Adoption and impact of rain water harvesting technology on rural livelihoods: The case of Makwanpur district, Nepal

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Abstract. Rain water harvesting (RWH) technology was introduced in Nepal as a climate change adaptation mechanism for sustainable crop production. Using data from 120 farmers (60 RWH technology adopters and 60 non-adopters) in Makwanpur district, the study employed a probit model to identify factors that influenced the adoption decision of RWH technology. The impact of RWH technology on farm income was then determined by a multiple regression model. The results showed that years of schooling, total physical assets and organizational membership of household members were the major determinants of the adoption of RWH technology. The results also showed that the adoption of RWH technology, gender of household head, total household members engaged in agriculture occupation, and total educated household members contributed significantly to annual farm income. Considering weather uncertainties faced by farmers in rainfed areas, RWH technology would be a potential option to improve the rural livelihoods. However, government should focus on its up-scaling through policy intervention.

Key words: rainfed agriculture, climate change, adoption, probit, household income

Introduction

Water has long been regarded as the main limiting resource for crop production in the rainfed region of South Asia in which Nepal is located. Rainfed agricultural land accounts for 65 percent of the total cultivable land area in Nepal. The sector is highly dependent on the weather (Regmi 2007; Malla 2008). Annual rainfall is characteristically heavy and erratic and soils are generally infertile with poor water holding capacity. Uncertainty and variation of rainfall distribution makes rainfed cropping risky especially for the production of crops that have a reasonable market value such as rice, maize, wheat and vegetables (Gurung & Bhandari 2009).

Rain water harvest (RWH) technology generally involves harvesting rainwater and diverting it to reservoirs for the purpose of coping with rainfall variation and drought (Kattel 2015). The introduction of novel agricultural technologies such as RWH can play a vital role in enhancing the socio-economic status of rural livelihoods and provide a climate change adaptation mechanism for sustainable crop production. The major advantages of rain water harvest are that it is simple, cheap, replicable, efficient and adaptable technology (Reiz, Maulder & Begemann 1988). It has superior qualities of small-scale, simple operation, high adaptation, and low cost; and therefore, is ideally suited to the socioeconomic and biophysical conditions of semiarid rural areas (Li, Wang & Zhao 1999). RWH also has been shown to improve water-use efficiency, reduce soil erosion, improve soil fertility, and increase agricultural productivity *(*Zhao 1996; Li, Wang & Zhao 1999). It has become a strategic measure for social and economic development in semiarid regions, providing an effective means of alleviating poverty, and allowing a breakthrough in dryland farming (Deng et al. 2004). The successful adoption of such technologies has the potential to alleviate problems faced by resource-poor 'subsistence' farmers (Mutekwa & Kusangaya 2006). A study by Ngigia et al. (2005) in Kenya showed that improved farm ponds provide one of the feasible options of reducing the impacts of water deficit that affect agricultural productivity in semi-arid environments in Sub-Saharan Africa. Fox, Rockstrom & Barron (2005) studied the risk associated with and economic viability of RWH for supplemental irrigation in semi-arid Burkina Faso and Kenya and suggested that supplementary irrigation can generate economic benefits and improve long-term food self-sufficiency compared to rainfed agriculture. Desai et al. (2007) conducted an impact assessment study of farm-ponds in Dharwad district of India, which revealed that the gross cropped area increased by 22 percent for farms with a farm pond over farms without a farm pond.

The RWH technologies are relatively recent in Nepal and their contribution to rural livelihoods has not yet been clearly assessed. The government of Nepal is promoting non-conventional irrigation systems like RWH, drip irrigation and treadle pumps as a part of the Irrigation Policy of Government of Nepal (MOI 2014). Facing food and poverty crises with climate change effects on agricultural sectors in developing countries like Nepal will require a new emphasis on small-scale water management in rainfed agriculture involving redistribution of water policy and large new investment. To date, very few farmers have been using RWH for crop production. Kattel (2015) reported that the probability of adoption of RHW technology will be increased by 29 percent if a farmer receives farm management training from agricultural extension services. There may be the several other factors that affect farmers' adoption decisions of this technology. Thus, if RWH technologies are to be scaled up in Nepal, it is important to understand farmer's adoption decisions and its impact on farm income. Therefore, this study was designed to identify factors that influence the adoption of RWH technology and its impact on farm income. Moreover, the outcome of this study may serve as a source of additional information, which may be of significant use to policy makers and planners during the designing and implementation of RWH technology strategies for its further scaling up.

