micro-catchments are used as water harvesting technology since last few years. Their use greatly increases productivity of fruit plants/ orchards. These are specially contoured areas with slopes and beams designed to increase runoff from rain and concentrate in a planting basin, where it infiltrates and is effectively stored in the soil profile. The water is protected from evaporation, thus made available to plants. Main advantage of micro-catchments is improvement in moisture availability to the plants with little effort. Micro-catchments also enhance leaching and reduce soil salinity. These are simple to construct and can be developed easily using local materials and family labour force or hired labour. These are cost effective and only little maintenance is required. Micro-catchments work best on gentle slopes (ideally less than 5%) but steeper slopes can be used if the catchment basins are small. Though basins can be made on flat ground (Ali *et al*., 2010). Soil should be deep, non-saline or sodic and should possess inherent fertility. Ideally catchment to cultivated area ratio varies from 1:1 to 3:1 (SAWCRI, 2018). Government of Punjab has made a strenuous effort to develop Pothwar region into an olive valley, through a mega project that was executed form 2015-16 to 2021-22. The target was olive cultivation on 15,100 acres of land with provision of 2,038,500 certified nursery plants. Total cost of the project was Rs.1672.445 million (BARI, 2022). Keeping all this in view, this study has been designed to analyze cost-benefits of moisture conservation for groundnut and wheat crops through gypsum application, and adoption of micro-catchments for olive and other fruits in rain-fed Pothwar; and to consider possibilities for large sale adoption prospects of these technologies.

Materials and Methods

The study is based on primary data collected from 110 randomly selected farmers of rain-fed Chakwal district of Pothwar region of Punjab-Pakistan. In the first step, technical experts from Soil and Water Conservation Research Institute (SAWCRI), Chakwal were contacted to obtain lists of the adopter farmers. In the second step, sixty farmers who used gypsum either for groundnut or wheat crops were interviewed. Moreover, to make comparison of the technology with general practices, ten farmers of each crop who did not apply gypsum were also interviewed to consider as control groups for the technological intervention. Furthermore, thirty farmers who adopted micro-catchment technology through project intervention were also interviewed. Adopter farmers of these technologies were belonged to Bagwal, Dhok Malkan, Narway, Jandial Faizullah, Saba Morha, Pindi Gujran and Chawali villages of Chakwal district.

Field surveys for the study was conducted in March and April, 2018 by using a set of pre-tested questionnaire. Farmers were asked about their socioeconomic characteristics, income sources, awareness and experience of these technologies, and costs and benefits of gypsum application for the crops, and making micro-catchments for fruit plants. Data have been analyzed separately for adopter and non-adopter farmers of gypsum technology. Cost-benefit analysis was carried out, and to highlight the impact of technological intervention differences in production parameters have also been determined both in net and percentage terms. Percentage differences are calculated by expression 1.

$$\frac{MSA - MSN}{MSN} \times 100 \dots (1)$$

Where; MSA= mean statistics of adopter farmers; MSN= mean statistics of non-adopter farmers.

Similarly, primary information was analyzed separately for the farming households who have adopted the micro-catchments technology for few fruit plants in vicinity to their homes or backyards, and farmers who have planted olive trees at their farms at relatively large scale. The data was analyzed through SPSS-22 for descriptive statistics. Thereafter, cost benefit analysis of wheat and groundnut production with and without gypsum application. Similarly, cost benefit analysis of micro-catchments for fruit plants and olive orchards was determined by using MS-Excel.

