Factors Affecting the Adoption of Rain Water Harvesting Technologies in Western Pare Lowlands of Tanzania

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Abstract

Adoption of technology is an important factor in economic development especially in developing countries. Successful introduction of technologies in developing countries requires an understanding of the priorities and concerns of smallholder farmers at the grassroots. This paper analyses the socio-economic factors that influence the adoption of rain water harvesting (RWH) technologies in Western Pare lowlands of Tanzania. Data for the study were collected from 70 smallholder farmers in Kifaru and Lembeni villages. These data were fitted in Probit and Logit models. The results of the probit model are used to explain adoption of RWH in Western Pare lowlands because it produced better fits compared with the Logit model. The results of the probit model shows that farm size, number of family members working in the farm, experience in farming, and extent of knowledge in RWH techniques were significant in explaining the intensity of adoption of RWH techniques. Regarding farmers perceived technology characteristics, the results show that farmers' appreciation of RWH as a factor contributing to increased crop yield was positively and significantly explaining the intensity of adoption of RWH. This suggests that higher yields attained with the use of RWH techniques will encourage adoption of the techniques. It is therefore recommended that efforts to promote the use of RWH techniques should go together with the use of other recommended improved inputs to bring higher returns to farmers.

Keywords: Adoption, Rain water harvesting, Probit, Logit, and Technology characteristics

Introduction

Increased domestic food production is one of the possible means of achieving food security in Tanzania. However, much of the agricultural land is located in arid and semi-arid areas where rain falls irregularly and much of the water is soon lost as surface runoff. Rain water harvesting (RWH) is one of the techniques which can be used to manage the scarce rainfall in semi-arid areas in order to enhance agricultural production. RWH is defined as any system that encompasses methods for collecting, concentrating and storing various forms of runoff for various purposes (Myers, 1995).

Indigenous knowledge of soil and water conservation practices in Africa has been well documented.(e.g. Reij et al. 1996). Celebrated examples of traditional soil and water management practices in Tanzania are the "majaruba" system of the Lake zone and the "ngoro" pits of the southern highlands. On-farm research into improved RWH technologies in semi-arid areas of Tanzania began in 1991. The objective of the research programme is to develop, test and introduce appropriate and socially acceptable management interventions for improving the capture of rainfall by soils and soil-water

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availability to plants in the semi-arid areas. The first Project under this programme was implemented from 1991 to 1995 in Dodoma to test the performance of different tillage and water conserving techniques (Hatibu et al., 1995a).

The second research project titled "Evaluation and Promotion of Rain-Water Harvesting" was implemented from 1992 to 1994 in Western Pare lowlands. The aim of the project was to increase sustainability of production and population carrying capacity of flood-and-drought prone semi-arid lowlands through more effective management of rainwater (Hatibu et al., 1997). The third was a follow up project titled "Development of improved rain fed cropping systems incorporating rainwater harvesting/conservation" which started in December 1996.

In the implementation of the last two projects, SUA is collaborating with the University of Newcastle upon Tyne (NUT) in UK. The work done by SUA has contributed to the validation of physically based model being developed at NUT for the prediction of runoff from macro and micro-catchments (Gowing and Young, 1996).

Apart from the technical aspects of RWH, a number of socio-economic studies were conducted as part of the RWH programme (Hatibu et al., 1995a, BACAS, 1997). These studies were carried out on the undertanding that past interventions in smallholder agriculture have failed because they have been based exclusively upon the perceptions of outsiders to the farming community. It should be recognized that success in the promotion of RWH techniques requires an understanding of the priorities and concerns of the smallholder farmers.

This paper is an analysis of the results of one of the socio-economic studies conducted in Western Pare lowlands to examine the factors affecting adoption of RWH technologies. The general objective of the paper is to quantitatively delineate the socio-economic factors that are likely to influence the adoption of improved RWH technologies among smallholder farmers.

Methodology

Theoretical model

Improved RWH techniques can be viewed as a form of technical change. Smallholder farmers in the semi-arid lands implicitly know the importance of RWH in increasing crop yields and their incomes. This scenario assumes that smallholder farmers have perfect kowledge about the RWH techniques and their objectives are economic, e.g.; profit maximization, cost and/or risk minimization. However, smallholder farmers may have non-economic objectives including social, cultural and personal factors. Hence, it may be reasonable to assume that the objective of some smallholder farmers in western Pare lowlands is utility maximization, where utility is a function of several economic, social, cultural and personal factors.

