CEECC Working Paper
No. 2

Economic Appraisal of Rooftop Rainwater Harvesting Technology in Bagh and Battagram Districts Pakistan

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Designed, composed, and finished at the Publications Division, PIDE.

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1. INTRODUCTION

Water is the most crucial commodity for all living beings on earth. It is essential for all basic human needs e.g., food, drinking water, sanitation, and health, [Secretariat of the Convention on Biological Diversity (2010)]. Access to water is everyone's basic right recognised by a number of development and human rights agencies. Management of water resources on sustainable basis is the most pressing issue of the present age. Imprudent use of water has reduced the natural replenishment capacity of water reservoirs. Due to which water scarcity has taken place and sustainable supply of water has become a challenge. The problem is more serious in hilly and fragile areas of developing countries, where supply of water is very costly business.

Presently a number of development and environment agencies are planning to introduce innovative practices to conserve and supply water on sustainable basis. For instance Earthquake Rehabilitation and Reconstruction Authority (IRRA) initiated RRWH technology in earthquake affected areas of Pakistan. The technology has the potential to conserve and supply water at sustainable basis but to date no formal action has been taken to utilise this option. Informally some households were using it as an adaptation strategy to water scarcity problem, but they were few in numbers. Moreover, this small scale use was more of a behavioural phenomenon, not planning. Now government has formally launched it as a big project in earthquake affected areas. These areas were more vulnerable in terms of water in post earthquake scenario. In this context, RRWH can be considered as an innovation as well as adaptation to changing water supply situation.

There were a number of factors due to which this technology has been implemented in earthquake affected areas. Mainly this includes rainfall in those areas which is considered as the basic ingredient of RRWH technology. These areas receive on average 1500 mm/annum rainfall that is highest in Pakistan. Second reason of implementing the technology is that, newly built houses[1] are made of Galvanised Iron (GI) sheet, known as the best catchment area for harvesting rainwater. It has the highest Coefficient of Runoff (0.9), which means 90 percent water which is falling on roofs can be harvested[2]. Third important factor is the failure of supply lines which are not successful due to hilly tIRRain, and fragile nature of water reservoirs.

Present study is the economic assessment of RRWH technology in earthquake affected areas of KP and AJK. Study attempts to estimate some of the economic benefits being accrued from RRWH technology. It compares few market and non market economic benefits (e.g., yields of kitchen gardening, saving of water related diseases expenditures, value of time being saved) to the costs (e.g., capital cost, O&M cost, administrative cost) of technology and analyses the viability and profitability of the technology. For this purpose study adopted some financial tools for instance; Net Present Value (NPV), Internal Rate of Return (IRR), and Pay Back Period for evaluation.

2. ECONOMIC APPRAISAL OF RRWH TECHNOLOGY

Economic appraisal of the technology is carried out to analyse the viability, practicality and profitability of RRWH technology. So far no empirical study has been conducted on ex-post scenario of RRWH that can provide some insights in local context and contribute to literature. Present study is first of its kind

[1]In post earthquake situation (reconstruction)

[2]RRWH Construction and Maintenance Manual, AFPRO (Action for Food Production) UNICEF.

which will fill the gap in literature of rainwater in Pakistan. However, there are a number of studies on RRWH from other countries which are covering some of the aspects of RRWH.

Baguma, *et al*. (2010) and Lehmann and Tsukada (2009) examined rainwater harvesting with reference to human health and time allocation. Studies have focused the socioeconomic aspect of rainwater and revealed that this technology reduces cost incurred on health as well as time allocation for curing sick people, which is used for profitable activities. Young children (both male and female) can go to school who are otherwise busy in fetching water. Moreover, this system improves the sanitation and hygiene facilities for rural population by providing them water at home on sustainable basis. Authors have also claimed that this technology has reduces the risks[3] associated with water fetching.

