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Rainwater Harvesting for Sustainable Water Resource Management in Eritrea: Farmers' Adoption and Policy Implications

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ABSTRACT Rainwater harvesting techniques are required to obtain a sustainable supplemental water source for groundwater, which is being depleted through time in arid and semi-arid countries including Eritrea. The aim of this study was to examine the factors that influence farmers' decisions to adopt rainwater harvesting techniques in Central Province *(Zoba Maekel)* of Eritrea, using a household survey of 307 farmers and a Probit model. The results showed that farmers who participated in a seed multiplication program, received extension services, and accessed credit were more likely to adopt water harvesting technology. The study recommends that the government should promote an integrated and holistic approach in order to provide technical and institutional support for farmers in order to sustain scarce water resources by enhancing access to credit, facilitating more extension service and encouraging farmers' seed networks for agricultural development.

INTRODUCTION

Rainwater harvesting technology (RWHT) optimizes the utilization of rainwater (Yosef and Asmamaw 2015). Water harvesting technologies improve the water available for crop production. Rainwater harvesting (RWH) has been practiced for many years and is essential in areas with adequate rainfall but without convectional water supply systems or where the ground water is lacking (Munyaneza et al. 2016).

Rainwater harvesting entails trapping and using runoff water more efficiently, thus improving food production and productive water use (ICARDA 2014). When there is no other water supply or no prospect of water, RWHT is a feasible way of sourcing water in challenging climatic extremes. Moreover in areas where lands are arid and semi-arid with a low precipitation, ground levels are very deep. In remote and scattered human settlements, RWHT is often used as a solution for water supply. Even if the importance of RWH has grown drastically in the last 20 years, the initial construction capital is high and thus limits use in resource-poor communities (Nijhof and Shrestha 2010).

Agriculture is challenging in sub-Saharan African countries due to arid and semi-arid environments. Marginal agricultural production is observed because natural resources are overexploited including lack of effective management of water, triggered by a quickly increasing population and poor land-use management practices (Murgor et al. 2013; Radhouane 2013; Jose and Padmanabhan 2016; Joshua et al. 2016). Eradication of poverty and food insecurity will continue to be a challenge unless sustainable food production is affected. Otherwise it will be difficult to achieve the 2030 agenda for sustainable development goals of ending poverty and hunger (Kirk et al. 2015).

The main aim of the RWH is to alleviate the lack of rain to cover household needs and productive use (Yazar and Ali 2017). In Eritrea, communities use various techniques to access water for planting crops. Water is usually diverted before planting during floods (flowing in short duration) for farming purposes. The diverted floodwater soaks into the soil, thus providing residual water for crop growth (Tesfai and Stroosnijder 2001).

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Even though there are a number of studies on Rainwater Harvesting Technology (RWHT), the relationship thereof to socio-economic variables in Eritrea is rare. Most studies focus on the type of technology of RWH practices, but rarely on the socio-economic and institutional aspects, which influence farmers' adoption of RWHT. Ghebreyohannes (2006) highlighted the importance of socio-economic factors on water harvesting and food security in Eritrea using a desktop study. However, his study is not sufficiently rigorous. Akroush et al. (2017) examined the socio-economic and institutional factors on adopting RWHT in Jordan. Xue-Feng et al. (2007) evaluated the factors, which the influence farmers' decisions to adopt RWH in China. Murgor et al. (2013) examined the factors, which determine farmers' decisions to adopt RWHT in Keiyo district of Kenya. Shikur and Beshah (2012) identified factors, which impact the adoption of trapezoidal RWH structures.

The potential impact of RWH has focused on crop yields, water and perception, adoption and farm income (Kosgei et al. 2007; Sturdy et al. 2008; Vohland and Barry 2009; Munyaneza et al. 2016). In view of the significant contribution of RWHT to farming, this research contributes to bridging the knowledge gap by rigorously examining the cause of farmers' choices of non-adoption of RWHT. Furthermore, the size of the sample surveyed enhances reliability and bring rigor to the results.

