Proceedings of the Pakistan Academy of Sciences:
B. Life and Environmental Sciences: 57 (3): 89-101 (2020)

ISSN: 2518-4261 (print), ISSN 2518-427X (online)

Pakistan Academy of Sciences

Research Article

Assessment of Micro-Structures Technology Adoption for Erosion Control in Chakwal, Punjab-Pakistan

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Abstract: Soil erosion is a serious environmental problem in the regions of Pothwar Plateau, Pakistan. Therefore, to solve this severe issue, Soil & Water Conservation Research Institute (SAWCRI), Chakwal demonstrated micro-structures to the farmers in several erosion-affected villages of Chakwal district under the research and development project "Pakistan Water Dialogue-Diffusion and Adoption through Partnerships and Action of the Best Watershed Rehabilitation and Irrigation Practices and Technologies to Help Rural Farmers" funded by USDA/ICARDA. Micro-structures are low-cost structures that are designed to control soil un-natural slopes and ensuring slopes that can be washed away by heavy rainfall. The main purpose of this study was to evaluate the adoption of micro-structures and socio-economic factors affecting its adoption in the study area. Primary data was collected with the help of a questionnaire through a household survey. In total, 22 farmers were interviewed who have adopted the micro-structure technology after the project interventions. The study findings revealed that the educated and relatively large land-owners are more interested in adopting this technology. The majority (66.8%) of the respondents recommended using stones as micro-structures material as they consider it most favorable to control soil erosion in the study area. Similarly, the material available for the micro-structure was not a big issue, but high transportation cost was a major concern. The micro-structure technology was not widely accepted because crop cultivation is not practiced on modern lines due to low crop productivity and the poor socio-economic status of the farmers. Another important reason for the low adoption was the time lag between investment and financial benefits from this technology as perceived by the farmers. Therefore, to improve the adoption of micro-structures technology, more awareness about its benefits, and financial assistance in the form of subsidy is needed.

Keywords: Soil erosion, Micros structure technology, Adoption, Socio-economic status, Farmers' perception

1. INTRODUCTION

Erosion is the process by which the earth is damaged by wind, water, ice, or gravity. Erosion is considered a major environmental threat [1], as it directly causes soil loss and flooding [2, 3], as well as 12 million hectares of productive land lost due to erosion each year [4]. Soil erosion is a major cause of soil degradation as it occurs naturally in all countries and affects crop growth, agricultural yields, water quality, and recreation [5]. In areas with population growth, agricultural production, urbanization, and human activities, soil erosion is a major problem [6]. Healthy soil is the basis of agriculture and an important source of sustaining human needs in the 21st century [7], such as food, feed, fiber, clean water, and fresh air. It is an integral part of the environment and natural resources that support the delivery of basic environmental services [8, 9]. Soil erosion is a broad natural process that affects man-made ecosystems in mountainous areas due to soil erosion and low-lying areas due to land loss [10, 11]. It is considered one of the most important factors in achieving sustainable agricultural development [12]. Major soil threats in semiarid areas include salinity, erosion, and degradation due to human activities [13]. Continued exposure to heavy rainfall weakens the soil and

Received: June 2020; Accepted: September 2020
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land degradation has occurred as a result of poor agricultural practices and has a direct and negative impact on farmers' food and livelihoods [14]. One of the major causes of soil erosion is poor land management which causes damage to the soil and leads to global water leakage instead of adequate drainage (15, 16). Many factors affect soil erosion, including topography, precipitation, lithology, and land use [17]. Soil provides food, clean water, and air and is a major carrier of biodiversity [18]. Soil erosion is a major environmental problem that slows the productivity of all-natural and agricultural products, threatening the lives of small farmers [19, 20-21]. About 80% of current land degradation in agriculture is caused by soil erosion worldwide [22]. The high erosion rate mainly affects developing countries due to over-cultivation, plowing of marginal lands, deforestation, and high climate risks [23, 24]. In cultivated fields, appropriate soil conservation measures are supported by crop efficiency strategies to control soil loss [25, 26].