Results and Discussion

Farmer characteristics and adoption of the technology

Demographic characteristics of the farmers by adoption categories are presented in Table 1, Panel A. Adopters of gypsum application technology were relatively younger, more educated, having large mean family size, operational land and livestock holdings, but less experienced than their counterparts. Ninety percent of the adopters and fifty percent of the non-adopters reported to own tractors. Thirty percent of the adopter farmers reported to have irrigated lands with dugwells (20%) and mini dams (10%) as sources of irrigation. Most of the adopters of micro-catchment technology were in young age group with mean age of 37.0 years and formal education of 9.5 years. They have mean farming experience of 10.5 years, with family size of seven members, and operational holding of 10.9 acre including one acre area with supply of irrigation water (9% of operational area). The adopters of micro-catchment technology have small livestock holdings with mean of two animals per farm. The technology is being adopted in house courtyard or on farm generally at small scale mostly by women, as sixty percent of adopters of the technology are females. Seventy-eight percent of the female adopters and half of the male adopters (50%) reported to be members of community based organizations. It has been observed that the adopters generally lack practical knowledge of the technology. Thus, community support organizations can play key role in large scale adoption of micro-catchment technology in the rain-fed areas.

Adopters of gypsum technology are found to have diversified sources of income, while non-adopters were mainly dependent on crop and livestock income (Table 1, Panel B). Thus, diversified income of a farming family increases chances of adoption of new innovative technologies. Though, crop and livestock are main contributors in the income of both categories of the farmers. While in case of micro-catchment technology, crop farming is taken as secondary activity by the adopters, as the sub-sector contribute less than one-third in household income (28.7%). Furthermore, household incomes of the sample farmers were not diversified. They obtained more than half of their income from public/ private services (55.8%) and remaining 15.5 percent from livestock farming.

Table 1: *Demographic characteristics and income sources.*

Farmers' characteristics and income sources	Gypsum application		Micro-catchments
	Adopters (n=60)	Non-Adopters (n=20)	(n=30)
A. Farmers' characteristics			
Age of the farmer (year)	50.7 (9.3)	52.0 (6.8)	37.0 (11.5)
Education of the farmer (year)	9.9 (1.9)	8.0 (1.9)	9.5 (4.1)
Farming experience	21.8 (11.3)	27.5 (10.6)	10.5 (8.1)
Family size (number)	11.5 (8.1)	5.0 (2.8)	7.0 (20.5)
Total operational holding (acre)	36.1 (32.4)	6.2 (1.7)	10.9 (20.5)
Rain-fed operational holding (acre)	33.9 (31.4)	6.2 (1.7)	9.9 (19.5)
Irrigated operational holding (acre)	2.2 (5.9)	0.0 (0.0)	1.0 (3.2)
Livestock holding per farm (number)	8.6 (5.0)	5.0 (2.4)	2.3 (4.5)
B. Income sources			
Crops	479500 (72.3)	50000 (83.3)	94286 (28.7)
Livestock	111000 (16.7)	10000 (16.7)	51071 (15.5)
Small enterprises, Agri. services and trade	15000 (2.3)	0 (0.0)	0 (0.0)
Remittances	40000 (6.0)	0 (0.0)	0 (0.0)
Job	17900 (2.7)	0 (0.0)	183714 (55.8)
Total	663400 (100.0)	60000 (100.0)	329071 (100.0)

Note: *In section A and B, figures in parenthesis are standard deviations and percentages, respectively.*

Farmers' awareness and experience of gypsum technology

According to the survey findings, on average adopters of gypsum use were acquainted with it as moisture conservation or soil ameliorating technology since last eight years, with wide variation in duration for which they have had knowledge of gypsum application, ranged from one to twenty-three years. They reported that extension agents (47%), project persons (38%) and fellow farmers (15%) created awareness about gypsum application in them. Respondents declared extension agents and project persons very effective in transfer of the information about the technology to them. Mean experience of the farmers in use of gypsum for crop production was more than six years, with gypsum application interval on same field of three years. Provincial agricultural extension department is playing active role in promotion of the technology. Sixty percent of the farmers reported that the department personnel persuaded them to adopt the technology. Benefits of gypsum application are quite convincing, as all the sample farmers reported to continue to use of the technology to conserve soil mositure in future. Similarly, interest of fellow farmers in adoption of the technology is quite encouraging in its wider adoption.