Basing on the utility theory, a household is assumed to maximize utility of production, consumption and marketing subject to a set of constraints such as income, production function and labour time constraints:

$Max\ U = U\ (C_o, C_p\ L\ C_{hi})$ (1)

s. t. Production constraints as represented by the production function

$Y = f(A, B, V_j)$ (2)

Time constraint

$T = B + L + H$ (3)

and full income constraint $I = p_i\ C_o + p_m\ C_p = wH + R + p_iY - 3P_j\ V_j$ (4)

Where:

C_o = Consumption of agricultural products produced by the farmer /Household

C_p = Consumption of markets purchased goods

L = Leisure time

C_{hi} = Characteristics I = 1, 2, . . . n, e.g. Household characteristics (age, years of education etc.) and technology characteristics (high yielding, palatability etc.)

Y = Total agricultural output (production function)

A = area of the land used for producing the output Y

B = Total Labour input (hired and family labour)

V_j = Other variable inputs used in the production of output Y
H = Net quantity of labour time hire in or out
R = Non-wage, non crop income
p_i = Price of agricultural products produced in the farm
p_j = Price of other production factors
p_m = Price of market goods consumed
w = wage rates per unit time of labour

As already pointed above, adoption of new technology is an exogenous scenario that affects production, consumption and marketing decisions, consequently assessing the adoption of new technologies and their effect on the household/farmer production consumption and marketing decisions is important (Jere, 1995).

However, modelling the whole system above is difficult. Attempts have been made to assess factors affecting adoption using the above basic assumption in a highly simplified way (Adesina and Zinnah, 1993).

Another problem in household decision making as represented by household utility function is that the decisions affecting production, consumption and marketing may/be made simultaneously with each decision affecting the other. This makes modelling household decision making to be more complicated and time consuming in terms of data needs. Kumar (1994) suggested modelling them recursively, with production decisions in one period affecting consumption outcome in the second period that could then affect production decisions and outcomes in the third period and so on. This however requires data in all those periods. Kumar (1994), suggested a methodology of resolving the problem when we have single season data. This method involves estimating recursive equations explaining adoption.

Kumar's method can be modified to suit RWH adoption. Defining A as observed RWH adoption and E_1 as a vector of exogenous variables, then

$A=f(E_1)$ (5)

and $RWHA = f(A^*, E_2)$, (6)

where A = *observed RWH adoption*

A^* = probability of RWH adoption

$RWHA$ = area applied with RWH techniques

E_1 E_2 = *vectors of exogenous variables*

Equations (5) and (6) are estimated using a two step or (Heckman approach), which first estimate the probability of RWH adoption, then estimates equation (6) by OLS and correcting for truncation bias. Similar approach can be used to estimate the likely influence of RWH to labour allocation, time spent in non-labour activities etc. (See Kumar, 1994:25-26).

Because of lack of data on consumption, labour allocation etc. the recursive equation system approach was not used in this study. Instead probit analysis which calculates maximum likelihood estimates for the parameters of the requested response model was used.

Specification of empirical model

The probit analysis centres on the hypothesis that a set of independent variables influences the decision to adopt RWH techniques. The probit model specified for this study included one dependent variable and 8 independent variables. Observations on all variables pertain to the cropping season of 1996/97. The variables were defined as follows: The dependent variable PROP= The proportion of RWH area to the area cultivated in 1996/97 season (Intensity of adoption). The variable takes the value of 1 if a farmer has adopted RWH techniques and 0 otherwise. The independent variables are:

AGE Age of the respondents in years;

EDU Number of years in education;

FARMSIZE Farm size in Hectares;

NOYEAR Number of years in farming;

WORKLABO Number of family members working in the farm;

OTHERDUM Dummy variable =1 if has off-farm activities; 0 if no off-farm activities;

DUMMKNOW Dummy variable = 1 if knowledgeable with RWH and 0 if not PERCEDUM Dummy variable =1 if perceive RWH as increasing yields and 0 if not.

Using SPSS PC+ the probit analysis was specified. In SPSS PC+, once estimation of probit model is specified, both logit and probit analysis can be done. Thus, both logit and probit models were estimated.

Data sources

Two main types of data were collected, namely primary and secondary data. The data were collected during the last quarter of 1997. Primary data for the two villages were collected using structured questionnaire covering 40 farmers from Lembeni and 30 farmers from Kifaru. Sampling was both purposive and random. A list of contact farmers and site visitors was made for Lembeni village where random sampling was employed to pick up 22 farmers, while the rest of the farmers were picked at random from the village register. In Kifaru, only 4 site visitors were identified and included in the sample, while the remaining 28 farmers were picked at random from the village register.

