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**Impact of Rooftop Rain Water Harvesting
Technology on Women Well-being in
Hilly and Fragile Areas: Evidence
from Pakistan**

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ABSTRACT

Availability of fresh water remained a serious issue and its severity is increasing day by day. The situation is further being deteriorating in earthquake prone, hilly, and rural areas. In these areas most vulnerable segment of population is women for they are the ones who have to fetch water far from their dwelling units. In order to resolve the water crisis, different approaches, techniques, and practices are being adopted, among which one is Rooftop Rain Water Harvesting (RRWH). This study assesses the impact of RRWH system with special reference to women health in the hilly and earth quake affected areas of Bagh and Battagram villages of Azad Jammu and Kashmir and Khyber Pakhtunkhwa province of Pakistan, respectively. Analyses are carried out using Negative Binomial Regression technique to quantify the results. The results reveal that RRWH technology is viable, profitable; women friendly and sustainable source of water supply, especially in the earthquake prone, hilly, and rural areas which are receiving comparatively high rain fall in Pakistan.

JEL classification: O13, Q25, Q56, Q58, R28

Keywords: Rooftop Rain Water Harvesting, Earthquake Prone and Hilly Areas, Women, Negative Binomial Regression, Pakistan.

1. INTRODUCTION

The significance of fresh water is well recognised and documented. Water is a prerequisite for life and without it there will be no living thing. The easy access to water remained a serious issue in both urban and rural areas in developing as well as developed countries [Tripathi and Pandey (2005) and Dwivedi and Bhadauria (2010)]. Particularly, its importance is further enhanced in earthquake prone, hilly, and rural areas where access to water is difficult, expensive and tiresome [Kumar (2009)]. According to United Nations, water is the basic right of all human beings. Millennium Development Goals set forth for 2015 have focused on the availability of safe drinking water [United Nations (2003)]. It is frequently asserted that quality of life depends on the quality of water being used. Beside its importance and necessity, fresh water is becoming a scarce commodity on earth.

Water demand has increased with alarming pace in the last few decades, whereas the availability of fresh water has decreased drastically in this period [Liaw and Tsai (2004) and Lehmann and Tsukada (2009)]. This is primarily due to the higher population and industrial growth, intensive agriculture production, and rapid urbanisation [Kumar (2009) and United Nations Environment Programme (2009)]. This surge in water demand is putting tremendous pressure on existing water supply sources with serious consequences for environment. United Nations Environmental Programme highlighted the gap between the supply and demand of water as the most critical issue of contemporary world [United Nations Environment Programme (2009)]. Consequently, a number of water supply schemes have been initiated by governments and

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international agencies. But, still millions of people are suffering from acute water shortage.

The growing scarcity of water in low income countries, where majority of the poor resides in the rural sector, results in water allocation problems [Xinshen, *et al.* (2005)]. Given the grim situation of availability of water, there is a dire need to formulate some water conservation strategies. There are many prudent approaches to conserve water at domestic as well as commercial level. Rain Water Harvesting (RWH) is one of them to conserve, store and utilise rain water. RWH is an old but useful approach to channel and use the rainwater in productive manners [Li, *et al.* (2000) and UNEP (2009)].

The history of RWH in Asia can be traced back to 9th or 10th century [Mihelcic, *et al.* (2007)]. It has been used by almost all societies in all parts of the world to provide water for drinking, livestock, and irrigation. Tripathi and Pandey (2005) examine the potential of RWH and find that it is an effective source of drinking water in drought prone and rural areas. Furthermore, RWH is also very useful for soil conservation which would otherwise erode due to flash flow of rains [United Nations Environment Programme (2009)]. Generally, there are two types of RWH; Surface Rainwater Harvesting (SRWH), and Rooftop Rainwater Harvesting (RRWH). Both are equally important and used as water conservation strategies.

This technology has special momentousness for Pakistan as the country is confronting acute water shortage problem World Bank (2005) declares Pakistan as water stressed country in South Asia. Furthermore, large part of total population lives in rural and hilly areas where high cost and low success rate make it difficult to provide water supply schemes. In addition to it, supplying water in hilly areas is time consuming and expensive business which involves numerous risks [Baguma, *et al.* (2010)]. Given these conditions, rain water harvesting is endorsed by World Bank (2005) as the most suitable and viable approach for hilly areas of Pakistan.