Objectives of the Study

The main objective of this study was to investigate factors, which influence farmers' decisions on adopting RWHT in Central Province of Eritrea. The findings would serve as an input for policymakers. The specific objective of the study was to identify the cause of non-adoption of RWHT and analyze the socio-economic characteristics of the respondents. This study has implications, not only from an Eritrean perspective, but also for arid and semi-arid regions to aid in sustaining globally scarce water resources. The study also answers the following research questions: What are the factors that influence farmers' decisions to adopt RWHT? Does the adoption of RWHT impact farmers' productivity and livelihood? Does the socio-economic characteristics impact farmers' decisions to adopt RWHT? The hypothesis is formulated on the stated aim and specific objective. The null hypothesis is: The institutional factors do not affect (access of credit, extension service, seed multiplication and others) farmers' decisions to adopt RWHT? Socio-economic characteristics do not affect farmers' decisions to adopt RWHT? The RWHT does not enhance farmers' productivity and livelihood?

METHODOLOGY

Overview of the Study Area

Eritrea is an arid to semi-arid country and is mainly dependent on rain-fed agriculture. The country is part of Sahelien Africa, which has been characterized by recurrent and devastating droughts (Gherezghiher 2010). Eritrea is located in the horn of Africa, has a land area of 12.2 million hectares, and borders Sudan, Ethiopia, Djibouti and the Red Sea. The population of Eritrea accounted 5.5 million with an annual population growth of 2.9 percent. The central province is one of the six administrative provinces of Eritrea. Rena (2008) stated that the Eritrean economic growth sector relies on agriculture, fishing, light industry, and services such as tourism. The central province is located at longitude of 38^0 41' 36'' - 39^0 3' 00'' East and Latitude 15^0 34' 36'' North and is divided into four districts, namely Asmara, Gala-Nefhi, Berik and Serejeka, with 59 administrative and 89 villages (Bahta and Haile 2013). The study was carried out in sub Gala-Nefhi, Berik, and Serejeka districts.

According to the statistical figures of 2008, the population of the Central province accounted 591,368 consisting of 139,921 households; out of which twenty-seven percent is involved in agriculture, 23.5 percent in services and trade, eighteen percent in handicrafts and manufacturing, 7.5 percent in civil service, and twenty-four percent in casual labour (*Zoba Maekel* Administration [ZMA] 2009).

Sample Design and Data Collection

A multi-stage sampling technique was used in this study. In the first stage, from four districts (Asmara, Gala-Nefhi, Berik and Serejeka), three districts (Gala-Nefhi, Berik, and Serejeka) were randomly selected. Each district is regarded as a stratum. The second stage, included 120 farm household heads who were randomly selected using a sample frame from the Director of Agriculture in each district.

Households were the unit of analysis and primary data were collected using semi-structured questionnaires. To collect quantitative data on households, questionnaires were administered per district. Three-hundred and sixty households were randomly selected from the three districts (120 households per district). Of the 360 households, 307 responded, the others (53 households) did not respond for different reasons (Table 1). Eighty-four respondents were from Galanefhi district (27%), 106 from Berik district (35%), and 117 from Serejeka district (38%). Information was collected from November 2011 to December 2012.

Conceptual and Analytical Framework

Conceptual Framework

The theory of utility was the base for the conceptual framework. A farmer's decision to adopt RWHT is a binary choice and thus a Probit Model was used. A Probit Model was preferred, because of the normal distribution of the respondents and it was easier to compute the marginal effects (Bahta et al. 2017). Studies related to adoption of technology mostly use the Probit Model, because everyone have a chance to participate in RWHT and the respondents do not lose anything by participating. The Probit Model was applied in recent adoption studies (Gebregzibher et al. 2016; Kifle et al. 2016; Khatri-Chhetri et al. 2017; Mittal and Mehar 2016; Maguza-Tembo et al. 2017). For farmers to decide on whether to adopt RWHT, he/she primarily studies the benefit gained from participating in adoption of technology. If the benefit gained from adoption of rainwater harvesting technology *(Rwht)* is greater than not adopting rainwater harvesting technology *(Rwhtn)*, then the farmer is more probable to adapt to the technology, thus, *Rwht* > *Rwhtn*. The farmer's decision to adopt RWHT relies on socio-economic variables. Following the work of Maddala (2001), the model written as:

$$RWHT_i = \begin{cases} 1, & rwht_i^* \geq 1 \\ 0, & rwht_i^* \leq 0 \end{cases} \tag{1}$$

$$rwht^*_i = x'\eta_i + u_i \tag{2}$$

The probability of farmers' decisions to adapt RWHT is expressed by equation (3):

$$P(RWHT_i = 1) = \varphi\left(\frac{-\mathbf{x}_i'\eta}{\sigma}\right) \tag{3}$$

Where $RWHT_i$ represents the observable variable, $rwht_i^*$ represents a latent dependent variable, x'_i represents a (M x 1) vector of independent variables, η is a (1 x M) unknown parameter, and μ_i represents the error term. P represents the probability, and *f* is the cumulative probability distribution.

The marginal effect indicates the effect of unit change in each independent variable on the dependent variable. Taking the partial derivatives of (1) with respect to x_i gives the respective marginal effects. The marginal effect of a variable is the effect of a unit change of this variable on the probability P (RWHT = 1|X = x), given that all other variables are constant. The marginal effect is expressed as follows (4):

$$\frac{\partial P(\mathrm{RWHT}_i = 1 \mid x_i)}{\partial x_i} = \frac{\partial E(\mathrm{RWHT}_i \mid x_i)}{\partial x_i} = \varphi(\mathbf{x}_i'\eta)\eta \tag{4}$$

Analytical Specification of Probit Model

Farmers' decision to adapt RWHT is expressed as (5).

$$\begin{aligned} RWHTI = {} & \eta_0 + \eta_i Crediti + \eta_2 Seedmpi + \\ & \eta_3 Extension_i + \eta_4 Remittance_i + \eta_5 Hiredlabor_i \\ & + \eta_6 Radio_i + \eta_7 Cellphone_i + \eta_8 Gender_i + \\ & + \eta_9 Maritalstatus_i + \eta_{10} Age_i + \eta_{11} Education_i + \\ & + \eta_{12} Nchildren_i + e_i \end{aligned} \tag{5}$$

Where $RWHT^*_i$ represents adoption of rainwater harvesting technology (0 if farmers did not adopt RWHT and 1 otherwise), $Credit_i$ represents access to credit (0 if farmers did not have accesses to credit and 1 otherwise), $Seedmp_i$ represents seed multiplication (0 if farmers did not participate in a seed multiplication program and 1 otherwise), $Extension_i$ represents extension contact (0 if farmers did not access extension contact and 1 otherwise), $Remittance_i$ represents remittances (0 if farmers did not receive remittances and 1 otherwise), $Hiredlabor_i$ represents hired labour (0 if farmer did not have the capacity to hire labour and 1 otherwise), $Radio_i$ represents radio (0 if farmers did not own a radio set and 1 otherwise), $Cellphone_i$ represents cellular phone (0 if farmers did not own a cellular phone and 1 otherwise), *Gender*$_i$ represents gender (0 if farmers were male and 1 otherwise), *Marital status*$_i$ represents marital status (0 if farmers were not married and 1 otherwise), *Age*$_i$ represents age, *Education*$_i$ represents level of education (years farmers spent in formal school), *Nutrition*$_i$ represents (number of children in the household), and e_i represents the error term. Maximum likelihood procedure was applied to estimate the parameters specified in equation (5). This study preferred the maximum likelihood procedure over ordinary least square (OLS), due to efficiency and more reliable estimates. Moreover the dependent variable is binary.