Methodology

Makwanpur district was selected for the study as it is one of the districts where rain water harvest technology is being widely adopted. It is a hilly district of Nepal, in which about 53% of people are involved in subsistence agriculture. The district had 239,076 hectares of land, of which 40,482 hectares was cultivated land. The average annual rainfall varies from 1900 mm to 2300 mm. More than 80% of the annual rainfall takes place between June to September (DDC Makwanpur 2016). We selected six Village Development Committees (VDCs) namely Manohari, Basamadi, Bhimphedi, Palung, Hadikhola and Aamvanjyang. The study was carried out in 2012 through a semi-structured interview schedule followed by focus group discussion in each VDC. Farmers adopting RWH technology were identified with the help of the District Agriculture Development Office (DADO). After that, another farmer identified in the same locality and so on. Altogether, 120 respondents (60 adopters and 60 non-adopters) were selected from six VDCs, where 20 households (10 adopters and 10 non-adopters) from each VDC were selected randomly. Collected information was entered in CS Pro (version 4.1.0) and data analysis was done by using computer software packages: Statistical Package for Social Science (SPSS version 16.0) and Stata (version 12.0). Both descriptive and econometric methods were used to analyse the data. Socioeconomic and farm characteristics of the respondents like family size, age, social background, education status of household head, years of schooling of household head, occupational pattern, land holding size, distribution of economically active population were described by using simple descriptive statistics like frequency count, percentage, mean, standard deviation, t- test and chi square test. A probit model was used to identify factors affecting adoption of RWH technology. A multiple regression model was used to measure the impact of RWH technology on farm income.

Identification of factors affecting adoption decision of RWH technology

The decision to adopt an agricultural technology depends on a variety of factors (Wiersum 1994; Calatrava-Leyva 2005; Mendola 2007; Kattel 2009; Gairhe, Gauchan & Timsina 2017), including farm households' asset bundles and socio-economic characteristics, characteristics of the technology proposed, perception of need, and the risk bearing capacity of the household. According to Bekele & Drake (2003), Asfawa & Admassie (2004), He, Cao & Li *(*2007) and Kattel (2009) the general assumption is that there is a desire to maximize the expected utility of adopting new technologies.

He, Cao & Li (2007) in China found that educational background, active labour force size, contact with extension services, access to credit and other assistance, technical training received and diversity of irrigated crops grown were positive and significant factors affecting adoption while farmers' age and the distance from water storage tanks to farmers' dwellings were significant and negative factors correlated with rainwater harvesting and supplemental irrigation technology. Amha (2006) reported in Ethiopia that the household size, educational status of household head, ownership of livestock, homestead plots and type of pond were positive and statistically significant. In this study, farmers' adoption of RWH technology will be based on an assumed underlying utility function. According to this theory, RWH technology will be adopted by the farmer if the utility obtained from RWH exceeds that for non-adoption. The farmer's behaviour towards RWH technology is described by the following equation;

$$Prob(Y^*_i) = \sigma_0 + \Sigma\ \delta_n X_i + \varepsilon_i \quad (1)$$

$$Prob(Adopt=1) = \Upsilon' K + \varepsilon_i \quad (2)$$

Where:

Y^*_i = A latent variable representing the propensity of a farm household i to adopt RWH technology (1 if farmer adopt technology and 0 otherwise)

X_i = K= the vector of farm households' asset endowments, household characteristics and location variable that influence the adoption decision

σ_0, δ_n = parameters to be estimated

ε_i =error term of the i^{th} farm households

i = 1, 2, 3, … n farm households

Table 1. Description of the variables used in the probit model

Variables	Description	Value	Expected sign
s102_ahh	Age of the household head	Year	-
s107_ysh	Education level of household head	Years of schooling	+
s2132_tc	Total size of cultivated land	Hectare	+
totalphy	Total household assets	Number	+
totalliv	Total livestock in each household	Number	+
s6470_mo	Member of any organization	=1 if yes; 0= No	+
s7530_cc	Know about climate change	=1 if yes; 0= No	+
s8610_et	Whether farmer participative in training or not in last 3 years	=1 if yes; 0= No	+

Measure the impact of RWH technology on farms' income

We use the following model to estimate the impact of the RWH technology on farm income from the agriculture sector.