The Pothwar region consists of a high-yielding area where water conservation strategies and remedial measures are essential for sustainable crop production. Soil erosion is the severe problem faced by the farmers in district Chakwal, and it has been estimated that the average annual soil loss in this area would be up to 268,619 tons/acre/year near the steep slope and river channels [27]. The current project focuses on watershed rehabilitation for enhancing the productivity of available land and water in this region. The objectives of this study were to evaluate the adoption and effectiveness of micro-structure technology and to find out the socio-economic factors that influence the adoption of technology in the study area.

1.1. Major Categories of Soil Erosion

1.1.1. Water Erosion

Water erosion is caused by the removal of soil content by flowing water. The following are some common types of soil erosion caused by water;

a) Splash Erosion
b) Sheet Erosion
c) Rill Erosion
d) Gully Erosion
e) Bank Erosion
f) Slip Erosion

a) Splash Erosion

The removal of soil particles due to raindrops is called splash erosion. Splash erosion is the first and smallest stage in the soil erosion process. It is the primary cause of soil detachment and destroying soil structure due to the bombardment of the soil surface by raindrops. Splash erosion results in the formation of cracks that reduce internal penetration leading to the onset of recurrence.

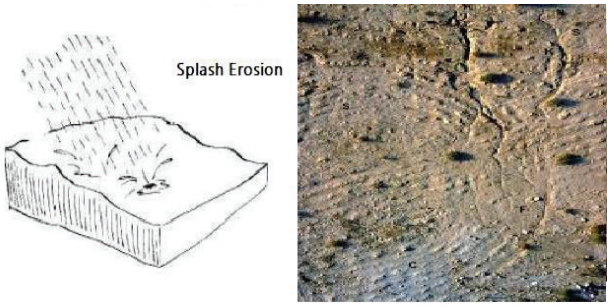

Fig. 1. Raindrops falling resulting in the formation of surface crusts is an indication of splash erosion.

b) Sheet Erosion

The uniform downslope removal of soil in thin layers from the land surface by the forces of raindrops or runoff water is termed as sheet erosion. Sheet erosion is a gradual erosive process and less apparent in its early stages than other types of erosion. It is usually worse as the slope gradient increases.

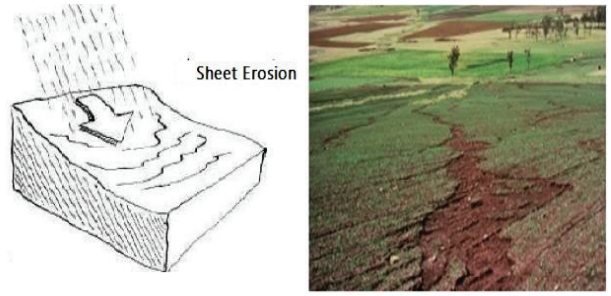

Fig. 2. Soil accumulation and crop contamination at the end of the field is an indication of sheet erosion.

c) Rill Erosion

Rill or channel erosion happens as a result of concentrated overland flow that creates small channels up to a few inches in depth. The extent and fragmentation of these channels will depend on soil structures such as texture, composition, and

management practices. It may occur in a desert land or on land that slopes more gently. It can be removed by normal farming activities.

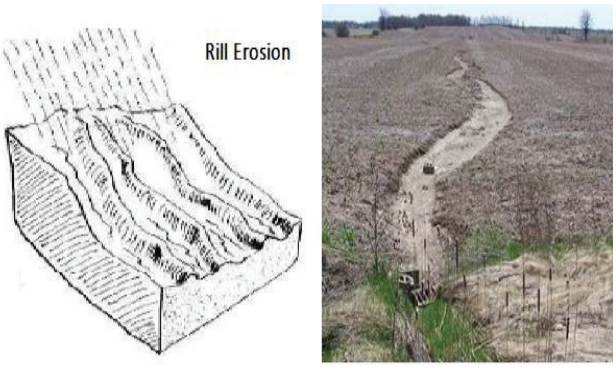

Fig. 3. The soil is washed away by the surface water runoff is an indicator of rill erosion.

d) Gully Erosion

It is a more visible type of erosion that can happen when runoff concentrates and flows strongly enough to detach and move soil particles. Gully erosion usually occurs in watercourses or near the bottom of slopes where runoff concentrates.