Testing for Multi-Collinearity-Model Adequacy Test

Multi-collinearity may cause wrong conclusions about the correlation among independent variables, while the model may be significant. Correlation matrix tests are carried out to detect the presence of multi-collinearity (Gujarati 2003). Bonate (2011) highlighted that multi-collinearity measured and assessed off-diagonal elements r_{ij} in $X^{1}X$. If regressors' x_i and x_j are nearly linearly dependent, then r_{ij} will be near unity. Therefore, a correlation coefficient more than 0.90 shows multi-collinearity.

Table 2 shows the correlation matrix among independent variables and the results indicated that there was no linear relationship among the explanatory variables, indicating that there is not a multi-collinearity problem in the model. As a result the Probit Model is the perfect fit for such an analysis.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Respondents

Demographic and socio-economic characteristics played a significant role in farmers' decisions to adopt technology (Gautam and Andersen 2016). Most of the respondents were male (71.7%), of which 77.4 percent were from Gala Nefhi, 75.5 percent from Berki and 64.7 percent from Serjeka districts. Respondents' ages ranged from 13.4 percent for 18-34 years, 15.6 percent for 35-44 years to 71 percent for 45 years and above (Table 1). Most respondents were married (79.5%), 16.3 percent divorced or widowed

Table 1: Selected districts for survey and some socio-economic characteristics of the respondent (n=307)

Districts	*NHHS*	*RS*	*TNR*	*Sex*		*Age*			*Education*				*Marital status*		
				M	*F*	*18-34*	*35-44*	*Over 45*	*No*	*Primary*	*Secondary*	*Higher*	*Single*	*Married*	*Divorced/ Widow*
Gala-Nefhi	3076	120	84	65 (77.4%)	19 (22.6%)	14 (16.7%)	13 (15.5%)	57 (67.8%)	26 (31%)	41 (48.8%)	11 (13.1%)	6 (7.1%)	4 (4.8%)	68 (81%)	12 (14.2%)
Berki	3021	120	106	80 (75.5%)	26 (24.5%)	13 (12.3%)	16 (15.1%)	77 (72.6%)	40 (37.7%)	40 (37.7%)	26 (24.6%)	0 (0%)	4 (4.7%)	87 (82.1%)	14 (13.2%)
Serejeka	2667	120	117	75 (64.1%)	42 (35.9)	14 (12%)	19 (16.2%)	84 (71.8%)	3 (2.6%)	12 (10.3%)	46 (39.3%)	56 (47.8%)	4 (3.4%)	89 (76.1%)	24 (20.5%)
Total	8764	360	307	220	87	41	48	218	69	93	83	62	13	244	50

NHHS- Number of households; RS= randomly selected; TNR= Total number respondent; M=Male; F=Female and 4.2 percent were single (Table 1). The average household size was seven persons. The study revealed that 22.5 percent were illiterate, about 30.3 percent had primary schooling, 27 percent secondary schooling and 20.2 percent had a higher education. Education enables people to discover existing opportunities in the production process (Baiyegunhi 2015).

Access to credit is vital to expand farm enterprise, however, the study found that there was limited access to credit for farmers, particularly women. Only twenty-nine percent of farmers had access to credit, of which fourteen percent were women. Bahta et al. (2017) found that women are less likely to be able to access credit.

Approximately half (47%) of the respondents had access to extension services, of which eighty-eight percent were men. Maoba (2016) highlighted that extension services provide the necessary information to enhance production. Moreover, twenty-three percent of the respondents participated in seed multiplication programs, of which eighty-eight percent were men. Coomes et al. (2015) and Bahta et al. (2017) emphasized the importance of a farmer seed network for agricultural development. Adequate supply of water is required to sustain agricultural production. Thus, respondents were introduced to RWHT to collect rainwater for sustainable agricultural production and to ensure a sustainable water resource management. Out of the nine percent who received remittances, the majority were men (66%). Agriculture is labor intensive and additional labor (hired) is required to carry out various activities in the value chain. The majority of respondents (92%) depended on family labor while eight percent hired extra labor to work on the farm. Graeub et al. (2016) mentioned that worldwide, farmers mostly relied on family labor for farm management and operation.