I_i = f (RWH, Gender, Total members, Members in agri. occupation, Educated members, Loan, Credit, Environment meeting, Agri. production meeting)

L_n Income = $\alpha_0 + \alpha_i X_i + e_i$ (3)

Where:

L_nIncome = Annual farmer's income from Agriculture (In natural Log form)
α_0 =Constant
α_i= Coefficient
Xi= Explanatory variables
e_i = Error term.

We assumed that the farm income is also affected by the adoption of RWH technology and other variables such as gender of the respondent, total number of household members, total number of members involved in agricultural occupation, number of educated members in the family, loan receiving status, credit receiving status, participation in environmental related meeting and participation on crop production and marketing related meeting. The detailed explanation of variables, types of measures and their expected sign are presented in Table 2.

Table 2. List of variables used in the multiple regression model

Variables	Description	Type of measures	Expected sign
	Dependent variable		
log_agiIncome	Total income from farm (Agriculture)	Nepalese Rupees (NRs.) in Natural Log Form	
	Explanatory variables		
s3250_rwh	Whether adopt RWH technology or not (1/0)	=1 if adopt; 0=otherwise	-
s103_ghh	Gender of the respondent (1/0)	=1 if male; 0=otherwise	+
s1853_tm	Total number of members	Number	+
s1854_ao	Total number of member in agri. occupation	Number	+
s1855_en	Total number of educated members	Number	+
s5390_tl	Whether farmers received loan or not (1/0)	=1 if yes; 0= No	+
s5410_fi	Whether farmer access to credit or not (1/0)	=1 if yes; 0= No	+
s8590_ee	Whether farmer participates in environmental meeting or not (1/0)	=1 if yes; 0= No	+
s8580_em	Whether farmer participates in agri. production and marketing meeting or not (1/0)	=1 if yes; 0= No	+

Results and discussion

Socio- demographic characteristics

We collected socio-demographic characteristics such as age of household head, gender of the household head, year of schooling of household head, family size, economically active household members, total number of male, total number of female, size of low land, size of upland, total own land, total cultivated land, total physical assets and total number of livestock. The dummy variables were gender, access to credit, loan received, membership, knowledge about climate change and training received. The continuous variables age of household head, years of schooling of the household head, upland land, total cultivated land, total owned land, total physical assets in household, total livestock and the total area of cauliflower were statistically significant and greater among RWH non-adopters than adopters.

Table 3. Socio-demographic characteristics of the respondents (N=120)

Continuous variables	**Total**	**Adopters**	**Non-adopters**	**t-value**
Age of HH head (Years)	46.28	43.97	48.60	1.91*
Year of schooling	2.90	3.88	1.93	3.02***
Family size	4.25	5.35	4.75	0.77
Economically active HH members (15 to 60 years old)	4.25	4.40	4.09	0.77
Total male in HH	3.29	3.44	3.15	0.87
Total female in HH	3.30	3.42	3.19	0.73
Lowland (Hectare)	0.14	0.14	0.15	-0.28
Upland (Hectare)	0.26	0.30	0.22	2.03**
Total own land(Hectare)	0.45	0.51	0.38	2.17**
Total cultivated land (Hectare)	0.42	0.48	0.36	2.08**
Total physical assets	12	14	10	3.14***
Total no. of livestock	18	24	12	1.65*
Total area of cauliflowers(Hectare)	0.17	0.21	0.12	1.89*
Total area of tomato(Hectare)	0.16	0.19	0.13	1.35
Dummy variables				**Chi²-value**
Gender				
Male	90 (75)	48 (53.3)	42 (46.7)	1.6
Female	30 (25)	12 (40)	18 (60)	
Access to credit (Yes=1)	93 (77.5)	50 (53.8)	43 (46.2)	2.34
Loan received (Yes=1)	68 (57.5)	36 (52.9)	32 (47.1)	0.543
Membership (Yes=1)	84 (70.6)	47 (44)	37 (56)	4.64**
Knowledge about climate change (Yes=1)	59 (49.2)	33 (55.9)	26 (44.1)	1.63
Training received (Yes=1)	32 (26.9)	19 (59.4)	13 (40.6)	1.68

Note: *Significant at 10% level, ** significant at 5% and *** significant at 1%
Figures in Parentheses indicates percentage.