Farmers' awareness and experience of micro-catchment technology

Male and female adopters of micro-catchment technology reported to have knowhow of the technology since more than three years, and more than two and half years, respectively. Sixty-seven percent of the male adopters reported that they gained awareness about benefits of making micro-catchments from project persons in farmer field days organized under the project. While remaining male farmers (33%) got awareness about the technology from their fellow farmers. Half of the male adopters reported that staff of project technical partners /collaborating institutions convinced them to adopt the technology, while remaining half were motivated for the adoption by their fellow farmers. Seventy-seven percent of the female adopters reported that project person/ collaborators provided them information about the technology in farmer field days organized under the project. While remaining female adopters (23%) got awareness about the technology from other female adopters. Two-third of the female adopters (67%) reported that other female adopters convinced them to adopt the technology, out of the remaining, 2 percent were motivated for the adoption by the female staff of project collaborating institutions, and 11 percent by project persons. Seventy-three percent of the adopter farmers reported to make visit demonstration sites developed under the project.

Access to market and enabling institutions are critical for adoption of any technology. Both local input and output markets are quite away from sample gypsum technology adopting farms with mean distance of

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11.4 and 13.8 kilometers, respectively. There is no financial support/ subsidy for the adoption of gypsum application. Furthermore, number of Agricultural Service Provider (ASPs) is quite low, as sample farmers reported access to just one or two of them, each. Ninety-one percent of them declared their number is insufficient to meet the demand of area farmers for gypsum. While in case of micro-catchment farmers have not to face any constraint, as purchased material is not required for its adoption. Generally, farming household in rain-fed areas use family work force or hired labour for preparation of catchments.

Out of sample farmers, ninety percent reported to apply gypsum for groundnut crop and forty percent for wheat crop during crop season 2016-17, with mean area of 8.18 and 3.63 acre per farm, respectively. Snapshots of gypsum application and farmers expressing their views about the technology are given in Figure 1. Adopter farmers generally have large land holdings and are able to arrange the supply of gypsum. Most of the farmers reported to sow both crops at recommended time. Rainfall after gypsum application and during crop season in year 2016-17 was quite good. Few farmers (22%) reported non-availability of gypsum and labours for gypsum application/ adoption. Chakwal-50 and Galaxy were the main wheat varieties sown by the farmers, reported by seventy-five and twenty-five percent of them, respectively. Half of the farmers reported to sow BARI-2011 variety of groundnut, followed by variety 'No. 334' and local/non-descript varieties (15% each), BARI-2013 (8%), variety 'No. 335' (6%) and American variety (6%).

Figure 1: *Gypsum incorporation in soil, and getting farmers' feedback about the technology.*

Profitability and adoption prospects of gypsum

Use of gypsum results in better crop productivity. Average productivity of groundnut crop was 26.8 and 15.0 mounds/ 40kg per acre at farms of adopters and non-adopters of the technology, respectively (Figure 2). Cost of production, gross income and profitability of the groundnut crop are presented in Table 2. Mean use of gypsum for groundnut crop was 0.26 ton (7.8 bags of 50 kg) per acre, against recommended usage of 1.0 ton per acre. Use of gypsum for the crop was ranged from 0.20 ton to 0.75 ton per acre, with a standard deviation of 0.20 ton. Mean gypsum application cost was Rs.3011 per acre with share of 11.36 percent into total cost of groundnut production per acre i.e. Rs.26495. It is found that cost of groundnut crop production was higher at the adopters' farms than that of non-adopters by 29 percent, mainly due to higher usage of seed, weedicides and chemical fertilizers. Seed rate was higher at the farms of adopter by 8.5 kg per acre. Similarly, costs of weedicide and chemical fertilizers application were higher at the adopters' farms by Rs. 883 and Rs. 2755 per acre, respectively. Profitability of the crop was higher at adopters' farms by 78.3 percent than their counterparts. Benefit-cost ratios of groundnut production with and without gypsum application were 4.47 and 3.23, respectively (Figure 3).