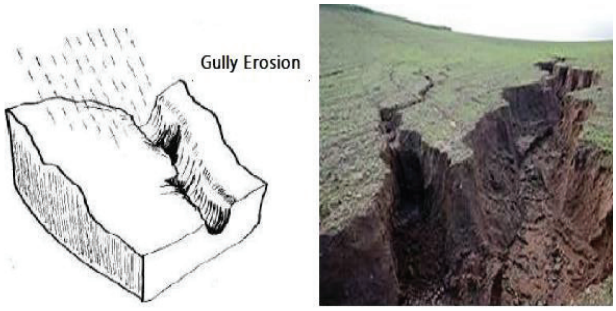

Fig. 4. Gully erosion can occur in areas where rill erosion was not active.

e) Bank Erosion

Bank erosion is the discharge from a river or riverbank. Fountains and rivers flow naturally, water levels rise and fall, and banks and valleys line up with erosion. Natural radios and built-in water stations serve as wells for drainage and groundwater drainage systems. Bank erosion is a continuous process, the collapse of the bank, and the collapse of these tug-of-war systems. It is enhanced by the removal of vegetation, grazing, or plowing near river banks.

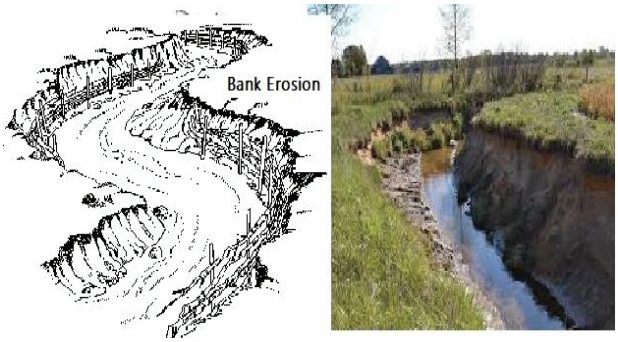

Fig. 5. Bank erosion involves the collision of the natural stream and drainage channel banks.

f) Slip Erosion

This type of erosion is caused by gravity when big piles of soil and rock slide to the ground due to heavy rainfall, thus damaging mountain fields and creating barriers to communication. The result of the slip erosion has been localized.

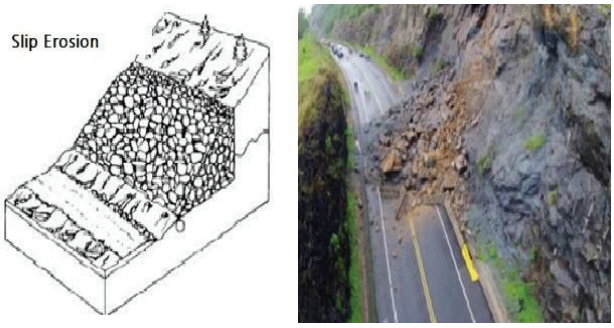

Fig. 6. Slip erosion may also culminate in landslides, which can damage buildings and roads.

1.1.2. Wind Erosion

Wind erosion is the detachment and movement of soil particles by air moving at least 20km per hour and it is a common cause of land degradation especially when strong winds blow over light-textured soils that have been heavily grazed. Wind erosion occurs in regions of low rainfall and particularly during periods of drought. Wind speed and its length of time the wind blows are major factors in wind erosion. The hazards of wind erosion are more increased when reducing or removing vegetation. Similarly, the sandy soils are more vulnerable to wind erosion because they cannot store abundant moisture and have low fertility.