Dwivedi and Bhadauria (2010) analysed the domestic rainwater harvesting in India. Study is based on primary survey of households to examine the size of rooftops, storage capacity and per unit cost of water. The unit cost of the water which can be harvested from rooftop area was calculated by considering the 30 years of serviceable life of RRWH system and water tank at 7 percent rate of interest. The salvage value of the RWH system was assumed 25 percent and annual maintenance and repair cost as 0.5 percent of the capital cost. In this study authors have calculated the unit cost of water but have not explicitly indicated that what approach has used.

Singwane and Kunene (2010) carried out a study in rural areas of Swaziland to analyse the viability of rainwater harvesting technology. By using households' survey, investigators studied the price of equipment in local market and linked it to the affordability of community. Findings showed that majority of the households are using rainwater harvesting technology which shows that the technology is affordable. However authors have not clearly

[3]Study highlighted a number of risks associated with water fetching being faced by people, and in particular, women who are commonly involved in fetching water. These include; risk of hurting, falling, being raped etc.

mentioned whether the installation was done by households or some other agency. Study also reported that although households are using this technology, but due to poor financial condition they want to increase the storage capacity which they want to increase.

3. METHODOLOGICAL FRAMEWORK

Present study is based on the analysis of RRWH technology in ex-post scenario to investigate some of the benefits and costs of technology by demonstrating their net value to the economy in general and community in specific. Analysis enables implementers to compare the expected benefits estimated in ex-ante situation with actual benefits which are being accrued. A number of tools have been adopted to study the net benefits of the project initiated by ERRA. In this regard; first tool is NPV that compares the value of a currency today to the value of that in the future, taking inflation and rate of returns into account. If the NPV of a prospective project is positive it means that the project is expected to contribute in social welfare. In this case the project can be implemented or scaled up, if other financial parameters also support the results of NPV. However, if the NPV is zero or negative, the project is considered as unprofitable.

In that case it depends on the nature of the project and urgency of its implementation. In other words implementation decision of the projects (specifically in public sector) is not only determined by the associated monetary gains. For instance; in case of water even if project is not profitable, urgency or need of water supply cannot be ignored. IRR is applied as a second tool to examine the net value of technology. It is the discount rate often used in capital budgeting that makes the net present value of all cash flows equal to zero from a particular project. It is also defined as the rate of growth a project is expected to generate for domestic economy. If IRR of a project is more than its social discount rate, which is its opportunity cost, the project can be undertaken.

The third technique which present study has used to assess the technology is PBP. It refers to the time period required for the return on an investment to repay the sum of the original investment cost. For example, a $10000 investment has made by some agency and it has $1000 per year return. This investment would be recovered in ten years. And it will have a ten year PBP. It is comparatively weaker tool to evaluate the investments in projects because; it cannot take into account the time value of money. PBP intuitively measures how long something takes to "pay for itself" or stream of earnings required covering the sunk cost. All other things remain same, shorter PBPs are preferable to longer ones. This analysis provided the relevant ex-post evidence within the frameworks of discounted cash flows and Benefit Cost Analysis (BCA).

Study has used primary as well as secondary data in order to examine the economic benefits and costs of the project. Data on cost of the project of RRWH was collected from the implementers of the project. Cost of each installed RRWH unit mainly includes capital cost, operational and maintenance (O&M) cost, and administrative costs. All other costs were taken at one point of time except O&M cost, because it changes over time due to depreciation of the unit, inflation, and some other exogenous factors. In order to encompass this, study has used a specific percentage for annual increment in O&M cost which is 5 percent and is based on the inflation.

Benefits of the system are monetised and computed using the primary data collected through survey of beneficiaries in 2010. For this purpose actual or estimated monetary value of each individual benefit was summed up to reckon the aggregate benefits. Mainly there are three types of benefits accrued from RRWH technology. First was the monetary value of kitchen gardening which became possible after the implementation of technology. It is a saving for households because earlier they were purchasing vegetables from market. Second benefit was annual saving of medical expenditures on women health. It was calculated by computing the difference of women medical cost of households which were using this technology as of those which were not using this technology. Moreover, the computed cost was based on water fetching related diseases. Third component of benefits was saving of time due to RRWH technology, which was otherwise invested for water fetching.