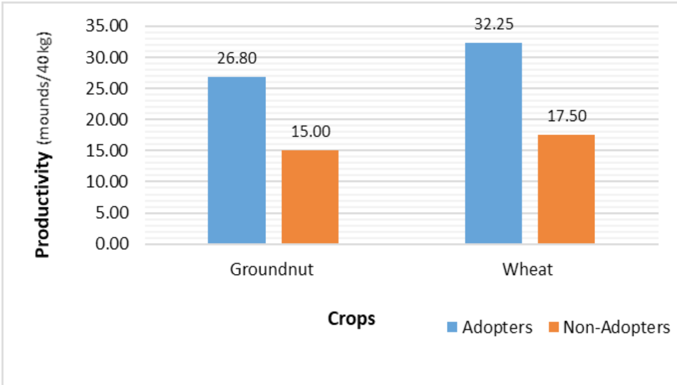

Figure 2: *Crop productivity.*

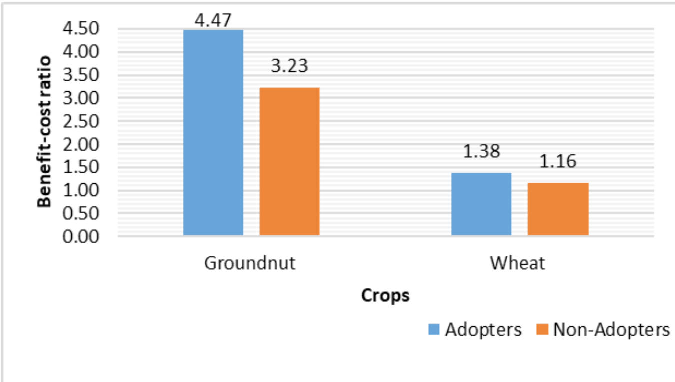

Figure 3: *Benefit-cost ratios.*

Productivity of the wheat crop was 84.3 percent high at the adopters farms; 32.25 mounds/ 40 kg against 17.50 mounds per acre at the farms of adopters and non-adopters, respectively (Figure 1). Cost of production, gross income and profitability of the wheat crop are presented in Table 2. Mean use of gypsum for wheat crop was 0.66 ton (13.17 bags of 50 kg) per acre against the recommended level of one ton per acre. Use of gypsum for the crop was ranged from 0.40 ton to 1.0 ton per acre with standard deviation of 0.31 ton. Cost of gypsum was Rs.4306 per acre, with share of 15.4 percent into total cost of wheat production per acre i.e. Rs. 27871. Along with gypsum use, application of farm yard manure, chemical fertilizers and weedicides at the adopters' farms were considerably higher than non-adopters' farms. Cost of farm yard manure, chemical fertilizer and weedicides were higher by Rs. 750, Rs. 3071, and Rs. 300 per acre than that of non-adopters, respectively.

Table 2: *Cost of production, gross income and profitability of groundnut and wheat crops with and without gypsum application (Per acre).*

Crop specific attributes	Adopters (A)	Non Adopters (B)	Difference (A-B)
A. Groundnut crop			
Gypsum application	3011	0	3011
Weedicides cost	1661	778	883
Fertilizers cost	2755	0	2755
Other Misc. Costs*	19282	19921	-639
Total cost of production (Rupees)	26709	20699	6010 (29.0)
Gross income (Rupees)	119372	66938	52434 (78.3)
Profitability (Rupees)	92663	46239	46424 (100.4)
B. Wheat crop			
Gypsum application	4306	0	4306
Weedicides cost	300	0	300
Farm yard manure cost	750	0	750
Fertilizers cost	3467	396	3071
Other Misc. Costs*	19048	17773	1275
Total cost of production (Rupees)	27871	18169	9702 (53.4)
Gross income (Rupees)	38458	21000	17458 (83.1)
Profitability (Rupees)	10587	2831	7756 (274)

Note: *Figures in parenthesis are percentages * Include land preparation, seed and sowing, bund making, harvesting, threshing costs and land rent for six months.*

