POTENTIAL FOR INVESTMENT IN INDIGENOUS TECHNOLOGIES: A CASE OF LOW COST SOIL AND WATER CONSERVATION STRUCTURES IN RAINFED POTHWAR, PAKISTAN

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ABSTRACT:- The rainfed Pothwar area of Pakistan is one of the most eroded areas where 20% of the total land is affected by soil erosion and 4.2 billion cubic meter of water is lost from surface runoff annually. Soil erosion, along with arid climate, erratic rainfall and undulating topography makes land productivity very low and the livelihood of rural people even hard. Soil and water conservation under such an environment could provide the foundation for agricultural and natural resource development. To develop appropriate technologies for increasing land productivity through soil and water conservation, applied research has been carried out during 2001-07 in the rainfed Pothwar area. Low cost soil and water conservation structures were developed and demonstrated in the area. The investment appraisal based on the cost incurred and benefits realized by the farmers recorded through assessment survey revealed that the technology had a short payback period along with internal rate of return varying in the range of 25-37% under rainfed conditions and positive net present value. The farmers' perceptions revealed that the technology can solve the erosion problem along with 10-35% increase in crop yield and save repair and maintenance cost incurred on eroded lands. The technology is compatible with farmers' resources and practices along with availability of the raw material and technical skills for its adoption. The results from the assessment and financial evaluation of the technology provide logical base for investment in up scaling the technology.

Key Words: Soil and Water Conservation; Structures; Indigenous Technology; Erosion; Investment Appraisal; Pothwar; Pakistan.

INTRODUCTION

Total geographical area of Pakistan is 79.61 mha. Area under cultivation is 21.59 mha; of which, only 5.34 mha (i.e., 25%) is free from soil limitations and is fit for intensive agriculture (Mian and Mirza, 1993). The remaining agricultural lands have various types of problems including formation of slow permeability, water logging, salinity and sodicity and wind and water erosion (Ahmed et al., 1998). Almost 15.9 mha of land (20% of total) is affected by soil erosion. Out of this, 11.2 mha is affected by water erosion (Ashraf et al., 2000).

In Pakistan about 17% of the cultivated area is rainfed and depends on rainfall for crop production. Rainfed areas are concentrated in Pothwar Plateau, northern mountains and northea-

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stern plains of the country forming the largest continuous block of dryland farming in Pakistan. The Pothwar plateau (latitude 32 º 10' to 34 º 9' N and longitude 71 º 10' to 73 º 55' E) is a part of the great Indo-gangetic synclinorium. It covers 1.82 mha, and topography ranges from flat to gently undulating, locally broken by gullies and low hill ranges (Nizami et al., 2004). According to Ali (1967), the climate of Pothwar ranges from semi-arid to sub-humid, sub-tropical continental. Rainfall is erratic, about 60-70% of the total is generally received during monsoon, i.e. from mid June to mid September (Shah et al., 2011). Concentrated rainfall and undulating topography are the main causes of erosion in Pothwar (Shaheen et al., 2008).

Rainfed agriculture plays a dominant role in providing food and livelihoods for an increasing world population (Rockstrom et al., 2010). This rainfed tract has lot of potential for raising crops which can significantly play an important role in the economy of the country. The main soil problems of Pothowar include soil erosion, loss of soil water and low soil fertility due to uneven sloping topography (Ullah et al., 2009). In general, soils of Pothwar plateau are medium to coarse textured because these soils were mainly derived from sandstone and loess parent material containing much fine particles (Ali, 1967). Surface crusting is more in soils having high proportion of fine silt and clay (Nizami and Naseer, 1989). The soil crusting decreases infiltration rate, thereby causing an increased runoff and it results in losses of both water and nutrients (Shaheen et al., 2008). About 4.2 billion cubic meter of water is lost from this Plateau as surface runoff annually (Bhutta, 1999).

Soil erosion is the process of detachment and transport of soil particles caused by water and wind (Morgan, 1995). Soil erosion by water and wind leads to decline in soil fertility, brings on a series of negative impacts of land degradation and other environmental problems, and creates a threat to sustainable agricultural production and environ-mental quality (Yang et al., 2005). Degradation of land resources also threatens prospects for economic growth and future human welfare (Barbier, 1995).