RRWH system is simple, economical, and based on indigenous resources. Local people can easily be trained and mobilised to implement such technologies [Helmreich and Horn (2009)]. Construction material is readily available and system is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own system. It greatly reduces operational and maintenance problems because of its individualistic use and ownership. Water collected from roof catchments is usually of as acceptable quality as from other available water sources [Kumar (2009)].

An important advantage of RRWH is for women as it reduces their fatigue as well as time required to fetch water from other water sources. The available saved time can thus be used for productive purposes such as domestic work, agriculture and livestock activities, and child care. In this regard, Lehmann and Tsukada (2009) and Baguma, *et al.* (2010) examine rainwater harvesting with reference to health and time allocation. They conclude that this technology reduces cost incurred on health as well as time allocation for curing sick people, which could be used for profitable activities. Similarly, 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 to rural population by providing them water at home on sustainable basis [Thomas and Martinson (2007)].

Provision of water through RRWH technology has special importance for women wellbeing because, being the direct beneficiaries, they can harness number of benefits out of this technology. Although, substantial work on economics of RRWH has been done in many countries, yet this is an unfortunate fact that no ample attention was devoted to research on this technology with special reference to women in Pakistan. The current study attempts to fill this gap in literature by examining the impact of RRWH facility on women health with special reference to water fetching in hilly and earthquake prone areas.

Rest of the study proceeds as follows; the second section describes theoretical considerations and econometric specification. Section 3 discusses methodology of the study including the estimation technique. The fourth section presents results and discussion, while Section 5 concludes the study along with some policy implications.

2. THEORETICAL CONSIDERATIONS AND ECONOMETRIC SPECIFICATION

This section briefly describes the channels through which the Rooftop Rain Water Harvesting (RRWH) technology and other control variables affect the women health. Theoretically speaking, the RRWH technology is expected to have positive effect on women health in terms reducing the number of times they become ill. The RRWH technology facilitates women by providing them required amount of water which is otherwise brought from distanced water sources.¹ Consequently, this facility saves them from both physical hardship and mental stress. Moreover, the time saved as a result of this facility can be used in other social and healthy activities resulting in improved health considerations. Hence, one may expect positive impact of the RRWH technology on women health in rural and hilly areas. This variable is quantified by using a dummy variable where “1” represents the household possessing this technology (also called the “treated group”) and “0” represents the household where this facility is not provided (also named as “control group”). On the other hand, the women health (WH) is quantified as the number of times a woman become ill in last six months.

The control variables used in the women health model include (Region) to capture the difference between two regions, (Age) and education of the woman (Edu), per day time for water

¹The supply of water through RRWH system can be calculated by using the formula given by Tripathi and Pandey (2005). According to this formula $S = R \times A \times Cr$ where S , R , A and Cr represent supply of water by RRWH system, mean annual rainfall in millimeters, catchment’s area in meter squares and coefficient of runoff of rooftop respectively. Potential of RRWH with respect to catchment area is provided in Table I in Appendix.

fetching (PDTWF), distance from water sources (DWS), sleeping time (ST) and social activities time (SAT). The variable ‘Region’ is quantified using ‘1’ for Bagh and ‘0’ for Battagram. This variable is incorporated in order to investigate whether there is any impact of regional differences or not. ‘Age’ denotes the age of water fetching woman. The sign of its coefficient is ambiguous depending upon the age group of women. A transfiguration from childhood to adolescence may reduce the frequency of illness due to strengthening of body resistance to different diseases. However, after a particular age, the body and, therefore, the resistance weaken as the woman enters to older age group. Subsequently, a negative sign of the coefficient may also be expected.