Furthermore, few of the adopters (10%) also reported to apply supplemental irrigations to the crop. Cost of wheat production was higher at adopters' farms by 53.4 percent than that of non-adopters. The results are in line with (Shah *et al.* 2012), who studied the impact of gypsum application on groundnut yield in rain-fed Pothwar and found that use of gypsum at 0.2 ton per acre could result into 14 percent increase in productivity in case of local variety and 16 percent in improved varieties of the crop. They reported that use of gypsum at this rate generated higher marginal rate of returns up to 132 percent for local and 202 percent for improved varieties of groundnut. According to finding of current study, profitability of the crop at the adopters' farms was even much higher than their counterparts by 274 percent. Benefit-cost ratios of wheat production with and without gypsum application were 1.38 and 1.16, respectively (Figure 2). The benefits of gypsum application for wheat crop can be increased by use of recommended level of gypsum. Shah *et al.* (2011) reported that application of one ton gypsum per acre results into the highest yield of the crops and financial benefits to farmers in rain-fed conditions of Pothwar. Similarly, Khan *et al.* (2021) reported considerable success in the promotion of the use of gypsum by Agricultural Service Providers (Agric. SPs) for moisture conservation in Pothwar-Punjab. They concluded that the technology has good income generation potential for Agric. SPs. However, they stressed that on technical and entrepreneurship capacity building of the Agric. SPs in the provision of services to farmers in multiple technologies to achieve sustainability in service provision and adoption of new technologies.

Profitability and adoption prospects of Micro-catchments

There was wide variation in area under the technology at the sample farms i.e. it ranged from 0.07 acre (0.6 kanal) to 75 acre (600 kanal), with mean area of 7.14 acre (57.12 kanal) per farm. Similarly, there was great difference in number of plants per farm, ranging from just three to about ten-thousand, with a mean of 796 plants per farm (112 plants per acre). Sixty percent of the farmers reported to make micro-catchments just for fruit plants at their farms, and remaining farmers (40%) for both fruit and forest/ shade trees. However, just forty percent of the sample farmers reported to have plants at fruiting stage (even not on whole orchard area), out of these 47 percent reported to have plants at full fruiting stage, 13 percent at initial fruiting stage and remaining (40%) at vegetative growth stage. Snapshots of use of the technology for olive orchards is given in Figure 4. Out of the farmers, who have had plants at full fruiting stage, 75 percent were found to get financial benefits of adoption, while remaining (25%) were not getting reasonable benefits due to proportionally less number of fruit plants at their farms as compared to forest/ shade trees.

Table 3: *Cost and benefits of micro-catchments (Per annum).*

	Olive	Other fruits
Number of fruit plants / catchments per farm	2550	11
A. Costs		
Establishment cost		
Plant cost (Rs. per plant)	0*	(11 x 150) =1650
Labour for preparation of catchments (Man Days)	340	1.5
Wage rate (Rs./ Man Day)	600	600
Labour cost for preparation of catchments (Rs.)	(340 x 600) = 204000	(1.5 x 600) =900
Total establishment cost	204000	2550
a. Establishment cost per annum	(204340 / 40) = 5100	(2450 / 40) = 61
b. Maintenance cost		
Labor for maintenance (Man Days)	85	1
Labor cost for maintenance (Rs.)	(85 x 600) = 51000	(1 x 600) = 600
c. Irrigation cost (Rs.)	27500	0
d. Fertilizers cost (Rs.)	40000	0
e. Total Cost (a+b+c+d) (Rs.)	123600	661
B. Benefits		
f. Labour cost saved	25000	0
g. Diesel cost saved	60000	0
h. Water hauling cost saved	65000	0
Productivity per farm (kg per plant)	0.25	14.02
Total production per farm (kg)	(2550 x 0.25) = 637.50	154.22
Produce consumed at home or gifted	25.00 (4%)	29.25 (19%)
Produce sold out (kg)	612.50	124.97
Mean price (Rs. per kg)	80	132.50
i. Income from fruit production	(637.5 x 80) = 51000	(154.22 x 132.50) = 20434
j. Gross Income [f+g+h+i] (Rs.)	201000	20434
k. BCR (j/e)	1.63	30.91