Empirical Results of Probit Model

The results of the model and marginal effects are presented in Table 3. The marginal effect showed the effect a unit change had on a probability variable of RWHT adoption.

The model was statistically significant and fit as indicated by the likelihood ratio chi-square of 39.19 (p-value of 0.0001) and an increasing pseudo R^2. Table 3 indicated that availability credit access *(Credit)* seed multiplication program *(Seedmp)* access to extension service *(Ex-*

Table 2: Result of correlation matrix

	RW	*C*	*S*	*E*	*R*	*H*	*RO*	*CE*	*G*	*MS*	*A*	*ED*	*NC*
RWHT (RW)	1.000												
Credit (C)	0.206	1.000											
Seedmp (S)	0.134	0.099	1.000										
Extension (E)	0.162	0.183	0.127	1.000									
Remittances(R)	0.066	0.037	0.058	0.121	1.000								
Hired Labour (H)	0.050	0.103	0.072	0.146	0.018	1.000							
Radio (RO)	-0.037	-0.027	-0.005	-0.047	0.009	-0.054	1.000						
Cellphone (CE)	-0.002	-0.092	0.028	-0.066	0.004	-0.041	-0.087	1.000					
Gender (G)	-0.103	-0.191	-0.188	-0.333	0.049	-0.115	-0.021	0.124	1.000				
Marital Status (MS)	0.077	0.137	0.195	0.183	-0.037	0.037	-0.018	-0.120	-0.448	1.000			
Age (A)	-0.164	-0.006	0.110	0.099	0.071	0.120	-0.000	-0.175	-0.297	0.144	1.000		
Education (ED)	0.028	0.085	0.061	0.083	0.021	0.026	0.097	0.019	0.088	-0.158	-0.342	1.000	
Number of Children (NC)	0.122	0.241	0.011	0.026	-0.065	-0.033	-0.023	0.172	-0.216	0.322	0.013	0.049	1.000

Source: Author's calculation (RWHT: Rainwater Harvesting Technology)

Table 3: Estimated coefficient for the probit regression and marginal effect

Variables	*Parameter*	*Coefficients*	*Average marginal effects*	*Standard error*	*z-statistics*	*Probability*
Constant	δ_0	0.034	-	0.529	0.06	0.949
Credit	δ_1	0.447	0.107	0.188	2.37	0.018**
Seedmp	δ_2	0.383	0.092	0.197	1.94	0.050**
Extension	δ_3	0.367	0.088	0.255	1.87	0.062***
Remittances	δ_4	0.338	0.081	0.295	1.33	0.184
Hired labour	δ_5	0.160	0.038	0.571	0.54	0.588
Radio	δ_6	-0.289	-0.069	0.222	-0.51	0.613
Cell phone	δ_7	-0.039	-0.009	0.235	-0.18	0.860
Gender	δ_8	0.292	0.070	0.254	-1.24	0.214
Marital status	δ_9	0.044	0.011	0.077	0.17	0.862
Age	δ_{10}	-0.281	-0.067	0.070	-3.66	0.000*
Education	δ_{11}	0.075	0.018	0.034	-1.07	0.286
Number of children	δ_{12}	0.037	0.009	0.529	1.10	0.273
Wald Chi-square	$\delta_1=...=\delta_{12}=$	39.19 (0.0001)*				
Log pseudo likelihood	-132.75694					
Pseudo R2	0.1247					

***Significant at 1%, ** significant at 5% and *** significant at 10%
Probit regression estimation using the STATA-11 software

tension), gender *(Gender)* and age *(Age)* were statistically significant. Credit and seed multiplication had the greatest impacts on RWHT adoption to ensure sustainable water resource management. This is in contrast to Akroush et al. (2017), who found that credit and age were not significant in the decision to adopt RWHT.