Farmers' perception of the problem of soil erosion, its costs and benefits, is key to determining the adoption of soil conservation practices (Leyva et al., 2005). Similar to the feasibility concept of Swinkels and Franzel (1997) the compatibility concept assesses the extent to which a technology is compatible with environmental and socio-cultural factors, and farmer needs and objectives. For a technology to be adoptable, it must be compatible with the physical environment of the target area. However, their acceptability component depend on a diverse range of factors, including perception of risk, suitability to accepted gender roles, cultural acceptance, and compatibility with other enterprises (Reed, 2007).

The present paper is based on the analysis of technology assess-ment surveys during tech-nology validation and financial analysis of the investment to provide the logical base for up scaling the technology. The purpose of the paper is to provide an overview of the potential returns based on financial analysis of erosion control structures.

MATERIALS AND METHOD

This paper is based on the work carried out under the applied research component of Barani Village Development Project (BVDP) during 2001-07, in collaboration with International Centre for Agriculture Research in Dry Areas (ICARDA). Erosion was identified as one of the problems limiting productivity in the rainfed project area. According to baseline study (Shah et al., 2003), 28.64% of the operational land holding was subjected to erosion and its severity increases with the steepness of the land. From 27% to 50% of the sample respondents at different sites were facing erosion problem at their farms depending upon the topography of the area. It was suggested that low cost erosion control methods should be developed to address this problem. The scientists from Soil and Water Conservation Research Institute (SAWCRI), Chakwal, developed, validated and demonstrated low cost soil and water conservation structures at different sites in the project area.

The analysis is based on the actual cost incurred and benefits realized by the farmers estimated through their assessment of the impact in increasing productivity through conservation of soil (fertility) and water (moisture) along with cost saving due to erosion management through these structures. All the required information was collected through field survey from the beneficiary farmers. Farmers' perceptions regarding these structures were recorded through a formal survey of the host farmers in different years starting from the year of construction to assess the technology for compatibility with farmers' resources, acceptance and sustainability with respect to adoption and maintenance. The primary focus was on the on-site and farm level impact of investment in conservation technology. The scope of work and data did not allow for off-site cost and externalities to be included in the analysis. Generally farmers were more interested only in the cost and benefits of investing in such technologies in the short run and in the net profitability of the farming system overtime. That is, the on-site cost of soil erosion is the difference between the present value of net returns of the farming system with soil conservation and the present value of net returns with erosion (Barbier, 1995).

For the financial analysis, the required information about the material, equipment cost, transportation and labor charges involved in the construction of the structures, catchment area, maintenance cost, etc., were provided by the SAWCRI scientists, while farm level information regarding cropping pattern, yield increases (before and after) and cost saving due to control of erosion was collected from the farmers whose fields were used for the experimentation. The difference in yield before and after and resource saving as assessed/observed by farmers were used to calculate the net benefits.

There was no change in plot size (*watt bandi*) except at Damal where farmer had made additional bunds and divided the land from 4 to 7 plots and very little tractor levelling was done except to make adjustments with the new bunds. There was no need of levelling for changing the slope of land after construction of structures. All the other structures were constructed without disturbing the existing topography of the fields. The structures were constructed at the point of flow of water considering all the other technical requirements, i.e., height, water flow, catchment area, etc.

The erosion problem after construction of structures and the cost involved for erosion management were thoroughly investigated in the old structures; it was interesting to know that there was no erosion problem at any of the structures. However, some work like earthing up at stones was required which was mainly done by the SAWCRI staff. Maintenance cost @ 5% of investment was added. The resource saving aspects (maintenance cost of bunds without structures), a conservative estimate of reduce soil/nutrient loss (@ 14 kg Nha^{-1}) as judged by the farmers to use additional fertilizer at the eroded land to get yield equal to uneroded level, and a 10-15% increase in productivity due to more moisture availability as reported by the farmers are used for analysis. As alternate fallowing is practiced in the study area, the returns were adjusted for two years, one with crop production and other with no returns due to fallow land. The current interest in farmer participation is mainly related to Farming Systems Research (FSR) (Tripp; 1989). The field trials managed on participatory principles provide farmers' views, acceptance of the intervention and information on the compatibility of the intervention within the farming systems hence allowing an opportunity to further fine tune their practices (Anderson et al., 1985 and Hildebrand and Poey; 1985). Each site was taken as a case study and benefits were based on the crop rotation and differences experienced by the host farmers regarding increase in yield, moisture, resource saving, etc. The technology was at validation stage where the technology is to be evaluated with respect to farmers' conditions, resources and market environment. Therefore farmers' perceptions are considered as the main criteria for quantification of cost and benefits.