** Plants were provided free of cost under federal/ provincial olive promotion projects.*

Figure 4: *Micro-catchments for olive orchards.*

Out of monetary reward getting farmers, who have had fruit plants at fruiting stage (even not at whole farm), 29 percent solely have olive trees, and 71 percent mix orchards of grapes, citrus, pomegranate and lemon plants etc. Thus, economics of micro-catchments for the farmers having only olive trees, and other fruit trees have been calculated separately (Table 3). Mean number of fruit plants at olive producing farms was 2550 per farm, with total production of 15.94 mounds/ 40 kg, and productivity of 0.25 kg per plant. Thus, olive orchards were still at initial stage of production with mean orchard age of three years. All the olive farmers reported to give supplemental irrigations to their orchards (on an average three irrigations per annum), along with improving moisture availability to the plants through making micro-catchments. However, they reported that micro-catchments have resulted into lot of savings for them due to reduction in costs of water hauling, diesel and labour for application. They consumed or gifted 4 percent of the total produce and sold out remaining produce (96%) at mean prices of Rs. 80 per kg. Total annual benefits for olive producers averaged at Rs. 210000 with total costs of Rs. 123600 per farm. Thus, micro-catchments' adoption in olive orchards resulted into benefit-cost ratio for the farmer of 1.63.

In the study area, fruit trees of grapes, citrus, and pomegranate and lemon etc. are still planted on very limited scale. Mean number of other fruit plants per farm was eleven with productivity of 14.02 kg per plant. Sample farmers reported to use tap water to give supplemental irrigation to these fruit trees and not to apply chemical fertilizers. Thus, total cost of production per farm was just Rs. 661 per annum. They consumed or gifted 19 percent of the total produce and sold out remaining produce (81%) at mean prices of Rs. 132.5 per kg. Total annual benefits for them averaged at Rs. 20434 per farm. Thus, micro-catchments' adoption in fruit orchards (other than olive) resulted into benefit-cost ratio for the farmer of 30.91.

The results are in line with Shah et al. (2011), they professed that it is a farmer and nature friendly technology that is suitable for in situ water conservation for fruit plants, cost effective, water saving, labour and resource economizing under rain-fed conditions of Pothwar with scarce supplemental water availability. They stressed that its cost/ labour charges for preparation and maintenance could be recovered from single rainfall after adoption. Usman *et al*. (2022) reported that agricultural productivity is adversely prone to extreme heat and heat waves. Micro-catchment technology can protect fruit trees from adverse impacts of climate extremes. Batool *et al*. (2019) stated that moisture conservation technologies result in decrease in the cost of production. Thus, use of micro-catchments in combination with application of compost can further decrease the cost of production. Siddiqua *et al*. (2019) also stressed that farmers can receive significant positive benefits from adaptation of the combination of strategies. Similarly, maximum returns can be achieved by the farmers by adopting combination of technologies. Adopters of the micro-catchment technology are satisfied with the technology, an over-whelming majority of the farmers (93%) reported that micro-catchment technology is suitable for wider adoption in the study area. Sixty percent of the sample farmers reported that their fellow farmers are highly interested in adoption of the technology. Thirty-three percent reported medium level of interest by their fellow farmers in the adoption of the technology. While, remaining (7%) reported low level of interest by fellow farmers in the adoption. Based on their estimation, 46 percent of the total study area is suitable for adoption of the technology. However, adoption of the technology is quite slow, may be due to lack of awareness, deficiency in practical experience and belief, and poor resource base of the farming community. Similar findings have been reported for adoption of compost technology by Batool *et al*. (2019).