Edu, taken as the years of schooling of the water fetching woman, is expected to improve the women health for the reason the educated women are aware about the health issues. Therefore, its expected sign is negative. *DWS* measures the distance of water source in kilometres and its probable sign is positive, *ST* is the time available to women (in hours) for sleeping purpose and it is expected to reduce the frequency of illness. *SAT* is the social activities time for women (in hours) in which they can interact with their friend, relatives and neighbours in daily life. It may reduce the mental stress and helps them relax their bodies after daily physical hardships. Subsequently, the expected sign of its coefficient is negative. *PDTWF* is the per day time (in hours) required for carrying water from water source to dwelling unit and its anticipated coefficient sign is positive. In the light of above discussion, the following econometric specification can be given:

$$WH = \alpha_0 + \alpha_1 RRWH + \alpha_2 Region + \alpha_3 SAT + \alpha_4 DWS + \alpha_5 ST + \alpha_6 Age + \alpha_7 PDTWF + \alpha_8 EDU + \varepsilon \quad \dots \quad \dots \quad (1)$$

3. METHODOLOGICAL ISSUES

3.1. Description of the Study Area

This subsection provides the detailed description of study area where RRWH project has been initiated by Earthquake

Reconstruction and Rehabilitation Authority (ERRA) with Maqsood Welfare Foundation (MWF) and Save the Children as its implementing partners. ERRA was established by the Government of Pakistan on October 24, 2005 to take up the task of rebuilding in the earthquake affected regions of Khyber Pakhtunkhwa and AJK. Maqsood Welfare Foundation (MWF) is local NGO of Bagh, AJK which implemented the project of RRWH in Bagh. Save the Children is an international NGO operating in different areas of Pakistan. It is involved in the implementation of RRWH project in Battagram.

Battagram is a district of Hazara division of the Khyber Pakhtunkhwa province of Pakistan. It has a total land area of 1301 square kilometres and the estimated population of Battagram district in 2004-2005 was 361,000. It is 90 km away from Abbottabad and 240 km from the capital Islamabad. The main language of the district is Pashto, but Hindko and Gojri are also spoken. Apart from that English and Urdu are spoken and understood in offices. Battagram obtained the status of district in July 1993 when it was upgraded from a Tehsil and separated from Mansehra district. Before Battagram obtained the status of district, it was a Tehsil of the Mansehra district.

The project of RRWH has been executed in Saroona, a village of Allai. It is one of the two Tehsils, or subdivisions, of Battagram district. 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 Allai valley was badly affected by the Kashmir Earthquake on October 8, 2005 which also destroyed the 'cable way'; a way to allow residents to cross the Indus River. Pilot project of RRWH system was implemented in Saroona which is one village of union council of Allai. The total no of households of Saroona village are 330 [Battagram (2007)]. The total population of the village is 5000, whereas the average household size is 8. In pilot phase the facility of RRWH was provided to 45 households.

Bagh is one of the eight districts of Azad Jammu and Kashmir, Pakistan. The total area of the district is 1,368 square kilometres [Bagh (2007)]. Bagh district was created with three subdivisions, namely Dhirkot, Bagh and Haveli, with its headquarters at Bagh. It is said that a *Bagh* (garden) was set up by the landowner of the area, where the premises of the forest department are now located. As a result, the area that is now the district headquarters was named “Bagh”. Bagh was severely affected by the Earthquake on October 8, 2005 which destroyed the overall infrastructure of the district.

Specifically, survey of this study has been carried out from, Chitra Topi, which is the project site of RRWH. It is a village of union council Topi in district Bagh. This village is situated in the North East of Main Bagh City at an altitude of 7000 feet above the sea level and on a distance of 18 KM. Topography of the area is hilly. Number of the households in this village are 274. Total population of the village is 1918 in which males are 940 and females are 978. Overall literacy rate of the village is above 80 percent [Bagh (2007)]. The main clans of the Chitra Topi are Suddhen, Mughal, Qureshi. Suddhen is the most influential clan that take the lead and dominate in taking decisions at the local level.

3.2. Survey Methodology

For a comprehensive and in-depth analysis, primary data has been collected through surveys from selected study areas in year 2010. The data was collected through personal interviews of respondents in the selected villages of both districts (Bagh and Battagram). For this purpose, pre-tested questionnaire was followed to construct a sound and well-developed questionnaire.

Sampling is the process of selecting units (e.g. individuals, households, and organisations) from a population of interest. Based on the sample, the results are fairly generalised for the population from where the respective sample is drawn. Population of the present study comprises of two groups; the

one provided with RRWH systems is called the “treated group”, while the other using the traditional water supply sources within the same localities is entitled as the “control group”. The purpose behind this sampling pattern is to carry out comparative analysis of RRWH system. The present analysis has been carried out in two villages; one is Chitra Topi village from district Bagh which has comparatively less population of 175 households, whereas the second village is Saroona from district Battagram with a population of 375 households.