The monetary value of time was calculated using prevailing women wages as proxy. To minimise the error, study investigated from respondents that, out of total saved time, how much they were using in productive activities. They reported that they were using approximately 30 percent of total time which was being saved due to RRWH facility. In order to attain precision and robustness of results, sensitivity analysis was adopted. For this two comprehensive scenarios were developed where saving of time was considered as 20 percent and 30 percent.

3.1. Discount Rate

Discount rates are widely used in the public sector projects to assess the proposals where costs and benefits accrue over long time periods. Socially optimal policy requires an appropriate choice of discount rate. It reflects the opportunity cost of the funds committed to the projects. The opportunity cost depends upon what other options are available to invest and market conditions. Discount rate is a measure to check and ensure the efficiency in allocation of scarce resources. The underlying assumption is that these funds could be used for other projects with a specific percentage of national rates of return. Following is the mathematical formulation of discount rate for a particular project.

$$E(ri) = Rf + \beta i\,(E(rm) - Rf) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

$E(ri)$ = return required on financial asset *i*.
Rf = risk-free rate of return.
βi = beta value for financial asset *i*.
$E\,(rm)$ = average return on the capital market.

The discount rate used in this analysis is 12 percent which is used to evaluate the public sector projects/investments and is determined by market rate of interest on which different agencies are lending money to government.

There are few assumptions which are used in financial analysis of the projects like; markets are clear, there is one market interest rate, perfect information and all aspects are covered by markets. Under these assumptions the market clears at a rate where the time preference for consumption equates to the opportunity cost of capital. The opportunity cost of capital is a rate of return the capital must pay back to investors in order to justify investment decision. In this case the market-clearing rate would be the discount rate.

3.2. Life of the Project

Life of the RRWH technology varies across different regions depending upon the nature of material used, operational and maintenance (O&M) cost, weather conditions etc. But in case of this project which has been implemented by ERRA, the minimum life of each unit (which includes gutter, pipes, first flush diverter, and storage tank) is 20 years. It starts from implementation of the pilot project that has taken place in year 2010. This life time of RRWH technology was defined by the technical agencies involved in implementation [NESPAK (2010)].

3.3. Salvage Value

Whenever any project is implemented in which some physical capital is involved; it has certain life or time period which is determined by the material which was used. When life of any physical material or object is over there is always some leftover of that material which was used as physical capital in that project. That material or left over from physical capital is called ‘Salvage Value’. This value which is established and defined by implementing agencies varies with time, place and project.

Specifically it depends on number of factors; for instance, nature of the material which is used in a specific project as physical capital, maintenance and care, weather conditions etc. Salvage value is presented in percentage of total material which has left. In case of RRWH technology salvage value is 10 percent which is provided by the technical staff of implementers. It means the leftover of total physical capital used is 10 percent.

3.4. Description of the Study Area

Study area includes one village of Bagh and one village from Battgram, where RRWH project has been initiated by IRRA with the coordination of two NGOs Maqsood Welfare Foundation (MWF) and Save the Children as its implementing partners. MWF is local NGO which is operating in Bagh AJK. It has implemented the pilot project of RRWH in Bagh. Save the Children is an international NGO operating in different areas of Pakistan. It was involved in the implementation of RRWH project in Battagram.

Battagram district lies in Hazara division of the KPK province in Pakistan. Total land area of the district is 1301 square kilometres. It was estimated in 2004-05, that the population of Battagram district is 361,000 (Battagram, 2007). It is at a distance of 90 km from Abbottabad and is 240 km far from the capital city Islamabad. The mainly three languages Pashto, Hindko and Gojri are also spoken. In offices English and Urdu is used and understood. Battagram was notified a district in July 1993 when it was upgraded from a Tehsil and separated from Mansehra district. [Battagram (2007)].

The project of RRWH has been executed in Saroona, which is a village of Allai, the subdivision of Battagram. The Allai valley is bounded by Kohistan on the north and east, by the Kaghan valley, Nandhiarh and Deshi of Deshiwals on the South, and by the Indus river on the West. The valley was ruled by Khans (tribal rulers) until 1949, when it signed the Instrument of Accession with

Pakistan. The valley was badly affected by the earthquake on october 8, 2005 which also destroyed the ‘cable way’; that used to allow residents to cross the Indus River. The Saroona village is comprised of 330 households and most of them are low income families [Battagram (2007)].