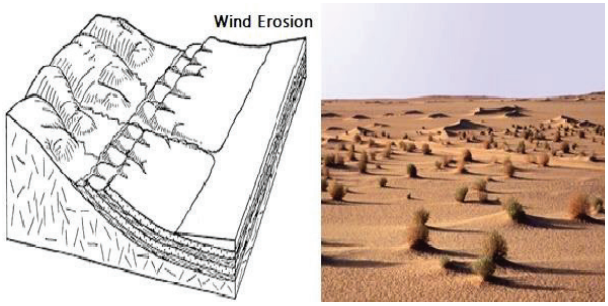

Fig. 7. Wind Erosion can be severe on long, unsheltered, smooth soil surfaces.

1.2. Factors Affecting Soil Erosion

Many factors influence the process of soil erosion. The vulnerability of soil erosion is dependent on several factors:

i) Rainfall
Rainfall is the most dynamic cause of soil erosion through splash and excessive runoff. Erosion is highly dependent on time, quantity, intensity, and occurrence of rainfall and it is greater when rainfall is heavy and severe over short periods.

ii) Slope of Topography
The slope accelerates soil erosion as it increases the flow of flowing water. Mini variation in slope generates a massive difference in destruction. According to hydraulics laws, a four-time increase in slope doubles the velocity of flowing water. This doubled velocity can enhance the biting power four-times and the transfer capacity by 32 times.

iii) Vegetation
The presence of vegetation reduces soil erosion. As a protector, forests and grasses are more efficient than crops. Plants also act as a barrier to the flow of flowing water, thus reducing its flooding capacity.

iv) Tillage
Soil infiltration is improved by compacting the soil and reducing the risk of erosion. However surplus tilling exposes soil to erosion, especially by the wind.

v) Nature of the Soil
Some soils move more easily than others under similar conditions. The erodibility of the soil is influenced by the soil texture, structure, quantity, and types of salts existing, organic matter, existence of hardpan, and high water table in the soil. The detachability of soil increases as particle size increases but transportability of soil increases with decreasing particle size. Clay particles are more challenging to isolate than sand, but are easily transported on a smooth land and much more quickly on slopes.

vi) Soil Moisture
The presence of a high water table monitors entry and exit, thus allowing more water to flow over and greater erosion. At the same time, long periods without rain cause the soil to loosen and thus expose the soil to wind erosion.

vii) Wind Velocity
The wind speed required for erosion depends on the size, weight, and shape of the soil particles. Strong winds have a great potential for decay, so wind speed is directly proportional to the magnitude of erosion. Wind speeds of 20 to 30 miles per hour are required for major erosion.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out in district Chakwal of Punjab-Pakistan, located 90 km south-east of the federal capital, Islamabad, and 270 km from the provincial capital, Lahore (Fig. 8). The Chakwal district is located in the Dhanni Region of the Pothwar in northern Punjab-Pakistan and is divided into five Tehsils, namely, Kalarkahar, Chohsaidan Shah, Talagang, Lawa, and Chakwal. The city of Chakwal itself is divided into five union councils and Chakwal district is divided into 68 union councils.

2.2. Sampling Design

This research analyzed the economic viability and socio-economic factors that influence the adoption of microstructures to control soil erosion at farmers' fields in the study area. For the investigation of socio-economic determinants of adopters, the primary data was collected with the help of a well-structured comprehensive questionnaire by the household survey. The questionnaire was devised to obtain information regarding the respondents' age,

Fig. 8. Map of the Study Area (Chakwal District)

highest education, and current occupation. The data obtained from the field survey was substantiated by information obtained from technical partners of the project. The data collected was carried out by using Statistical Package for the Social Science (SPSS) and frequency tables and related summary statistics such as averages and percentages were computed through descriptive statistics.

3. RESULTS AND DISCUSSION

The Socioeconomic status of farmers plays a key role in agriculture. In most developing nations; agriculture remains the key source of income. Similarly, education plays an important role in the learning of any new skills and improved income-generating skills because educated people are considered to be very rich in knowledge and have a great ability to learn and embrace new ideas.