In most developing countries, the main obstacle farmers have in adopting modern technologies and inputs is a shortage of capital and lack of finance, which includes cost of labor, transportation, and construction material. The coefficient availability of credit, was strongly significant at five percent and had a positive impact on probability of RWHT adoption. The marginal effect of 0.107 showed that respondents were more likely to increase their probability of adoption of RWHT by 10.7 percent. Credit access could enable farmers to finance their own RWH systems and enhance their productivity. Rainwater harvesting is a feasible water sourcing option in challenging climatic extremes. There is also the possibility that farmers' incomes are enhanced if RWHT is combined with income generating activities and programs. Without collateral, farmers do not have access to credit and without credit they cannot buy the material or apply technologies required for adoption of RWHT and enhance production. If the production level is not sufficient, it leads to food insecurity. Without improving farmers' access to resources or credit, it becomes challenging to achieve a desired level of efficiency and subsequently has a long-term effect on food security.

Extension services positively correlated with the probability to adopt RWHT and was highly significant at a ten percent level. Respondents' contact with extension services increased by one percent, and their probability to adopt RWHT increased by 8.8 percent. Respondents who receive extension services such as training are probably exposed to different RWH techniques, which in turn leads to improved household food security. Improving farmers' capability to invest in technology would improve their long-term financial security. Improving farmers' knowledge of different RWHT through an extension services was also a vital in developing self-esteem and a sense of independence. Access to information and resources, training and prospects to participate in on-farm activities through contact with extension officers enhances a farmer's capability to adopt RWHT (Baiyegunhi 2015).

Respondents who participated in seed multiplication programs were positively correlated with the possibility to adopt RWHT at a highly significant five percent level. The results show that as respondents' seed multiplication increased by one percent, their probability to adopt RWHT increased by 9.2 percent.

The average age of respondents was 50 years and forty-nine percent were older than 55 years. Older respondents were less likely to adopt RWHT by 6.7 percent. The reason might be that older farmers are not prepared to take risks or adopt new technologies or practices. As age increases farmers are more conservative, become more reluctant to adopt new technologies and prefer their indigenous methods. This is consistent with the study of Baiyegunhi (2015) who found that younger farmers had a better chance of applying new knowledge and technologies.

The results also showed a significantly positive relationship between gender and RWHT adoption, suggesting that men were 7 times more likely than women to adopt RWHT. This result is consistent with Tanellar et al. (2014) who also found that men were more likely than women to adopt farming technology.

The other variables were not significant, but remittance, hired labor and education level were more likely to increase the probability of RWHT adoption. This finding is similar to that of Akroush et al. (2017) where farmers with higher education levels were more likely to adopt RWHT. Assets radio (*Radio*) and assets cellular phone (*Cellphon*e) reduced the probability of RWHT adoption. Respondents who received remittance from relatives were more likely increase their probability of adopting RWHT by 8.1 percent.

CONCLUSION

This study examined the factors that influence farmers' to adopt RWHT in central Eritrea. More specifically, the study identified the cause of non-adoption of RWHT and analyzed the socio-economic characteristics of the respondents. Conclusions were drawn, which provided insight on ways to increase the adoption of RWHT in central Eritrea. Firstly, RWHT should be integrated taking into consideration farmers' age, gender, credit, seed multiplication program, and access to extension services. The important lesson from the study is that ignoring socio-economic characteristics of farmers could lead to misdirected targeting of RWHT and unsustainable water resource management. Secondly, the benefit of RWHT were highly correlated with the socio-economic conditions of respondents. In a semi-arid area like Eritrea, increasing farmers' knowledge and perception of rainwater harvesting techniques is important for developing self-confidence and the sense of independence. Improving farmers' capability to invest in technology and to secure their rights to resources would definitely improve their long-term financial security and household food security.

Thirdly, when there is no other water supply or no prospect of water, RWHT has been confirmed to be a feasible water source in challenging climatic extremes. The study recommends that to ensure water resource management, the government should promote an integrated and holistic approach to provide technical and institutional support for farmers. In this way, scarce water resources are sustained by enhancing access to credit, facilitating more extension services and encouraging farmer's seed networks for agricultural development. Generally this would work towards achieving the 2030 agenda for sustainable development targets in ending poverty and hunger.