Semi-structured interviews and some PRA techniques (group discussions, interviewing key informants, and field observations) were used to complement the collected primary data. Secondary data were collected from reports and documents at the Soil and Water Management Research Programme and at the Mwanga District offices.

Results and Discussion

RWH techniques and the preferred crops for RWH

The various techniques of RWH used in the survey villages are reported in Table 1. The most common source of runoff is from external (macro) catchment, which include runoff from steep slopes, uncultivated land, culverts and ephemeral streams. No respondent attempted the use of internal (micro) catchments. Macro-catchment is a system that involves collection of runoff from large areas that are at an appropriate distance from where the water is being used. Micro-carchment RWH, on the other hand, is a system where there is a distinct division of catchment area and cropped basin but the areas are adjacent to each other.

Whereas culvert diversion and ephemeral stream diversions are very common external catchment methods in Kifaru, only ephemeral stream diversions are popular in Lembeni. In

Table 1: Percentage distribution of respondents by techniques used for RWH

Technique / Village	Lembeni	Kifaru	Overall
External Catchment.			
Ephemeral stream diversions	24.1 (13)	22.7 (50)	23.7 (18)
Culvert diversions	7.4 (4)	22.7 (5)	11.8 (9)
Infield Methods[1]			
Infield water spreading furrows	25.9 (4)	18.2 (4)	23.7 (18)
Contour ploughing across the field	13.0 (7)	22.2 (4)	15.8 (12)
Ridges	7.4 (4)	9.1 (2)	7.9 (6)
Trash lines	5.6 (3)	4.5 (1)	5.3 (4)
Deep tillage	3.7 (2)	-	2.6 (2)
Stone barriers	5.6 (3)	-	3.9 (3)
Furrow to check flow of water	1.9 (1)	-	1.3 (1)
Bigger planting holes	1.9 (1)	-	1.3 (1)
Other Techniques			
Roof top harvesting	3.7 (2)	-	2.6 (2)

Source: Survey data, 1997

Number in parantheses are responses

[1]Can either be in situ or depending on external catchment. In the study area most of the runoff for infield methods is from external catchment

Kifaru village there were about 55 culverts feeding the farms located on the western side the Moshi- Arusha road. The culverts collect runoff from mountain blocks and uncultivated land. Farmers pointed out that the runoff from external catchment has high velocity and most often they fail to control it and that it creates gullies across their farms. Another worry about external catchment is the unfavourable location of some fields in relation to the source of runoff. For example some fields are surrounded by others, thus one has to negotiate the right to convey runoff across the fields. However, some farmers may be unwilling to cooperate if they fear the structure may fail and thereby damage their own crops.

Another important RWH technique, is the use of infield water management and distribution (Table 1). The most frequently used are infield water spreading furrows. Relatively more responses were observed in Lembeni compared with Kifaru. Contour ploughing across the slope was more common in Kifaru compared with Lembeni. This is because the method lends itself to land preparation by tractor that was more common in Kifaru compared with Lembeni. Field observations showed that many farm plots are narrow across the slope and tractor operators prefer to plough along the length of the field. In Kifaru there is a premium charged for contour ploughing. Several farmers do adopt this method but if the slope is not aligned within the field, across the field ploughing does not necessarily follow the contours and water distribution may be uneven. Slope alignment is one of the technical knowledge that is lacking. Training farmers in the use of simple farm lay out tools such as A-frame and Line levels can help in solving this problem.

The use of roof top harvesting for agricultural production was also observed. This was practised in Lembeni where two farmers were using it. The problem noted was insufficient runoff to cater for bigger farms. Usually that method is useful for smaller areas of horticultural gardens.

When asked which is the most preferred crop for RWH, most of the respondents suggested that maize is the preferred crop because it is the major food crop and also the source of cash through sale of surplus maize (Table 2).

Cowpeas were shown as the second crop of choice for RWH mainly because of their importance as a food crop and a cash crop. Although sunflower was mentioned by only a few respondents, it was at the same time suggested that this crop is now becoming important due to the introduction of household oil pressing machines. The potential for sunflower becoming an important RWH crop in the area is thus high.

Sources of information in RWH

The overall survey results revealed that most farmers are applying RWH through their own initiatives (Table 3). Kifaru has a higher percentage of farmers using RWH through their own initiatives. This is because of low and erratic rainfall in the area which causes crop failure. Most farmers in Lembeni learned about RWH from the SUA RWH project at Kisangara. This has been mainly through site visiting, and seminars conducted by SUA RWH project.