3.1. Age Group of Sampled Farmers

The mean age of respondents was 49.4 years (Table-1), while 46 percent of respondents were in their young age (31-40 years), followed by middle age (36%) and in old age (18 %).

Table 1. Age Group of Sampled Farmers

Age group (years)	Number	Percent	Average
Young (31-40)	10	46	**49.4**
Middle (41-50)	08	36	
Old (Above 50)	04	18	
Total	**22**	**100**	

Source: Field Survey 2018, Chakwal

3.2. Literacy Level of Sampled Farmers

Education is playing a key role in getting and sharing knowledge with others. Table 2 indicated that the majority of respondents (36.4%) had metric level education followed by (22.7%) were primary level, (22.7%) were middle level and (18.2%) were intermediate level education respectively. while the average education of the respondents was 09 years in the study area.

Table 2. Literacy Level of Sampled Farmers

Literacy Level	Number	Percent	Average
Primary	05	22.7	**09**
Middle	05	22.7	
Metric	08	36.4	
Intermediate	04	18.2	
Total	**22**	**100**	

Source: Field Survey 2018, Chakwal

3.3. Farming Experience of Sampled Farmers

Table 3 indicated that more than half (54.5%) of sampled farmers were mostly young or middle-aged persons having reasonably good farming experience (below 15 years). The average farming experience of sampled farmers was 20.2 years in the study area.

Table 3. Farming Experience of Sampled Farmers

Farming Experience	Number	Percent	Average
Below 15	12	54.5	
16-30	06	27.3	**20.2**
Above 30	04	18.2	
Total	**22**	**100**	

Source: Field Survey 2018, Chakwal

3.4. Major Causes and Control of Soil Erosion

Soil erosion happens when land is disturbed by natural elements or influenced by the presence of human daily activities. Table 4 shows the main causes of soil erosion and useful ways to control it in the study area. It was noticed that the major cause of soil erosion was erratic rainfall and 60-70% of total rainfalls occur in the summer season (June to September) [28]. According to sampled farmers, the best possible and feasible way to control soil erosion are micro-structures as well as vegetation perform a very effective role against soil erosion and efficiency in crop safety. Similarly, the majority (63.6%) of sampled farmers had used stones and 36.4 percent had used bricks to build micro-structures in the study area. Due to the rain-fed area, micro-structures are one of the best solutions to control soil erosion in the study area. Other studies also confirmed that mulching, vegetation cover, terracing riprap, matting, retaining walls, and reforestation are the basic and common treatments against water erosion [23, 24, 25, and 26].

3.5. Adoption Perspective of Micro-Structure Technology

Table 5 showed the adoption potential of micro-structure technology in the study area. As the majority of sampled farmers had already familiar with micro-structures and they consider it a beneficial intervention in controlling soil erosion. Similarly, 63.6 percent of sampled farmers had attended farmer field days (FFDs) about this technology while 72.7 percent were presumed its adoption possibility through financial support in the future. Furthermore, 68.2 percent were assured that educated people have a better understanding of technology as compared to illiterate. Similarly, 27.3 percent of sampled farmers were in contact with

Table 4. Major Causes and Control of Soil Erosion in the study area

Statements	Description	Responses	Percent
Main causes of soil erosion	a. Erratic Rainfall	Yes	90.9
	b. Wind	No	0.0
	c. Flood	No	9.1
	d. Others	No	0.0
Erosion occurs mostly in a season	a. Spring	No	0.0
	b. Winter	No	0.0
	c. Summer	Yes	100
	d. Autumn	No	0
Best way to reduce soil erosion	a. Vegetative	No	22.7
	b. Retaining walls	Yes	77.3
	c. Mulching	No	0.0
	d. Others	No	0.0
The material used to build micro-structures	a. Bricks	Yes	36.4
	b. Stones	Yes	63.6
	c. Wood	No	0.0
	d. Concrete	No	0.0