Age of household head was statistically lower among non-adopters as compared to adopters. This shows that young farmers were more aware of new technology and innovative towards adoption. Among dummy variables, membership in any organization (like saving and credit group, cooperative) was significantly higher among adopters than non-adopters. However, gender, access to credit, taking a loan and knowledge about climate change and training received by the respondents were also higher among adopters, but not significant.

Identification of factors affecting adoption decision of RWH technology

This analysis focused on the identification of factors influencing adoption of RWH technology. The LR chi^2 for the model indicates that the model has good explanatory power at 1% level. The pseudo R^2 is 0.147. The overall predictive power of the model is 67.5%. The goodness of fit yields a chi- square with a large p value indicating that the model presents a good adequacy and fits the data well. The area under ROC curve for the regression is 0.74 which reveals that the model presents adequate discrimination. Among the different variables, year of schooling, total physical assets and membership of any organization were statistically significant. While age, total cultivated land, total number of livestock, knowledge about climate change and training received were not significant. Year of schooling of a household has a positive impact, suggesting that more educated farmers were more likely to adopt RWH technology than less educated farmers. It is statistically significant at 10% level of significance. Holding other factors constant, when education increases by 1 year, there is an increase 2.7% in the probability that the farmer will decide to adopt rain water harvest technology. This conclusion is also similar with Chinau & Tsujii (2004) and He, Cao & Li (2007).

The variable Household physical asset had a positive and significant impact on RWH technology adoption at 5% level. This indicates that adoption of RWH technology requires large resources. Thus, households with more physical assets were more likely to invest in RWH technology than those with few physical assets. Holding the other factors constant, when physical assets increase by 1 unit, there was an increase 2.5% in the probability that farmer would decide to adopt rain water harvest technology.

Table 4. Probit regression results to identify the factors affecting RWH technology adoption

Variables	Coefficients	SE^b	dy/dx^b	SE
Age	-0.126	0.009	-0.005	0.004
Education	0.069*	0.040	0.027	0.016
Land Size	0.009	0.021	0.003	0.008
Household assets	0.062**	0.027	0.025	0.011
Total livestock	0.013	0.015	0.005	0.005
Membership	0.481*	0.290	0.190	0.112
Know about climate change	0.027	0.264	0.010	0.105
Training	-0.051	0.305	-0.020	0.121
Constant	0.967	0.622		
Number of observation (N)	120(Rain water harvest adopters and non-adopters)			
LR chi^2 (8)	24.56*** (Prob> Chi^2= 0.000)			
Prob> Chi^2	0.0000			
Pseudo R^2	0.1476			
Log likelihood	-70.899			
Goodness of fit test:	Pearson chi^2 (111) = 115.17 prob> chi^2 = 0.374			
Overall correct prediction	67.5%			

* Significant at 10% level of significant, ** significant at 5%

Membership is an important variable, with positive significant coefficient at 10% level. Results suggest that for farmers who were members of any organisation like agriculture cooperative, saving and credit group and livestock group; the probability of adoption of rain water harvest technology was increased by 19%.

Measuring the impact of RWH technology on farm income

Table 5 presents the impact of rain water harvest technology on farm income. Initial regression runs revealed Heteroscedasticity (i.e. data with unequal variability (scatter) across a set of second, predictor variables). To achieve approximately normality and homogeneity of the error term, the variable of farm's income was transformed by taking logarithms.

The value of a coefficient of multiple determinations (R^2) 0.27 shows that 27% of the variation in the income from a farm is explained by the independent variables included in the multi-regression model. The F- statistics (4.47) confirms the stability of the overall regression equation and joint significant at 1% level. The Breusch-Pagan test for heteroscedasticity showed a constant variance of errors and model has no heteroscedasticity. Variance Inflation Factor (VIF) presents results according to expectation; mean VIF was 1.22 and none of the variables had VIF higher than 2. It means there was no multicollinearity between independent variables included in the model. Also, the regression coefficient error test (RESET) confirms the model had no omitted variables.