Investment appraisal was carried out to determine the extent of incentives for future investment in such structures. The entire subsidy and the expenditures of the farmers, if any in the establishment of the structures and family labor, were included. The analysis is conducted considering the prices of inputs as well as output during the year of construction of the structures at different locations. Based on the experience, the life of the structures was estimated at 20 years, hence depreciation/ maintenance @ 5% on initial investment was used to calculate the fixed cost. The prevailing market interest rate of 12% in Pakistani capital markets was deemed appropriate as the discount rate for NPV calculations. This rate estimate is admittedly conservative as it represents the return on relatively risk free investments in the Pakistan capital markets. The cost varies due to the location, slope and size depending upon the expected flow of water, rainfall pattern and catchment area (Table 1)

Table 1. Number, cost and catchment area of structures at different locations

Sites	Damal	Khabbal	Jarmot	Hafizabad	Khallabut
Year of construction	April 2002	May-2002	Oct-2003	July-2004	Jan 2004
Number of structures	7	12	7	5	5
Original cost Rs./ structure	1036	1855	2457	4340	2030
Catchment area (ha)	16	7.2	6	10	8

Source: Estimates provided by SAWCRI, Chakwal

The standard project evaluation techniques can be applied if the feasibility study or business plan shows that project will bring direct tangible benefits (Brzozowska, 2007). Having data for projected capital expenditures, projections of turnover, income and cost statement projections and expected cash flows, a detailed project evaluation can be conducted using various methods. These methods include the payback period, accounting rate of return, break-even-point (Mishan, 1982), and discounted methods such as NPV and IRR (Myers, 1984). This paper utilizes the payback, NPV, and IRR methods in evaluating the economic feasibility of the water conservation investment project.

Net Present Value (NPV)

The NPV decision rule is to accept only those projects which have a positive net present value (Lumby, 1991). The present value of an investment is the sum of its net discounted future cash flows:

$$NPV = \sum_{t=0}^{n} \frac{A_t}{(1+r)^t}$$

Where, "A_t" is the project's cash flow at time 't' (inflow or outflow) 'r' is the constant discount rate, and time 't' varies from the present time '0' to final project year 'n'.

Internal Rate of Return (IRR)

The internal rate of return (IRR) is that rate of return at which NPV is zero (a financial break-even point).

The IRR is the value of 'r' which satisfies the following expression:

$$\sum_{t=0}^{n} \frac{A_t}{(1+r)^t} = 0$$

This equality is typically solved through a trial and error procedure to obtain a specific "r" value for the project's IRR which is essentially a financial break-even return of the project (Fujimoto and Suzuki, 1994). Hence, the IRR decision rule is to accept those projects that have an IRR greater than the prevailing market rate of interest (i.e., the discount rate for NPV).

RESULTS AND DISCUSSION

Assessment from Farmers' Point of View

For moisture conservation and erosion control, low cost water disposal outlets were introduced by the Soil and Water Conservation Research Institute (SAWCRI), Chakwal. The technology was initially tested at two sites i.e. Dammal and Khabbal during 2002. Seven structures were constructed at Damal and 12 at Khabbal before rainy season in 2002. Also, seven structures were constructed at Jarmot during 2003, seven at Khallabut during 2004, and finally five at Hafizabad during 2004. The last five structures were constructed at small dam irrigated area at Hafizabad while all other were at rainfed area. The most interesting observation during the technology validation surveys was that almost all of the host farmers did not believe that this technology would work. The same perceptions of the host farmers were found in the last structures constructed at Hafizabad during July 2004. However, the perceptions of host farmers have changed a lot overtime, and the opponents of the technology during the first year had become the supporters during the second year. All the host farmers were fully convinced with the benefits and durability of the structures. Hence, the technology fulfils the evaluation criteria of Nagy and John (1987) who considered that for every new intervention it is necessary that each intervention should be evaluated relative to existing farm practices with respect to: a) technical feasibility in the field, b) economic feasibility (profitability) and risk considerations, c) resource fit or compatibility with on-farm resources and, d) socio-cultural acceptance and equity considerations. Structures at the first two sites were constructed with a single farmer, while in 2003 at Jarmot and in 2004 at Hafizabad, structures were constructed at the lands that belonged to different farmers. All the costs of material and construction were paid through the project. The objective of transfer of skill/knowledge to farmers by involving them in planning, designing and executing was not achieved. However, it has changed the attitude of the farmers from negative to very positive regarding this technology.