Source: Field Survey 2018, Chakwal

Table 5. Adoption Perspective of Micro-Structure Technology

S. No.	Questions	Response Category	Response
1.	Did you know about the technology before project intervention	% Yes	77.3
2.	Did you consider that this technology is a beneficial intervention	% Yes	100
3.	Have you get any training about this technology	% Yes	63.6
4.	Could this technology be adopted in your area	% Yes	72.7
5.	Do you think that educated people have a better understanding as compared to illiterate	% Yes	68.2
6.	Do you have some contacts with any extension worker in this regard	% Yes	27.3
7.	Does the availability of resources affect the adoption of the technology	% Yes	81.8
8.	Do you have access to micro-structures material in your locality	% Yes	90.9

Source: Field Survey 2018, Chakwal

extension workers while 81.8 percent believed that less availability of farmers' resources affects the technology adoption. Indeed, stones are abundant in the study area and the availability of material required for micro-structures is not a constraint in adoption but the high cost of transportation on the material was the main concern.

3.6. Effectiveness of Micro-Structure Technology and the Need for Adoption

Those farmers having stable in the economy, believe in technologies while old and conservatives do not. Figure-9 shows the effectiveness of micro-structure technology and its adoption needs in the study area. The majority (86.4%) of respondents were convinced that micro-structures are effective in controlling land loss while 77.3 percent indicated better yield as a great advantage. The main reason for interest in this technology was to control soil loss, crop saving, and better yield. These structures also minimizing the expenses of re-arranging the distressed fields due to heavy rains every year.

3.7. Other Adoption Aspects of Micro-structure Technology

Figure-10 shows various adoption aspects of micro-structure technology in the study area. It is evident from the figure that the majority of sampled farmers (80%) had no soil loss during last year because of minimum rain. Similarly, fellow farmers' acceptance of this technology is low and only one farmer adopted this technology after project intervention in the study area. Similarly, major problems in the adoption of this technology were the high cost of transportation and awareness in farmers about the technology. Most of the sampled farmers (60%) had access to credit and (80%) had needed subsidies for the adoption of micro-structure technology in the study area.