There was little evidence of farmers learning RWH techniques through extension workers (Table 3). Discussion with extension workers revealed that this is because of lack of RWH extension packages in the District Agricultural Office, poor training of extension workers in RWH techniques and the extension workers orientation to soil and water conservation, i.e. runoff is seen as erosion causing rather than increasing soil moisture.

Farmer to farmer information dissemination regarding RWH was not very apparent (Table 3). However, this might have been due to low competence among farmers in RWH techniques, and since on-farm experimentation has not yet started farmers are still not ready to take larger risks in up taking RWH. Formal discussion with farmers and key informants showed that there are potentials for farmer to farmer information dissemination in RWH in future, provided RWH extension and on-farm research are strengthened. The literature on Farming Systems research stresses the convergence of perception among farmers, extensionists and researchers. This convergence can be brought about in many ways.

Table 2: Percentage distribution of respondents by preferred crops for RWH

Crop / Village	Lembeni	Kifaru	Overall
Maize	75.0 (21)	91.7 (11)	80.0 (32)
Cowpeas	14.3 (4)	-	10.0 (4)
Sunflower	7.1 (2)	-	5.0 (2)
Sugarcane	3.6 (1)	-	2.5 (1)
Tomatoes	-	8.3 (1)	2.5 (1)

Source: Survey data, 1997
Numbers in parentheses are responses

Table 3: Percentage distribution of respondents by where they got RWH knowledge

Village / Source of information	Lembeni	Kifaru	Overall
Own initiatives	36.3 (12)	69.2 (9)	60.0 (21)
RWH project at Kisangara	48.5 (16)	7.7 (1)	48.6 (17)
Fellow farmers	9.1 (3)	23.1 (3)	17.1 (6)
Roman Catholic Workshop at Same	3.0 (1)	-	2.9 (1)
Extension workers	3.0 (1)	-	2.9 (1)

Source: Survey data, 1997. Numbers in parentheses are responses

Extent of adoption of RWH

In this study, adoption of RWH techniques was examined in two ways, namely the rate and intensity of adoption as categorised in Nkonya et al. (1997). The rate of adoption of RWH strategies implies the proportion of farmers who have adopted at least one of the RWH techniques. Intensity of adoption of RWH techniques refers to the level of use of RWH, measured by the number of hectares applied with RWH techniques. Table 4 shows the rate of adoption of RWH by villages. In the survey villages about 48.6% of the respondents are practising RWH techniques in their farms and 51.4 % are not practising (Table 4). The results are as expected, i.e. more than 50% of the users are in Lembeni village. This is because of the contact with the project while Kifaru village that had poor contact with the Project had only 34% of adopters.

For those who used RWH techniques (Referred to as adopters), only 31.4% applied it to all their farms, while 68.6% applied it only to parts of their farm(s).

The ratio of area applied with RWH to the area cultivated (Table 5) shows that intensity of adoption is highest in Kifaru village compared with Lembeni village. Kifaru had also the highest mean area under RWH compared with the other village. Generally, intensity of adoption of RWH in the two villages using the calculated ratios is above 50% suggesting a high adoption rate.

Results of the Probit model

Both logit and probit models were estimated but the results of probit model fitted the data better compared with the logit model. Thus the discussion which follows is based on the results of the estimated probit model presented in Table 6. Generally the model produced significant fit at 6% as indicated by the Pearson CHI-square and the Maximum Likelihood (ML) converged. Variables that were significant in explaining the intensity of adoption of RWH techniques are farm size, number of family members working in the farm, experience in farming, and extent of knowledge in RWH techniques. Farmers with large farm size are likely to be able to take risks of adopting new technology and have chances of experimenting with the new technology. Technical knowledge in RWH was significant in explaining intensity of adoption of RWH. Farmers who are knowledgeable in RWH are expected to adopt the techniques compared with those who are not knowledgeable. This supports the innovation diffusion model as pointed in earlier works of Rogers (1962), that access to information about

Table 4: Percentage distribution of respondents by use of RWH by village

Village / Users	Adopters	Non-adopters
Lembeni	60.0 (24)	40.0 (16)
Kifaru	34.4 (11)	65.6 (21)
Overall	48.6 (36)	51.4 (37)

Source: Survey data, 1997. Numbers in parentheses are respondents

Table 5: Intensity of adoption of RWH techniques in the surveyed villages

Village	Ratio of Area with RWH to area cultivated	Mean area with RWH (hactares)
Lemben	0.60 (0.41)	0.8 (0.5)
Kifaru	0.71 (0.27)	2.7 (3.1)
Overall	0.63 (0.36)	1.38 (2.0)