The total population of the village is 5000, whereas the average household size is eight. In pilot phase the facility of RRWH was provided to 50 households. Bagh is one of the eight districts of Azad Jammu and Kashmir (AJK), Pakistan. The total area of the district is 1,368 square kilometers [Bagh (2007)]. Bagh district is composed of three sub-divisions, namely Dhirkot, Bagh and Haveli. Bagh was also severely affected by the Earthquake on October 8, 2005 which destroyed the overall infrastructure of the district.

Survey of the present study has been conducted in Chitra Topi which is one village of union council Topi in district Bagh. It is situated in the north east of main city of Bagh at an altitude of 7000 feet above the sea level and on a distance of 18 KM [Bagh (2007)]. Topography of the area is hilly. Chitra Topi village has relatively small number of the households which was 274. Total population of the village was 1918 in which males are 940 and females are 978. Literacy rate of the village is above 80 percent which is comparatively high [Bagh (2007)]. The main clans of the Chitra Topi are Suddhen, Mughal, Qureshi.

3.5. Survey Methodology

In order to carry out detailed analysis, data was collected through personal interviews of respondents in the selected villages of both districts (Bagh and Battagram). The survey was conducted in year 2010. In this regard a pre-tested questionnaire was developed and used. Study is based on pilot phase of the project in which only 50 households were provided with technology. To assess the net benefits all of the households were interviewed and there was no sampling involved in it.

4. RESULTS AND DISCUSSIONS

Present study is based on economic appraisal of RRWH technology that has been conducted using certain financial tools like NPV, IRR, and PBP. For robustness of results, sensitivity analysis has been carried out. It is based on two comprehensive scenarios developed by using the variation in time saving that is one benefit. It is worthwhile to observe that results produced by present analysis are inflation adjusted. Appendix of the study gives the comparison of the findings with and without inflation adjustment. To avoid the complexities inflation was assumed to be constant throughout the project life. Moreover, since the study focuses the net benefits of the technology, examining the inflation variations was beyond its scope.

4.1. Sensitivity Analysis

4.1.1. *NPV*

In first scenario of sensitivity analysis, keeping other benefits (saving of health cost, and saving due to kitchen gardening) constant, 30 percent of women saved time has been used. This saving of time was monetised and included in the aggregate benefits of technology by using the proxy of women wages. Based on this assumption net cash flow was developed for the estimation of NPV, IRR, and PBP. First is NPV that has been estimated for all individual households based on accrued benefits. The reported value is average NPV of all households that is 22488.98 rupees.

In case of project assessment, rule of thumb is that, NPV should be positive which is true in case of this scenario. However, the actual value of NPV showed some deviation from its mean which was due to the variations in accrued benefits across the households. This is because of individual usage and optimisation of technology. It is worthwhile to mention here that there are a number of ethereal benefits of the technology which have not been estimated because of some data related technical constraints. If those benefits are also included, value of overall benefits may increase by some percentage.

In second scenario, 20 percent of the saved time is being utilised by women in productive work. As it is mentioned in previous section, this change was made to achieve the robustness of findings. In this scenario the average value of NPV of all the households is 2583.61 rupees which is less than the value of NPV in first scenario. But still it is quiet significant for technology's viability and profitability. Moreover, it also shows that even if minimum benefits are accrued still RRWH can be adopted as an economical approach for supplying water in these areas. In other words, since the technology has the range of benefits for study areas, viability is less responsive to one individual benefit.

4.1.2. *IRR*

Second measure used to examine the feasibility and practicality of RRWH in study areas is IRR. In first scenario of sensitivity analysis IRR is estimated using 30 percent of saved time that was being productively utilised by women. IRR is calculated for all households but reported value is average IRR that is 24 percent in first scenario. However, the actual value of IRR has shown some variations which can be explained by the difference of benefits across the households. This value of IRR is higher considering the rate of return and market conditions. Finding shows that technology is profitable and communities are benefiting in terms of reported benefits. It also supports the implementation and scaling up of RRWH technologies.