Conclusions and Recommendations

Keeping in view better performance of the crops with the use of gypsum, and encouraging level of interest in the technology by the adopters' fellow farmers, it is concluded that the technology has good adoption potential. However, the use of gypsum is limited to large farmers having comparatively large land holdings, as they can arrange supply of gypsum through Agricultural Service Providers (ASPs)/ dealers by making advance payments, or by making their own arrangements directly with the factories in Khushab district of Punjab province. Project personal, ASPs along with the officials of Agricultural Extension Department have created awareness among the farming community about benefits of applying gypsum for soil moisture conservation and its fertility amelioration. Though, majority of the sample farmers perceive that number of ASPs is insufficient to meet their demand for gypsum. Introduction of the concept of micro-catchments technology have encouraged the people to plant fruit trees in house courtyards and at crop farms. Earlier, they were hesitant to plant fruit trees, as were unable to obtain better fruit production due to effect of moisture stress on plants health and vigor. Adoption of the technology has not only resulted into savings for the farmers due to reduction in costs of water hauling, fuel consumption and labour for application, but it also increased production of fruits and resulted into higher consumption at farm household level, and income through marketing surplus produce. Thus, it is concluded that in rain-fed ecology of Pothwar Punjab, moisture conservation through gypsum application for major crops, and water harvesting through micro-catchments for fruit trees are promising productivity and profitability enhancing farming technologies. After termination of the project, main responsibility to further promote these beneficial technologies, and make their use sustainable at the adopters' farm lies with the Agricultural Extension Department. The department should focus on the knowledge dissemination, skill development of farmers, along with site development for awareness as well as convinced adoption of these technologies. Based on the findings of the study, few areas for future research has been identified. As these technologies are still at adoption stage, thus diffusion of these technologies can be assessed after 3 or 5 years. Their economics should also be re-determined to check real impact on the livelihood of the farmers. Similarly, success stories of new adoptions may also be documented. Biological sciences should experiment impact of different doses of gypsum application, keeping in view different soil types in the country to determine recommended dosage by soil type instead of general recommendation of one ton per acre. Micro-catchment technology may also be promoted in combination with compost use for olive orchards and fruit plants, and benefits of synergetic technologies should be researched. In last few years, olive orchards have established in large number thus, detailed economic analysis of the use of micro-catchment technology in olive orchards with large sample size should be carried out.

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Novelty Statement

Characteristics of adopters of moisture conservation and water harvesting technologies in Pothwar region of Punjab province of Pakistan have been studied, and cost-benefit analyses are carried out. A serious consideration of these features of the technologies as well as their users can play an important role in the success of programs and projects designed for their large-scale adoption.

Author's Contribution

Abid Hussain: Conceived and materialized the research idea, carried out field surveys for data collection, provided technical input to the research team at each and every step. Prepared the draft article and incorporated comments of the anonymous reviewers.
Mubbashira Nazir: Overall management of the article entered, edited and analyzed the data.
Saira Batool: Assisted in preparation of draft article aby reviewing relevant literature and incorporation of reviewer's comments.
Sidra Majeed: Carried out field surveys for data collection and assisted in data analysis.

Conflict of interest

The authors have declared no conflict of interest.

References

Ali, A., A. Yazar, A.A. Aal, T. Oweis and P. Hayek. 2010. Micro-catchment water harvesting potential of an arid environment. Agric. Water Manag., 98 (I): 96-104. https://doi.org/10.1016/j.agwat.2010.08.002

Ashraf, M., 2015. Promising land and water management practices: A manual. International Center for Agricultural Research in the Dry Areas (ICARDA), PARC-NARC Premises, Islamabad, Pakistan.

BARI, 2022. Developing Pothwar into an Olive Valley. Barani Agricultural Research Institute (BARI), Chakwal. https://aari.punjab.gov.pk/developing%20pothwar

Batool, S., W. Akhtar, N. Habib and M. Nazir. 2019. Compost adoption impact on vegetables production in district Chakwal Pakistan: A smallholders' perspective. Sumerianz J. Agric. Vet., 2(12): 147-152.