To get farmers' perception on different aspects of the structures, a detailed investigation was carried out from the host farmers at all sites. The farmers were fully convinced after observing the performance for at least one rainy season. According to farmers' opinions, they were facing problem of erosion at these sites and such structures were much needed to control erosion and conserve moisture. The assessment survey results depicted that these structures had fully resolved the erosion problem. Not only the host farmers but also the fellow farmers' interest was reported high, as most of the fellow farmers had demanded these structures.

The catchment's area varies from site to site (Table 2). As all the cost was paid by the project and farmers involvement was very nominal, therefore farmers' knowledge about the costs involved was very poor. There was no change in cropping pattern or crop rotation after the construction of structures. Mainly wheat-sorghum/millet-fallow-fallow crop rotation at Jarmot and Khabbal while wheat-fallow-wheat-fallow or fallow-groundnut-fallow-groundnut at Damal while under dam irrigated conditions at Hafizabad mainly wheat-sorghum/millet-wheat was practiced.

The objective of these structures according to farmers' opinions was that these were constructed to control erosion and conserve moisture. Based on the previous experience of farmers, they felt that there was real need to construct the structures and fully resolve the problem. At all the sites farmers were convinced and would like to construct such structures at their own expenses at other similar lands. The difference in yields before and after the structures was based on the farmers' judgments; they reported that the yield of crops had increased significantly by 10% to 50% due to more moisture conservation as erosion was checked by these structures. The host farmers at Hafizabad reported that as the catchment area is already irrigated, the only impact would be on erosion management.

Regarding the erosion problem, it is noted that at almost all sites the problem of erosion was very serious and farmers had to repair their lands whenever there were heavy rains. So the repair cost depends upon the intensity of rainfall. Farmers reported that they mostly control erosion by making bunds/levelling once in a year after summer rains. The erosion management involves tractor levelling along with labour work and on an average the erosion control cost was reported between Rs. 3000 and Rs. 5000 per year at different sites. Considering the actual cost, payback period was calculated considering only the erosion management cost as provided by the host farmers. The average cost per structure (Table 1) showed a wide variation among sites and also in different time periods; in particular, the cost for the last site of Hafizabad was much higher than the initial structures constructed in the same area at Damal during 2002. A payback period less than 5 years is generally acceptable in the light of the returns expected on fixed investments of similar risk.

Farmers were convinced that grasses and weeds have the capacity to work as a binding force just like cement and were of the view that with the growth in grasses overtime their strength would increase further. The grass growth was observed after about 6 months. Positive impact of these structures was also noticed in terms of soil/fertility conservation and less soil sedimentation in the down stream.

The present analysis was carried out considering the original cost of structures, maintenance cost each year along the life of the project, benefits realized due to higher crop yield, savings from low erosion management cost after construction of structures, and saving in fertility due to erosion control as judged by the farmers. The main aim of technology assessment at different stages of its developments was to provide an assessment of farmers' priorities, decision criteria, resource availability, constraints and possible development opportunities (Anderson et al., 1985). Criteria used by farmers to evaluate and adopt technologies may be totally different from that of researchers and the returns to investment in agricultural research could not be achieved until the research recommendations are adopted by the farmers. Therefore farmers' point of view regarding the cost and benefits were used in the analysis

Financial Viability of Low Cost Soil and Water Conservation Structures

Net Present Value (NPV)

The results show that NPV is positive at all sites for all structures constructed over different years with different cost (Table 3). According to the NPV criterion the investment on the structures is a viable option for future development activities in the area.

Internal Rate of Return (IRR)

The analysis was done considering 20 years of life of the project intervention after discussion with farmers and the technical experts. The number of structures built at each site were decided after estimating the expected water flow depending upon previous rainfall data and slope of the soil and the selected site was considered as one unit irrespective of the ownership of land. The cost of each unit depends upon the size of the structures required for expected water flow,

Table 2. Farmer's assessment of Low Cost Soil and Water Conservation Structures (LCS&WCS)

