Adoption of Rainwater Harvesting Technologies by Farmers in Tanzania with Particular Reference to the Western Pare Lowlands.

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Abstract

Adoption of technology is an important factor in economic development. Successful introduction of technologies in the developing countries requires an understanding of the priorities and concerns of the smallholder farmers at the grassroots. This paper presents experiences of adoption studies in the Western Pare Lowlands, identifying the factors affecting adoption, constraints to adoption and methodological problems in studying adoption of RWH technologies. A survey approach was the main method used to collect the data from a sample of 86 farmers. The data collected were analysed using descriptive statistics and estimation of empirical model to determine the factors affecting adoption of RWH technologies. The empirical model used was logit regression. Important factors affecting the adoption of RWH were identified as number of plots owned by farmers and the sex of the head of household. Constraints in the adoption of RWH technologies were noted including constraints facing those who are already using the RWH technologies. Problems facing the users include difficulties with water distribution. Two important recommendations are made: First because adoption of technologies by farmers takes time, there is a need for collecting a series of data (separated in time) about adoption rather than depending on single season static data. The models used in evaluating adoption should also consider the time element. Secondly, since the main constraints to adoption is lack of technical knowledge, it is recommended that training of extension workers in RWH techniques and including RWH in the district extension package will reduce the problem of availability of technical knowledge to farmers.

Key words: Adoption, probit, logit regression, technology characteristics, rainwater harvesting

Introduction

Adoption of technology is an important factor for economic development especially in developing countries. Consequently many adoption studies have been undertaken to single out the most important factors that determine the diffusion of innovations. Since the earlier work of Rodgers (1962), efforts to explain determinants of adoption have been expanded (for example Feder *et al.*, 1985 and Nkonya *et al.*, 1997).

Feder *et al.* (1985) define adoption as the degree to which a new technology is used in long-run equilibrium when farmers have complete information about the technology and its potential. On the other hand, aggregate adoption is defined as the process of diffusion of a new technology within a given geographical region. Adoption at the farm level is related to

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the decisions made by farmers to use that particular technology in the production process.

Generally, two main questions were addressed by earlier adoption studies: The first is what determines whether a particular producer adopts or rejects an innovation and the second one is what determines the patterns of diffusion of the innovation through the population of potential adopters (Ghadim and Pannel, 1999). Nkonya *et al.* (1997) pointed out that factors affecting adoption differ across countries and are location specific, thus calling for studies that are location specific.

Despite the efforts that have been made in studying adoption of innovations in agriculture world-wide, very few studies have been done in Tanzania with respect to adoption of innovations related to Soil-Water Conservation (SWC) and Rain Water Harvesting (RWH) in particular. Adoption studies in SWC/RWH in Tanzania include that of Senkondo *et al.*, 1998; Semgalawe (1998) and Kalineza *et al.*, 1999. Findings from adoption studies are an important tool to extension workers, researchers and policy makers involved in RWH in targeting and delivering effective RWH programmes. Knowing the characteristics that have determined the adoption and diffusion of technologies would indicate what characteristics new technologies should posses to become quickly and widely adopted.

Based on the above, there is a need for understanding the relative importance of factors and constraints which may influence individuals' adoption of RWH technologies and thus stimulating peoples willingness to invest in RWH technologies.

The main objective of this paper is to present the results of socio-economic surveys conducted by the Soil Water Management Research Project (SWMRP) with particular emphasis on adoption of RWH technologies. The results of these surveys are also compared with the results obtained by other studies in Tanzania.

The need for RWH technologies

Increased domestic food production is one of the possible ways of achieving food security in Tanzania. However, much of the agricultural land in Tanzania is located in arid and semi-arid lands (about 50% of the total land area in Tanzania) where rain falls irregularly and much water is soon lost as surface runoff. RWH is one of the methods that can be used to manage the scarce rainfall in semi-arid areas in order to enhance agricultural production. Adoption of various RWH technologies in arid and semi-arid areas is therefore likely to bring about a sustained agricultural production, which will improve food security of the rural people.