In order to conduct the analysis, the study has taken the entire population of treated group. This had been possible due to less number of households (between 40 and 50) in each village. A proportional sample is picked from control group of population for analysis using Simple Random Sampling (SRS) methodology. The methodology is selected for the reason that all samples of the same size have an equal chance of being selected from the population. Secondly the population in control group was homogenous with respect to water supply. Lastly, the approach is suitable provided the resource limitation, location and facilitation. The optimum sample is the one which maximises precision per unit cost, and by this criterion, SRS is often superior over other methods.

3.3. Estimation Technique

In order to estimate the women health model, the study has adopted the Negative Binomial Regression technique. This technique has been used due to the count nature of the dependant variable. Count variables possess three interesting characteristics. First, they cannot have negative values and, therefore, hold zero as the lower bound. Second, these nonnegative numbers are integers, and hence count variables are discrete rather than continuous variables. Third, if a histogram is computed for a count variable, it will have a rapidly descending tail. With a count dependant variable, the appropriate estimation technique is Poisson Regression Analysis as a starting point.

However, the Poisson distribution assumes that the conditional mean of the count dependant variable is equal to its conditional variance. Nonetheless, this assumption is mostly violated in practical research as either over-dispersion or under-dispersion is observed in data. As a consequence, the coefficients estimates can still be consistent in Poisson regression, but their standard errors will be biased and, resultantly, very small. Since, the conditional variance exceeds the conditional mean in our specific case; therefore, the Negative Binomial Regression is the appropriate method for our analysis.² Furthermore, in order to deal with the effects of heteroscedasticity in data, the robust standard errors are used.

4. RESULTS AND DISCUSSIONS

With a count dependant variable, the model is estimated using Negative Binomial Regression. Several models with alternative specifications have been run to check the robustness of results.³ The first model, containing all possible determinants of women health, is the baseline model. The other three models are the variants of this model in the sense that each variant drops the insignificant variable(s) starting from the one with the lowest t-values. These variants ensure the robustness of results in terms of sign, significance and magnitude of coefficients. Moreover, the overall models are significant at conventional significance levels as demonstrated by the values of Wald test. The results in Table 1 confirm that Rooftop Rain Water Harvesting (RRWH) is a very important determinant of women health in the hilly and earthquake affected areas of Bagh and Battagram. Furthermore, besides social activities time and region, which is only marginally significant, the rest of variables are statistically insignificant. In the following lines, we explain the results of women health model in detail.

²The condition mean and variance are 5.29 and 5.90 respectively.

³Both area-wise and overall averages of different variables are given in Table II in Appendix.

Table 1

Results of Negative Binomial Regression for Women Health

Variables	Model 1	Model 2	Model 3	Model 4
Intercept	1.775 (11.25) ***	1.789 (20.49) ***	1.799 (23.52) ***	1.797 (23.49) ***
RRWH	-0.192 (-3.34) **	-0.190 (-3.46) **	-0.189 (-3.48) **	-0.189 (-3.49) **
REGION	-0.099 (-1.44)	-0.099 (-1.44)	-0.098 (-1.43)	-0.119 (-2.43)*
SAT	-0.029 (-2.09) **	-0.029 (-2.09) **	-0.029 (-2.08) **	-0.029 (-2.08) **
DWS	-0.054 (-1.18)	-0.053 (-1.21)	-0.052 (-1.20)	-0.052 (-1.20)
ST	0.002 (0.10)			
AGES	0.0003 (0.22)	0.0003 (0.22)		
PDTWF	0.006 (0.89)	0.006 (0.88)	0.0005 (0.87)	0.006 (0.92)
EDU	-0.003 (-0.45)	-0.003 (-0.45)	-0.003 (-0.45)	
Observations	367	367	367	367
WALD (χ^2)	27.65	27.57	27.34	27.22

Note: Robust z statistics in parentheses. *Significant at the 10 percent level. **Significant at the 5 percent level. ***Significant at the 1 percent level.