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ABBREVIATIONS

The following abbreviations are used in this manuscript:

RWH: Rainwater harvest/ing

RWHT: Rainwater Harvesting Technology

APPENDIX

Zoba Maekel Central Province

REFERENCES

Akroush S, Dehehibi B, Dessalegn B, Al-Hadidi O, Abo-Roman M 2017. Factors affecting the adoption of water harvesting technologies: A case study of Jordanian arid area. *Sustainable Agriculture Research,* 6(1): 80-89.

Bahta YT, Haile BO 2013. Determinants of poverty of Zoba Maekel of Eritrea: A household level analysis. *International Journal of Food and Agricultural Economics,* 1(2): 73-84.

Bahta YT, Strydom DB, Emmanuel Donkor 2017. Microcredit and gender empowerment: Policy implications for sustainable agricultural development in Eritrea. *Development in Practice,* 27(1): 90-102.

Baiyegunhi LJS 2015. Determinants of rainwater harvesting technology (RWHT) adoption for home gardening in Msinga, KwaZulu-Natal, South Africa. *Water SA,* 4(1): 33-39.

Bonate PL 2011. *Pharmacokinetic-Pharmacodynamic Modelling and Simulation.* New York: Springer.

Coomes OT, McGuire SJ, Garine E, Caillon S, McKey D, Demeulenaere E, Jarvis D, Aistara G, Barnaud A, Clouvel P, Emperaire L, Louafi S, Martin P, Massol F, Pautasso M, Violon C, Wencélius J 2015. Farmer seed networks make a limited contribution to agriculture? Four common misconceptions. *Food Policy,* 50: 41-50.

Gautam Y, Andersen P 2016. Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of Rural Studies,* 44: 239-249.

Gebregziabher G, Rebelo LM, Langan S 2016. Interdependence in rainwater management technologies: An analysis of rainwater management adoption in the Blue Nile Basin. *Environment, Development and Sustainability,* 18(2): 449-446.

Ghebreyohannes F 2006. Integrated Water Management: Socio-economic Factors of Water Harvesting Projects. *Proceeding of the Workshop of the Association of Eritrean in Agricultural Science (AEAS),* 2-3 March, Asmara, Eritrea.

Gherezghiher T 2010. Fog Collection Pilot Project in the Eastern Escarpments of Eritrea. *5th International Conference on Fog, Fog Collection and Dew Münster,* 25-30 July, Germany.

Graeuba BE, Chappell MJ, Wittman H, Ledermanne S, Kerr RB, Gemmill-Herren B 2016. The state of family farms in the world. *World Development,* 87: 1-15.

Gujarati DN 2003. *Basic Econometrics.* 4th Edition. Boston: McGraw Hill.

International Centre for Agricultural Research in the Dry Areas (ICARDA) 2014. *GIS Tools Help Identify Sites for Rainwater Harvesting in Eritrea.* Lebanon: ICARDA.

Jose M, Padmanabhan M 2016. Dynamic of agricultural land use change in Kerala: A policy and social-ecological perspective. *International Journal of Agricultural Sustainability,* 14(3): 307-324.

Joshua MK, Ngongondo C, Chipungu F, Monjerezi M, Liwenga E, Majule AE 2016. Climate change in semi-arid Malawi: Perceptions, adaptation strategies and water governance. *Jàmbá: Journal of Disaster Risk Studies,* 8(3): a255.

Khatri-Chhetri A, Aggarwal PK, Joshi PK, Vyas S 2017. Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agricultural System,* 151: 184-191.

Kifle S, Teferi B, Kebedom A, Legesse A 2016. Factors influencing farmers decision on the use of introduced soil and water conservation practices in the lowlands of Wenago Woreda, Gedeo Zone, Ethiopia. *American Journal of Rural Development,* 4(1): 24-30.