Chartres, C.J., R.S.B. Greene., G.W. Ford and P. Rangasmy. 1985. The effect of gypsum on macro porosity and crusting of two red duplex soils. Aust. J. Soil Res., 23: 467-479. https://doi.org/10.1071/SR9850467

Farina, M.P., W.P. Channon and G.R. Thibaud. 2000. A comparison strategies for ameliorating subsoil acidity: Long-term growth effects. Soil Sci. Soc. Am. J., 64: 646-651. https://doi.org/10.2136/sssaj2000.642646x

GOP, 2019. Agricultural Statistics of Pakistan, 2018-19. Statistics Division, Pakistan Bureau of Statistics, Government of Pakistan, Islamabad.

GOP, 2021. Economic Survey of Pakistan, 2020-21. Finance Division, Economic Advisor's Wing. Ministry of Finance. Government of Pakistan, Islamabad.

Hamza, M.A. and W.K. Anderson. 2004. Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy-sand soil contrasted with a sand clay loam soil in Western Australia. Aust. J. Agric. Res., 54(3): 273-282. https://doi.org/10.1071/AR02102

Khan, R. M., A. Hussain, A. Hassan and A. Majid. 2021. Promoting adoption of water conservation; soil fertility and health improving technologies through agricultural service provision in Pakistan. Life Environ. Sci., 58(4): 75-85. https://doi.org/10.53560/PPASB(58-4)685

Mahmood, A., T. Oweis, M. Ashraf, M. Aftab, N.K. Adal, I. Ahmad, M.R. Sajjad and A. Majid. 2012. Improving land and water productivities in the Dhrabi watershed. In: (eds. T. Oweis and M. Ashraf), Assessment and options for improved productivity and sustainability of natural resources in- Dhrabi watershed, Pakistan. ICARDA, Syria, pp. 27-60.

Oster, J.D., 1993. Sodic soil reclamation. In: (eds. H. Lieth and A.A. Masoom), Towards the rational use of high salinity tolerant plants. Springer, Dordrecht. pp. 485-49. https://doi.org/10.1007/978-94-011-1858-3_51

Oweis, T. and M. Ashraf. 2012. Assessment and options for improved productivity and sustainability of natural resources in Dhrabi Watershed Pakistan. ICARDA, Aleppo, Syria.

Rashid, M., M.N. Iqbal, M. Akram, M. Ansar and R. Hussain. 2008. Role of gypsum in wheat production in rain-fed areas. Soil Environ., 27(2): 166-170.

Siddiqua, A., M. Ahmad and N. Habib. 2019. Farmers' adaptation strategies to combat climate change impacts on wheat crop in Pakistan. Pak. J. Agric. Res., 32(2): 218-228. https://doi.org/10.17582/journal.pjar/2019/32.2.218.228

Shah, H., K. Hussain, W. Akhtar, M. Sharif and A. Majid. 2011. Returns from agricultural interventions under changing price scenario: A case of gypsum application for moisture conservation for wheat production under rain-fed conditions in Pakistan. World App. Sci. J., 14(2): 363-368.

SAWCRI, 2018. Rainwater harvesting through micro-catchments and rooftops (Leaflet), Published by Soil and Water Conservation Research Institute, Chakwal.

Shah, H., M.A. Khan, T. Azeem, A. Majid and A. Mehmood. 2012. The impact of gypsum application on groundnut yield in rain-fed Pothwar: An economic perspective. Lahore J. Econ., 17(1): 83-100. https://doi.org/10.35536/lje.2012.v17.i1.a5

Usman, M., A. Ali, S. Hassan and M.K. Bashir. 2022. Farmers' perception regarding natural hazards and impact on food productivity: Evidence from rice-wheat cropping zone of Punjab, Pakistan. Pak. J. Agric. Sci., 59: 147-156. https://doi.org/10.21162/PAKJAS/22.376

Yu, J., T. Lei, I. Shainberg, A.I. Mamedov and G.J. Levy. 2003. Infiltration and erosion in soils treated with dry PAM and gypsum. Soil Sci. Soc. Am. J., 67: 630-636. https://doi.org/10.2136/sssaj2003.6300