A dummy variable is used as proxy for 'RRWH' where '1' stands for treated group and '0' for the control group. This variable is included as the main variable to quantify the impact of the water harvesting technology on women health. The coefficient of RRWH is significant and has negative sign thereby providing evidence for the positive effect of this technology on women health. In more quantitative terms, the magnitude of coefficient of RRWH demonstrates that the probability of illness in women provided with RRWH facility is 21 percent less than those without this facility.⁴

⁴Due to the use of log link, the negative binomial regression model uses the log linear model. Consequently, for the interpretation of the estimated coefficients, we would need to exponentiate these coefficients. For example, for the coefficient of RRWH technology variable, we get $[100 * \{\exp(0.192) - 1\}] = 21$ percent.

This is a very important finding and one may conclude that RRWH technology brings improvement in the health of water fetching women, particularly in rural areas where they are the ones who use to collect water from source located far from their residences. This betterment in women health is not only due to lessening of fatigue of water fetching but also because of improved sanitation and hygienic condition. Which of these two have more contribution to this improvement in health could have been investigated separately. However, this was out of the scope of present study as it aimed only to find out the overall impact of RRWH technology on women health. Moreover, this estimated impact is cumulative and, hence, it is difficult to isolate each aspect of the health being affected by RRWH in this study.

The variable 'Region' is included in the analysis in order to differentiate the impact of these two regions on women health. It is a dummy variable in which '1' represents Bagh and '0' embodies Battagram. This variable is only marginally insignificant in the first three models and becomes highly significant in the fourth model. The quite low probability of accepting the null hypothesis of no impact of region on health in the first three models together with the highly significant coefficient in the fourth model power us to conclude region as an important factor in variation of women health. Furthermore, the coefficient is very stable in terms of sign and magnitude in all the models. The negative sign of coefficient indicates that the female residents of Bagh have 10.4 percent less probability of illness as compare to those of Battagram.

Several justifications may be given for this interesting result. The first important reason may be the difference in female awareness about health in two regions. This difference may be the consequence of disparity in female literacy rates as it is reasonably high in Bagh against the negligible rate in Battagram. The second justification for this outcome can be given with reference to the dissimilarities in access to medical services. Medical services are efficient and easily accessible in Bagh compare to Battagram. This result may also be the consequence of relatively poor sanitation and hygiene system in Battagram.

The variable 'social activities time' is also a significant determinant of women health and its coefficient is highly robust in terms of sign, significance, and magnitude. It is evident from results in Table 1 that allocating time for social activities is beneficial for women health. The coefficient of this variable has negative sign, as was expected, and it demonstrates that, *ceteris paribus*, each one hour increase in social activities time decrease the probability of illness by 3 percent. Social activities may include interaction with friends, relatives and neighbours, cultural and traditional events, and communal gatherings. All these activities help women release their mental stress and physical fatigue caused by domestic work load thereby reducing the probability of illness.

Since the sample areas for this study were taken from mountainous regions, it was intuitive to take the variable 'distance from water source' to investigate whether or not such distances affect the health of the women. Interestingly, this variable turns out to be statistically insignificant. This might be due to the shorter distance of water sources as the average distance of water source from dwelling unit is approximately one kilometre which is reasonable for the residents of hilly areas. Likewise, the insignificance of 'sleeping time' is an evidence that the sleep deprivation is not significant enough to adversely affect women health as the average sleeping time for these regions are found to be seven hours per day which is close to medical standards.

This is because people of these regions do practically follow the rule of "early to bed, early to rise". The dependence on agriculture and livestock for livelihood and the subsequent hard work in the mountainous fields, the early sunset in hilly areas and the resulting restraint on movement to avoid all kind of risks, and the absence of cable and other media are some of the reasons for the early sleeping patterns in these areas. From statistical point of view, the reason for the insignificance of sleeping time variable may be the extremely less variation among the observations of this variable.

The variable 'per day time for water fetching' has expected sign but its coefficient is statistically insignificant. There are two

possible justifications for this result. Firstly, and as mention earlier, the average distance of water source is not substantial and, therefore, the time used in water fetching is not significant. Secondly, and rather more importantly, during the visit to water source, the women also get the chance to interact with their friends and relatives which in fact is part of the social activities time. So perhaps this per day water fetching time is not purely that time which they spent for fetching water. As a consequence, this variable is not significantly affecting women health.