Table 1

Average Values of NPV, IRR, and PBP

	First Scenario (with 30% usage of save time)	Second Scenario (with 20% usage of save time)
NPV	22488.98*	2583.61
IRR	24 %	13 %
PBP	5**	7

*NPV is measured in rupees.
** PBP is measured in years.

In second scenario women saving of time is decreased to 20 percent of the total saved time, and value of IRR is 13 percent that is quiet lower than first scenario. It is comparatively low but still reasonable for technology to meet the condition of profitability and viability. The findings of IRR across the two scenarios shows the same pattern as it was in case of NPV that also decreased with the decrease in value of women time saving.

4.1.3. *PBP*

PBP is the third measure adopted by present study to assess economic viability of RRWH technology. In first scenario, keeping other benefits constant PBP is calculated on the basis of 30 percent of the women save time which was being utilised. With this saving of time analysis has revealed that average value of PBP is 5 years. It imply that on average this project required 5 years to get the total return of investment keeping in view the monetary value of above mentioned types of benefits. However, inclusion of a number of other benefits can decrease the PBP. Actual value of PBP also fluctuates due to the variation in each household’s individual benefits.

In second scenario the average value of PBP is 7 years which is also low. It is based on the 20 percent share of saved time in overall benefits of technology. It implies that on average RRWH technology requires 7 years to get the total return of investment. The variation in PBP shows that each household benefits have significant role in determining the PBP. By this finding we can conclude that profitability of a project is not the function of its cost and how it is implemented, but it is also determined by the way people use it.

5. CONCLUSION AND POLICY IMPLICATIONS

5.1. Conclusion

Present study is based on rural domestic water management using RRWH technology. Findings revealed that

RRWH has generated a number of benefits and has become very advantageous project in earthquake prone and hilly areas. Study analysed the potential benefits which are being accrued by the people of those communities in Bagh and Battagram. These benefits have tangible as well as intangible value. Since the ethereal portion of benefits is difficult to reckon, some of the tangible benefits were investigated and compared with the cost of the technology in order to develop the net cash flows. Study has exposed that this technology has huge potential in terms of benefits associated with it.

These benefits include some monetary benefits (saving of kitchen gardening, saving of medical cost) as well time saving which has also been monetised in this study. Due to a range of RRWH tangible benefits there is very less time period (PBP) required to pay back the investment. Present study also concludes that the technology has almost no chances of failure in all those areas which are receiving higher rainfall. Moreover, it can be initiated by individuals and communities by mobilising the resources and technical expertise. It is worthwhile to mention that the assessed benefits of the technology are one part and there are a number of other benefits which are yet to be investigated. This economic appraisal endorsed that technology is viable, profitable, time saving, and practical approach of water supply.

5.2. Policy Recommendation

The findings of the underlying study have put forward a number of policy implications. Some of the main policy implications are as follows;

(1) Present study has unveiled that RRWH technology is viable and suitable for earthquake prone, hilly, and scattered areas due to its cost effectiveness. Based on this finding study proposes that, RRWH system should be scaled up to other such areas which are facing the problem of water shortage. This is a best alternative

which would supplement and ease out pressure from traditional water supply sources.

(2) While computing the women health cost study found that women who are harvesting rainwater have comparatively better health and less health expenditures as of those who are not using this technology. Training on better sanitation and hygiene may enhance the health benefits of the technology. It may further contribute to better health and time saving to cure the illness.

(3) Study has explored that kitchen gardening has huge potential in both villages which was not being utilised before the introduction of this facility. It reduces the dependence of poor people on market and increases their personal savings. Present analysis suggests that this aspect should be included into future supply schemes.

(4) Time saving is also one important benefit of the technology which has become possible due to RRWH in Bagh and Battagram. This study recommends that some policy measures should be taken to ensure the efficient utilisation of this time saving.

(5) Traditionally women have to manage the water and most of the benefits (e.g. time saving, saving of medical cost, and kitchen gardening) of RRWH are also being accrued by women in study areas. They are the major stakeholders of this water supplying technology. Study recommends that they should be trained to optimise these benefits.