RWH can be defined in various ways, however, a basic definition is that given by Myers (1975) as 'any system that encompasses methods for collecting, concentrating and storing various forms of runoff for various purposes'.

RWH technologies used in Tanzania vary from in-situ methods (e.g. deep tillage, contour farming and ridging) for conserving rainwater where it falls, to a system for diverting ephemeral streams and culvert discharges to provide supplementary water for crop production. RWH technology therefore encompasses soil and water conservation and partly supplementary irrigation. It is therefore a complicated technology with multiple requirements for it to be adopted. In addition, it is not easy to draw a clear line between adopters and non-adopters of RWH. Thus, the use of intensity of adoption i.e. the proportion of the area applied with

RWH or carefully defining adopters and non adopters, assist in solving this.

Methodology

Data sources

So far the rainwater harvesting (RWH) research project has gathered valuable socio-economic information through a number of studies/surveys carried out in the project area. Among the studies/surveys, two main socio-economic surveys that relate to the adoption of RWH technologies are identified. The first survey was conducted in 1997 covering Lembeni and Kifaru villages. The second one was undertaken at Hedaru and Kiruru villages in 1999. All the villages are located in the Western Pare Lowlands (WPLL). This paper will focus its attention on the 1999 survey data, and use the information obtained from the 1997 data for comparison purposes.

Primary data were collected using structured questionnaire administered to 86 farmers for 1999 survey. The sampling was both purposive and random. In all the villages, the list of contact farmers and site visitors was made and the farmers were picked at random from a prepared list. A formal questionnaire was then used to collect the data. In addition to the formal survey, informal interviews of key informants were conducted. The key informants included village leaders, elders, religious leaders and others who were found to be conversant with RWH.

Specification of empirical model

Different adoption models have been used in describing the factors affecting adoption of technologies. They include Probit models (Lapar and Pandey, 1999, Senkondo *et al.*, 1998, Nkonya *et al.*, 1997); Discriminant models (Yapa and Mayfiled, 1978) and Logit models (Ayuk, 1977). However, with reference to RWH it is important to consider the nature of the dependent variable. Adoption of technologies at the farm level is often quantified using a binary dependent variable (i.e. adopters =1 and non-adopters =2). Because of the problem of clearly defining adopters and non-adopters in RWH, this method need to be applied with great care. However, since RWH can be a divisible technology, the use of intensity of adoption (e.g. proportion of the area applied with RWH) or extent of adoption (e.g. share of land or percentage devoted to the new technology) as dependent variable can be applied. This way of defining the dependent variable has been applied by Senkondo *et al.*, 1998 and Nkonya *et al.*, 1997. This paper however, defines the dependent variable as binary variable taking a value of 1 for adopters and 2 for non-adopters. This has been done after a careful definition of RWH adopters. RWH adopters are those farmers who are practising at least one technique of RWH.

Specification of the logit model

With careful definition of adopters and non-adopters the data from the 1999 survey were analysed using binary variables as the dependent variable i.e. adopters =1 and non-adopters = 2. The model estimated was logit regression.

The logit model was specified as:

$$P(e) = e^z/1 + e^z \text{ or } P(e) = 1/1 + e^{-z}$$

Where P(e) is the probability of an event, e is a natural logarithm and z is the linear combination, which can be expressed linearly as

$$Z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i$$

Where β_i are coefficients to be estimated and x_i are sets of independent variables.

The independent variables included are:

- CODVILL Proxy for external influence =1 if there is external influence and 0 if otherwise;
- PLOTNUM The number of plots owned;
- LOCAT Dummy variable =1 if highland area and 0 if lowland area;
- SEXCOD Sex code of the head of household =1 if male and 2 if female;
- NONFARM Non farm activities;
- LABOUR Labour availability

The above relationship was estimated using SPSS PC+ maximum likelihood method. Backward stepwise selection method was used in regression analysis.