The finding of the regression model showed that farmers who adopted rain water harvest technology had 48% more agriculture income (farm income) than non-adopters. This is significant at 1% level. Thus, rain water harvest technology had great impact on farm's income. Male-headed households had 50% more farm income than female-headed households. This is also significant at 1% level. The regression model showed that the number of total household members in agriculture occupation has a positive impact on a farm's income. If one member in agriculture occupation increases, income from agriculture is increased by 9.1%. It is significant at 5% level. The total number of educated members in household was also positive and statistically significant on farm's income. If one educated member increases in a family, the farm's income increases by 9%.

Table 5. Measure the impact of RWH technology on farm income (in natural log form)

Variables	Coefficient	SE	T value
Whether farmer adopt RWH technology or not	0.478***	0.152	3.14(0.002)
Gender of HH	0.498***	0.177	2.81 (0.006)
Total members	-0.015	0.030	-0.50(0.620)
No. of total members in agri.occupation	0.097**	0.045	2.14 (0.035)
No. of total educated numbers	0.090*	0.046	1.97 (0.05)
Whether farmers received loan or not	0.174	0.155	1.12(0.264)
Whether farmer access to credit or not	0.175	0.189	0.94(0.347)
Whether farmer participate in environmental meeting or not	-0.103	0.241	-0.43(0.668)
Whether farmer participate in agri. production and marketing meeting or not	0.195	0.180	1.08(0.280)
Constant	9.483***	0.291	32.52(0.000)

Number of observation	120
R- square	0.27
Adjusted R- square	0.21
F value (9,110)	4.47
Heteroscedasticity	Chi^2 (1) = 0.55 prob> chi^2 = 0.597 (constant variance)
Variance Inflation Factor (VIF)	1.22 (mean VIF) : No any independent Variance >1.65 VIF
Model has no omitted variable (ovtest): F (3,107) = 1.2 prob> F = 0.313	

* Significant at 10% level of significant, ** significant at 5%, *** significant at 1% level
Note: Figure in Parentheses indicates P value.

Problems associated with RWH technology adoption

Table 6 presents the problems associated with RWH technology adoption. Problems were categorized in four categories: very high, high, medium and no problem. Among different problems, seepage and weed management was higher followed by storage water management. Almost all surveyed farmers used plastic to line pond. However, farmers faced seepage problem because they used low quality plastic. Farmers suggested that water loss can be reduced by lining the ponds either with good quality plastic or cement. Therefore, support will be needed from government and different organisation to provide better quality plastic. If possible the RWH pond should be cemented to control seepage problems. Moges (2009) in Ethiopia also found that the main challenges of adopting RWH technologies are that much of the harvested water is lost through seepage.

Table 6. Types of problems related to RWH technology

Problems associated with RWH technology	Categories of problems			
	Very high	High	Medium	No problem
Storage water management	16 (26.7)	12 (26.7)	10 (16.7)	22 (36.7)
Management of watershed	5 (8.3)	6 (10.0)	8(13.3)	41 (68.3)
Roof top and pipe management	4 (6.7)	4 (6.7)	6 (10.0)	46 (76.7)
Management of distribution	4 (6.7)	2 (3.3)	9 (15.0)	45 (75.0)
Crop management	0	2 (3.3)	5 (8.3)	53 (88.3)
Management of drainage	0	3 (5.0)	3 (5.0)	54 (90.0)
Seepage and weed	18 (30.0)	11 (18.3)	12 (20.0)	19 (31.7)

Note: Figure in parentheses indicate percentage

Conclusions

The erratic nature of rainfall is the major problem for efforts to enhance agricultural productivity, which in turn threatens the lives of millions of people in the country, particularly in the Makwanpur district. Hence to mitigate this problem, Rain Water Harvest (RWH) technology plays a vital role in enhancing the socio-economic status of rural farmers of Nepal. About 80 percent of the cropping pattern of RWH adopters is changed after the adoption of the technology. Total revenue and income from vegetables were significantly higher than non-adopters.

To mitigate the erratic nature of rainfall in the arid parts of the country, development and implementation of rainwater harvesting technologies will be helpful to promote productivity and sustainable intensification of the rainfed agriculture. However, the success of the technology adoption is mainly constrained by problems related to seepage and management of storage water problems. Therefore, government and different organization will be need to provide awareness programs and extension services to farmers for better dissemination of RWH technology. The organizations should focus on efficient utilization of the technology in addition to careful site selection and improvement in monitoring.

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