The last two variables are demographic in nature. The first one represents the ages of water fetching women while the second is related to their education. The “Age” variable is insignificant although it has expected sign. This may be due to specific age group of water fetching women which is comprised of more young people, comparatively healthy and less vulnerable to diseases. The average age of this specific group of women is 31 years in our case.

The variable ‘education’ of the water fetching females is also statistically insignificant in all the models. This result may be interpreted in two ways. Firstly, one may argue that this result demonstrates the poor quality of education in the sense that it does not indeed educate the women about health care. In other words, it does not bring awareness in women about health issues. Alternatively, it may also be claimed that even if education is effective regarding health issues, it may not be observable from regression results due to dominancy of sample from Battagram where the literacy rate for these women is almost zero.

5. CONCLUSION AND POLICY IMPLICATIONS

The objective of the present study was to analyse the potential of RRWH in terms of water supply and the consequent implications for women health. By making use of the Negative Binomial Regression the study found significant positive impact of RRWH technology on women health. According to the findings, the RRWH technology has reduced the probability of women

illness in water fetching women in hilly and earth quake affected areas of Bagh and Battagram. Hence, one can conclude that the initiative of RRWH has not only addressed the issue of water supply but it also happened to be a very effective investment by the ERRA and Government of Pakistan particularly in terms of improving women health.

The findings of the underlying study put forward some policy implications as well. Firstly, there is huge potential of RRWH in hilly areas of Bagh and Battagram districts because these are the high rain fall areas in AJK and KPK. This is very useful findings of the present study because it has unveiled that RRWH system could be installed in all those areas which receive high rainfall. Furthermore this system is very suitable for hilly and scattered helmets, where providing water through supply schemes may be very costly. Most importantly, it helps improve women health by lessening their fatigue of water fetching as well as due to its improved sanitation and hygienic conditions. Therefore, the study proposes that the RRWH systems should be installed in all houses in rural and hilly areas as it is a best alternative which could supplement traditional water supply sources and thereby help in easing pressure from other water sources. Policy makers should consider this approach of water supply in rural areas because it provides water of acceptable quality at consumption point.

Secondly, it is direct adaptation to climate change. RRWH in response to climate extremes enhances the resilience of human society. Due to climate change extreme weather conditions increased and that caused water shortages. In this regard RRWH is a best alternative approach for rain water conservation and rural communities which are most likely vulnerable to climate change. Based on the results in Table I of appendix, which shows a significant amount of water conservation from RRWH, it is recommend that this technology should be used as water conservation system for all rainy areas of the country.

The above discussion on policy implications recommends that RRWH system is both feasible and beneficial and should be

promoted in rural communities in order to conserve and use rain water efficiently. For Pakistan being a water stressed country, this is a prudent approach of water conservation. It ensures sustainable use of rain water which is a gift of nature to our country. RRWH saves the precious time of household members which could be used productively. Furthermore, it is beneficial for women by providing them with water at home which enhances their wellbeing.

APPENDIX

Table I

Potential of RRWH with Respect to Catchment Area (Square Feet)

Rooftops Area (sq feet)	Harvested Water in Thousand Liters/Year	Harvested Water in Thousand Gallons/Year	Harvested Water in Thousand Pitchers/ Years	Per Day Pitchers
500	675	67.5	135	370
1000	1350	135	270	740
1500	2025	202.5	405	1110
2000	2700	270	540	1479
2500	3375	337.5	675	1849
3000	4050	405	810	2219
3500	4725	472.5	945	2589
4000	5400	540	1080	2959
4500	6075	607.5	1215	3329
5000	6750	675	1350	3699

*The calculation of harvested water is based on the mean annual rainfall (which is 1500 mm for Bagh and Battagram districts) and respective catchment area of Galvanised Iron Sheet (GIS).

Table II

Area-wise Averages of Variables

	SAT	DWS	ST	Age	PDTWF	Education
Bagh	1.1	0.9	6.9	36.3	2.6	7.4
Battagram	0.5	1.1	6.5	30.5	6.6	0
Overall	0.8	0.9	6.7	31.1	5.8	2.8

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