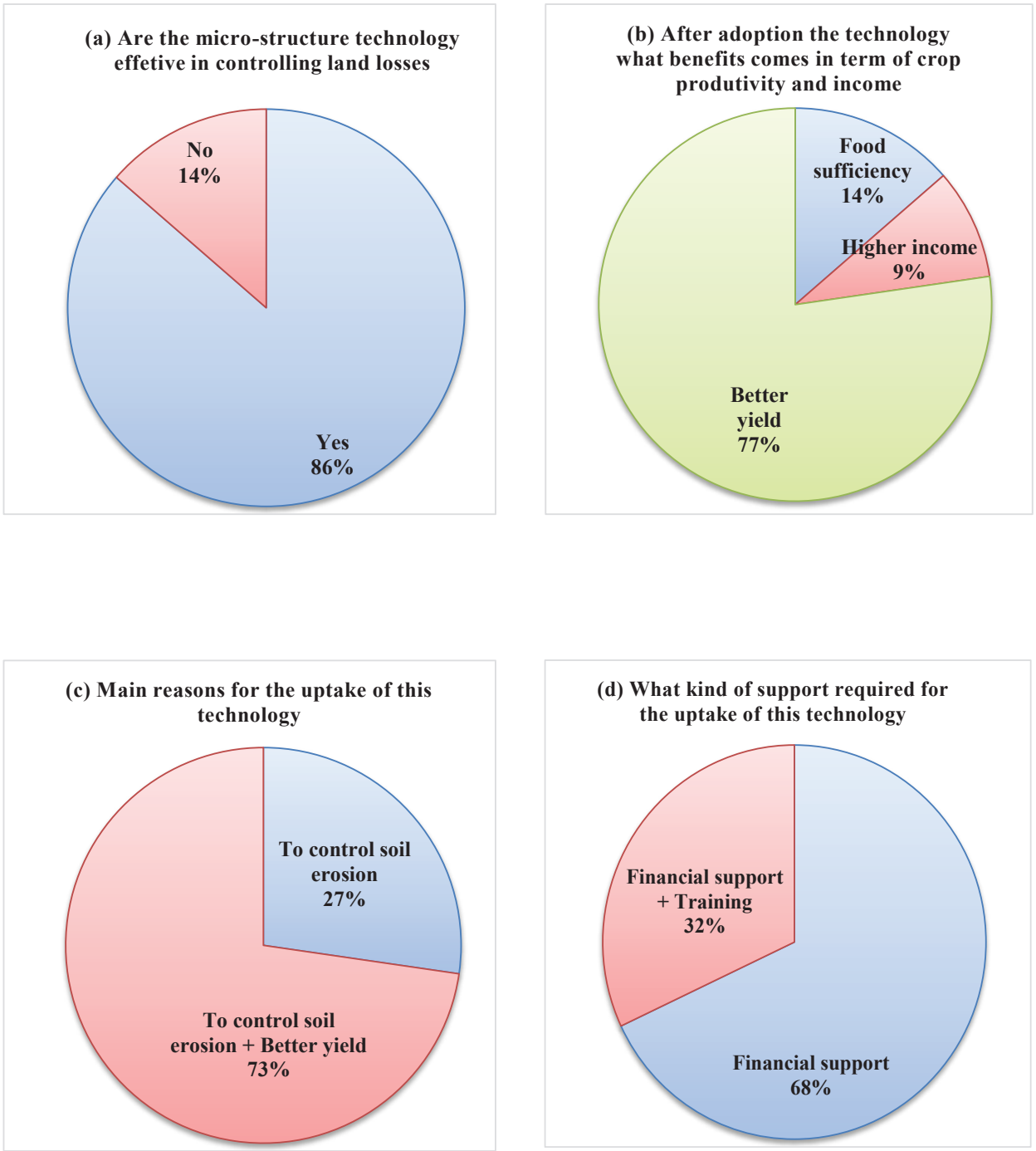

Fig. 9. (a-d) Effectiveness of Micro-Structure Technology and the Need for Adoption