Source: Survey data, 1997. Numbers in parentheses are standard deviations

Table 6: Estimated results of farmer adoption model

Variable	Maximum Likelihood (ML) Estimate	Standard Error	Asymptotic t	Significance at P=0.06
AGE	- 0.0052	0.0083	- 0.6265	NS
EDU	0.0055	0.0371	0.1482	NS
FARMSIZE	0.0146	0.0045	3.2444	SG
NOYEAR	0.0331	0.0106	3.1226	SG
WORKLABO	0.3800	0.1357	2.8003	SG
OTHERDUM	0.0444	0.1957	0.2269	NS
DUMMKNOW	0.4616	0.1728	2.6712	SG
PERCEDUM	1.7412	0.7128	2.4428	SG
INTERCEPT	2.5842	0.6100	4.2362	SG
Pearson Goodness of Fit CHI-SQUARE	78.972 P=0.061			SG
n	72			

SG = significant at 6 % level
NG = Not significant at 6% level

the technology is the key factor in determining adoption.

Farmers perceived technology characteristics are said to condition adoption of that particular technology. In this study only one farmer perceived technology characteristic was included in the model due to data limitation. The results show that farmers' perception in RWH as increasing crop yield was positively and significantly explaining the intensity of adoption of RWH. This shows the need for looking further on farmers' perceived technology characteristics in conditioning the adoption process. Perceived yield increase was also found significant in adoption of swamp rice varieties in Sierra Leone (Adesina and Zinnah, 1993). Under experimental conditions, the use of RWH has been found to increase maize yields in the survey areas (Hatibu et al., 1995b). RWH techniques at Kisangara experimental site, (in field micro catchments) produced a significant increase in grain yields in both *vuli* and *masika*. In the *vuli* season, yields increased by 420 kg/ha on the 8% slope and by 118 kg/ha on the 3% slope, while in *masika* yields increased by 185 to 642 kg/ha (Hatibu et al 1995b).

Applications of RWH techniques are sometimes labour intensive. Families with few number of their members working in the farm are likely to be non-adopters.

Experiences in farming as indicated by the number of years in farming (NOYEAR) are positive and significantly explained the intensity of adoption of RWH. This may be explained by the severity of the problem of low and erratic rainfall. Long time farmers have experience with the problems of drought compared with new farmers or less experienced. As a result adoption of RWH is higher to the experienced farmers compared with less experienced farmers.

Variables that were not significant included education, age and off farm income dummy variable.

Conclusions

The survey showed that many farmers are interested in RWH through the use of external catchments and infield water management and distribution. Their major concern is the failure to control and manage runoff from external catchment when its velocity is high. Runoff control and management is therefore an issue which needs to be addressed in technical experiments. Measurements of runoff from external catchments, methods of management and control of runoff to avoid gully erosion etc., are areas to be examined by technical experiments.

Extent of knowledge in RWH techniques was significant in explaining the intensity of adoption of RWH techniques. Implications of this finding includes the need for imparting RWH skills among the extension agents and conducting on-farm trials.

Regarding farmers perceived technology characteristics, the results show that farmers' perception in RHW as increasing crop yield was positively and significantly related to the intensity of adoption of RWH. This suggests that higher yields attained with the use of RWH techniques will encourage adoption of the techniques. It is therefore recommended that for the RWH techniques to be effective and bring higher returns to farmers, it should go hand in hand with other recommended improved inputs use. Considerations should be given to fertilizer use, pest and diseases management strategies and the use of improved storage techniques. Experiments involving both RWH techniques and other improved technologies need to be undertaken together as a package. These will have an impact on yields and returns to maize and will also increase productivity per unit land which will be very useful in the target area.

Farmers perceived RWH techniques as risky. This implies that improving farmers risk taking capacity will enhance adoption of this technology. It is therefore suggested that assisting farmers in forming their own rotating savings and credit schemes will help in getting capital/cash to invest in agriculture. This can be achieved through the formation of Rain Water Harvesting Users Groups.

Encouraging other crops with high income prospects to be included in RWH will also improve adoption of RWH. With the introduction of oil pressing mills at the household level, sunflower growing can improve farmers' incomes.

There may be other factors that undoubtedly influence the intensity of adoption of RWH. Since factors affecting adoption can change in each stage of technology adoption, socio-economic studies should continue to monitor adoption and factors determining its adoption.

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