	Damal	Khabbal	Jarmot	Hafizabad	Khallabut
Technical Assessment					
Year of construction	April-2002	May-2002	Oct-2003	July-2004	Jan-2004
Number of structures	7	12	7	5	5
Catchment area (kanal)	400	70	400	400	70
Yield improvement in summer crop (%)	10	35	18	10	18
Yield improvement in winter crop (%)	10	35	20	21	18
No. of potential places for LCS&WCS on your land	6	10	20	2	5
Solved the problem	Fully	Fully	Fully	Fully	Fully
Original cost (SAWCRI) (Rs./structure)	1036	1855	2457	4340	2030
Resource saving from controlled erosion (Rs./structure/year)	430	418	715	600	500
Pay back period only saving due to erosion control (years)	2.4	4.4	3.4	7.2	4.0
Interest of fellow farmers	High	High	High	High	High
Need of LCS&WCS on Area (% of total village area)	10	50	40-50	10-15	50
Crops grown at the field with structures	Wheat-groundnut	Wheat-sorghum/ millet	Wheat-sorghum/ millet	Wheat-sorghum/ millet	Wheat-sorghum/ millet

Source: Based on the results of on-going assessment surveys from 2003-2005 slope and the availability of material in that area. The resources saved in terms of each year repair that was earlier done (before structures) by the farmers were added to the benefits. Farmers have reported that there was loss of nutrients due to soil erosion and they had to apply more fertilizer at the eroded soils, therefore a conservative allowance of Rs.120 acre^{-1} was added for nutrient saving. Total cost and benefits of the total command area under each unit were estimated and used for the analysis. The value of IRR ranges from 25% to 37 % (except at Hafizabad) which is much higher than the market interest rate. At Hafizabad the structures were constructed at the irrigated area and there was no productivity increase due to more moisture conservation. Only the resources saved from control of erosion were considered as the return to investment. Even under such condition the IRR is 10%, and the IRR would be a little higher, if the fertility saving factor is also added. However, scientific rules if applied on the indigenous technologies and farmers' practices may develop such low cost technologies that are both easily adoptable and can serve the purpose at larger scale within same resources as compared to the imported or lab based technologies that are not integrated with the local knowledge and farmer's practices.

Table 3. Financial analysis for low cost soil and water conservation structures

Site	Number	Year	Initial total Cost (Rs.)	NPV (Rs.)	IRR (%)
Khabbal	12	2002	17760	27963	34
Jarmot	7	2003	17200	20044	28
Khallabut	5	2004	10150	9524	25
Dhamal	7	2002	7252	13693	37
Hafizabad*	5	2004	21700	2729	10

* Irrigated area

Source: Estimated by the authors based on cost data and survey results.

Based on the farmers' perception during on-going assessment survey during technology validation stage, positive impact of the structures was reported in terms of higher yield due to more moisture conservation and saving in soil fertility along with saving of resources that farmers had to use every year to repair eroded lands. The results of the financial analysis are encouraging. In terms of total area affected in the study area, water erosion is the most serious problem of land degradation and is widely found across the Plateau and leads to abandonment of land (Nizami and Shafiq, 1990; FAO, 1994). Gullies occupy 60% of Pothwar Plateau, leaving 1/3 suitable for agriculture (Haigh, 1989) where rainfed cropping is practiced (Dregne, 1992; Gary, 1996). The available evidences indicate that the costs of land degradation, and thus the benefits of conservation, may be substantial in developing countries, despite relatively low average returns to agriculture. Estimates of the cost of land degradation in these countries vary from under 1% to over 15% of GNP (Barbier and Bishop, 1995). The benefits of soil moisture conservation were more visible where soil fertility improvement measures were considered and incorporated (Barron, 2004). Many studies show that crop yields were increased through conservation of soil, water and nutrients (Ngigi, 2003; Stoonsnijder, 2003). The results of the present study also confirm the increase in productivity through soil and water conservation resulting in higher returns to the farmers. Hence there is a large scope for promotion of these structures along with other soil and water conservation technologies.

Recommendations

In the past, many soil conservation measures including installation of cemented erosion control structures were built in the study area. However, these structures are much costly compared to the intervention under discussion. There is a clear need to identify low cost technologies similar to the one undertaken in this study. Such technologies should be evolved through integration of the local knowledge using locally available material with dissemination of the profitability results to a potentially large scale application. For proper planning, implementation and rapid adoption of such technologies, there appears to be ample room for close collaboration and integration among research and development components. Although the technology is economically viable and socially acceptable as indicated in the results of this study, the dissemination of this technology is a task that is yet to be accomplished. The low-cost water conservation technologies that are developed and evaluated by researchers should be taken up by the concerned line department who must take ownership and responsibility for dissemination with pertinent backup by the technical experts.

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