Appendices

APPENDIX-I

Present study is the appraisal of RRWH technology. Reckonings are based on the financial tools like; NPV, IRR and PBP. Below is the NPV Table which gives a bird eye view of the net cash flow. Table provides the value of NPV for a single household who is using the technology and some major benefits of the technology are quantified using their monetary value.

Years	Capital Cost	O & M Cost	Total Cost	Revenue	Net Flow	NPV
2010	42970	0	42970	11550	–31420	37,883.86
2011	0	1000	1000	11550	10550	
2012	0	1050	1050	11550	10500	
2013	0	1102.5	1102.5	11550	10447.5	
2014	0	1157.625	1157.625	11550	10392.375	
2015	0	1215.506	1215.506	11550	10334.494	
2016	0	1291.281	1291.281	11550	10258.719	
2017	0	1355.845	1355.845	11550	10194.155	
2018	0	1423.637	1423.637	11550	10126.363	
2019	0	1494.819	1494.819	11550	10055.181	
2020	0	1569.56	1569.56	11550	9980.44	
2021	0	1648.038	1648.038	11550	9901.962	
2022	0	1730.4	1730.4	11550	9819.6	
2023	0	1816.922	1816.922	11550	9733.078	
2024	0	1907.768	1907.768	11550	9642.232	
2025	0	2003.156	2003.156	11550	9546.844	
2026	0	2103	2103	11550	9447	
2027	0	2208.166	2208.166	11550	9341.834	
2028	0	2318.574	2318.574	11550	9231.426	
2029	0	2434.05	2434.05	11550	9115.95	

APPENDIX-II

Table-II is the extended form of Table-I. Remaining all information is same is same as it was in Table-I. Use of discount factor yielded that there is no big difference in results with and without engulfing inflation into calculation of NPV. It is providing the NPV for same household, but it is calculated engulfing inflation into net cash flow. The inflation which has been adjusted in cash flows was 13 percent, and it was assumed as constant throughout the life of the project. Assumption of constant inflation was taken to avoid the complexity of analysis.

Years	Capital Cost	O & M Cost	Total Cost	Reve-nue	Net Cash Flow	Discount Factor	Inf.Adjusted Net Cash Flow	NPV
2010	42970	0	42970	11550	-31420	1	-31420	49,049.87
2011	0	1000	1000	11550	10550	1.0049558	10602.28369	
2012	0	1050	1050	11550	10500	1.00993616	10604.32968	
2013	0	1102.5	1102.5	11550	10447.5	1.014941202	10603.5982	
2014	0	1157.625	1157.625	11550	10392.375	1.019971047	10599.92161	
2015	0	1215.506	1215.506	11550	10334.494	1.02502582	10593.12318	
2016	0	1291.281	1291.281	11550	10258.719	1.030105643	10567.56433	
2017	0	1355.845	1355.845	11550	10194.155	1.03521064	10553.09772	
2018	0	1423.637	1423.637	11550	10126.363	1.040340937	10534.86997	
2019	0	1494.819	1494.819	11550	10055.181	1.045496659	10512.65814	
2020	0	1569.56	1569.56	11550	9980.44	1.050677931	10486.22805	
2021	0	1648.038	1648.038	11550	9901.962	1.055884881	10455.33197	
2022	0	1730.4	1730.4	11550	9819.6	1.061117635	10419.75073	
2023	0	1816.922	1816.922	11550	9733.078	1.066376322	10379.12392	
2024	0	1907.768	1907.768	11550	9642.232	1.07166107	10333.20466	
2025	0	2003.156	2003.156	11550	9546.844	1.076972008	10281.68375	
2026	0	2103	2103	11550	9447	1.082309265	10224.57563	
2027	0	2208.166	2208.166	11550	9341.834	1.087672974	10160.86037	
2028	0	2318.574	2318.574	11550	9231.426	1.093063263	10090.53263	
2029	0	2434.05	2434.05	11550	9115.95	1.098480266	10013.69118	

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