Kirk M, Brewer J, Hickel J 2015. Four Things You Probably Know About Poverty that Bill and Melinda Don't. Fact Co. Exist. From <http://www. sharing. org/information-centre/reports/beyond-sustainable-development-goals-uncovering-truth-about-global> (Retrieved on 25 January 2017).

Kosgei JR, Jewitt GPW, Kongo VM, Lorentz SA 2007. The influence of tillage on field scale water fluxes and maize yields in semi-arid environments: A case study of Potshini catchment, South Africa. *Physics and Chemistry of the Earth,* 32: 1117-1126.

Maddala GS 2001. *Introduction to Econometrics.* 3rd Edition. London: John Wiley and Sons Ltd.

Maguza-Tembo F, Mangison J, Edris AK, Kenamu E 2017. Determinants of adoption of multiple climate adoption strategies in Southern Malawi: An ordered Probit analysis. *Journal of Development and Agricultural Economics,* 9(1): 1-7.

Mittal S, Mehar M 2016. Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: Analysis using multivariate Probit model. *The Journal of Agricultural Education and Extension,* 22(2): 199-212.

Munyaneza O, Majoro F, Hagenimana E, Usabyisa W 2016. Impact assessment of hillside rainwater harvesting ponds on agriculture income: Case study of Ntarama sector in Rwanda. *Journal of Water Resource and Protection,* 8(9): 844-854.

Murgor FA, Owino JO, Cheserek GJ, Saina CK 2013. Factors influencing farmers' decisions to adapt rain water harvesting techniques in Keiyo District, Kenya. *Journal of Emerging Trends in Economics and Management Sciences,* 4(2): 133-139.

Nijhof S, Shrestha BR 2010. Micro-credit and Rainwater Harvesting in Nepal. *Proceedings of the International Water and Sanitation Centre (IRC) Symposium 2010: Pumps, Pipes and Promises: Costs, Finances and Accountability for Sustainable WASH Services,* 16-18 November, The Hague, The Netherlands.

Radhouane L 2013. Climate change impacts on North African countries and on some Tunisian economic sectors. *Journal of Agriculture and Environment for International Development,* 107(1): 101-113.

Rena R 2008. Women's enterprise development in Eritrea through microfinance. *The ICFAI University Journal of Entrepreneurship and Development,* 5(3): 41-58.

Shikur A, Beshah, T 2012. Analysis of influencing factors in adoption of rainwater harvesting technology to combat the ever changing climate variability in Lanfuro Woreda, Southern region, Ethiopia. *Wudpecker Journal of Agricultural Research,* 2(1): 15-27.

Sturdy JD, Jewitt GPW, Lorentz SA 2008. Building an understanding of water use innovation adoption processes through farmer-driven experimentation. *Physics and Chemistry of the Earth,* 33: 859–872.

Tanellari E, Kostandini G, Bonabana-Wabbi J, Murray A 2014. Gender impacts on adoption of new technologies: The case of improved groundnut varieties in Uganda. *African Journal of Agricultural and Resource Economics,* 9(4): 300-308.

Tesfai M, Stroosnijder L 2001. The Eritrean spate irrigation system. *Agricultural Water Management,* 48: 51-60.

Vohland K, Barry B 2009. A review of in situ rainwater harvesting practices modifying landscape functions in African drylands. *Agriculture, Ecosystems and Environment,* 131: 119–127.

Xue-Feng H, Cao H, Li FM 2007. Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology in the semi-arid Loess Plateau of China. *Agricultural Water Management,* 89: 243–250.

Yazar A, Ali A 2017. Water harvesting in dry environments. In: Muhammad Farooq, KHM Siddique (Eds.): *Innovations in Dryland Agriculture.* Springer, pp. 49-98.

Yosef BA, Asmamaw DK 2015. Rainwater harvesting: An option for dry land agriculture in arid and semi-arid Ethiopia. *International Journal of Water Resources and Environmental Engineering,* 7(2): 17-28.

ZMA 2009. *Annual Work and Budget Plan for 2010*. Asmara, Eritrea: Zoba Maekel (Central Province) Administration.

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