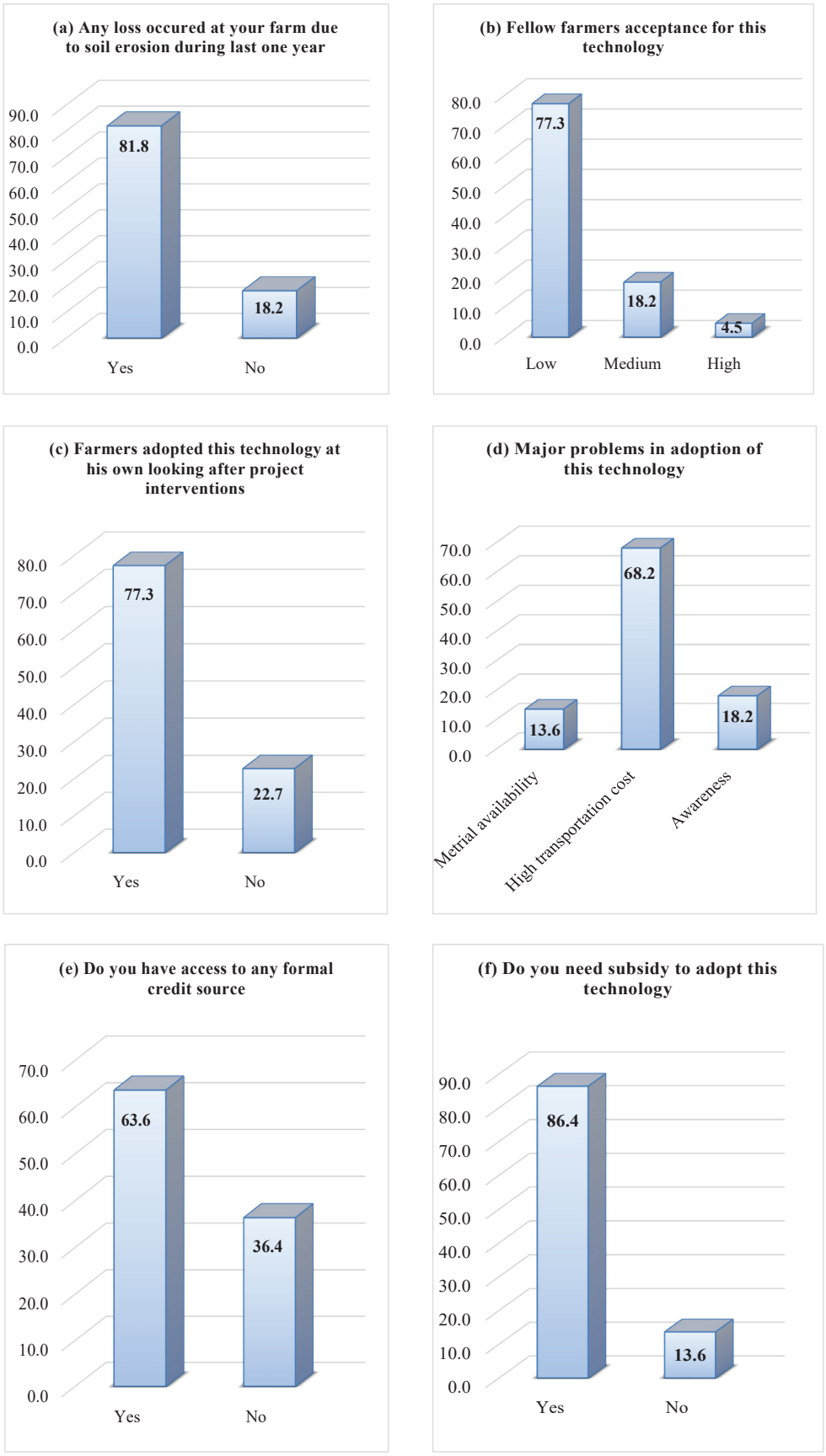

Fig. 10. (a-f) Other Adoption Aspects of Micro-Structure Technology

3.8. Glimpses of Field Activities

Fig. 11. Micro-structures demonstrated by SAWCRI scientists in the study area.

Fig. 12. Micro-structures constructed by sampled farmers after project interventions

Fig. 13. Interviews of sampled farmers by social scientist

4. CONCLUSION AND RECOMMENDATIONS

The study findings revealed that this technology is not new for the farmers, and has already been exercised in the study area for a long. It was assessed that after project interventions, the self-adoption of micro-structure technology was not encouraging and only five sample farmers adopted it on their own without any financial support. In the study area, rainfall is the most forceful factor causing erosion through splash and excessive runoff. Few of the microstructures developed by the sample farmers splashed away in the rainy season because they were not well trained in the construction of the structure. Acceptance of the technology is quite low as farmers are not well-educated and resource-poor having limited support of the relevant department. Though the adoption of micro-structures has slowed down in the study area, however, it is being considered a promising technology by the farmers to protect soil and crops from splash floods. That results in the saving of valuable resources and higher crop productivity. The adoption of this technology can be accelerated by creating awareness in farmers about the benefits of the technology with desirable support from technical institutions. Farmers must be suggested to make durable concrete structures instead of loose muddy ones. Farmers vowed that the public sector should come up with a 50% subsidy on the construction of the structures.

5. ACKNOWLEDGEMENTS

This paper is a part of the project "Pakistan Water Dialogue-Diffusion and Adoption through Partnerships and Action of the Best Watershed Rehabilitation and Irrigation Practices and Technologies to Help Rural Farmers" funded by USDA-ICARDA, Pakistan. The author greatly acknowledges the funding agency for financial and technical support to conduct this study.

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