In determining the factors affecting adoption of a new technology, the data from the two socio-economic surveys were analysed using two different models i.e. Probit (Senkondo *et al.*, 1998) and logit (in this paper). The probit and logit models differ in specification of the distribution of the random error term. In logit model the error term follows a cumulative logit distribution while in probit model it follows the cumulative normal distribution. However, the two distribution functions are very close to each other. According to Semgalawe (1998) the results obtained from the two models are comparable except for a very large sample size. However, the estimation of the coefficients differ from each other, although they are related via a transformation function (Maddala, 1992). The main reason for using the two models is, as pointed out by Aldrich and Nelson (1984) and Judge *et al.* (1985), that the choice between the two models is usually made on the basis of practical concerns such as personal preferences, experience, availability and flexibility of computer software.

Results and Discussion

Farmers' Perception on Rain Water Harvesting

It was necessary to get an understanding of farmers' perception of RWH. This is an important step before the identification of users and non-user. During discussions with key informants farmers were requested to describe their understanding of Rain-Water-Harvesting (RWH). This discussion was useful in identifying attributes of RWH as perceived by farmers. Generally, farmers reached a consensus that RWH involves collecting rainwater in the fields and conserving it. For effective RWH, they noted that there should be at least one of the following (i) existence of a river, gully or rills (ii) canals for diverting water into fields (iii) water reservoir and (iv) canals to divert water from the reservoir to the field. Based on this definition they identified four different RWH techniques as presented below.

(a) Deep Tillage (DT)

Farmers noted that deep tillage collects and conserves moisture in their fields. This practice is either done manually or by tractor. Farmers noted that there is a big difference between a field which has been tilled and that which has not. The yield difference is as high as 50%.

(b) Diversion of Rainwater from Gullies (DRG)

Farmers defined gullies (*makorongo*) as water streams that flow during the rainy season only. They usually dry during the dry season. Construction of diversion channels is either done individually or communally. Farmers with adjacent fields sometimes pull up resources and construct channels to water their fields.

(c) Collection of Water from Rills/Sheet flow (CWR)

Farmers defined rills as tiny or small gullies. They therefore construct channels to collect water from the rills and/or sheet flow and direct into their fields. This is usually done individually. This practice is common in areas without permanent water sources.

(d) Diversion of Water from Rivers. (DWR)

Farmers differentiated rivers from gullies in that, water flows in the rivers throughout the year. They don't dry up during the dry season. However, there were instances of confusion between the two concepts. There are some rivers e.g. Mtowashi in Hedaru that used to flow throughout the year, about 5-10 years back. But recently, due to increased use (diversion of water) up-stream the rivers tend to dry during the dry season in down-stream areas. DWR practice involves construction of canals from the rivers to divert the water to the fields. This practice is common in upland areas where the rivers flow throughout the year.

Farmers also identified three practices that are commonly used for providing water to livestock, these are:

Ndoroto

Ndoroto is described as a natural land depression, which collects water during the rain season. Livestock are then brought into these sites for watering. Usually, a *ndoroto* dries during the dry season.

Lang'ata

A *Lang'ata* is a site along a riverbank which is shallow. *Lang`atas* are common sites where livestock can cross a river during grazing or travelling from one place to another. Livestock are therefore brought to these sites and watered directly into the river. Livestock can be brought to these sites for watering throughout the year. During the dry season some livestock keepers travel very long distances to reach the nearest *Lang`ata* for watering the livestock.

Makono

These are described as natural canals, which develop during flooding of rivers. The water remains in the canals for a long time after the river subsides. Even during the dry season the soil remains moist and sometimes is used for crop production. It was noted during the study, that some farmers own these canals privately (individually). This results into conflict of interest between livestock watering and crop production in the canals. Table 1 shows different RWH techniques practiced by specific farming systems.

Sources of information in RWH

Adoption of any technology depends to a large extent on the availability of information about the technology. This helps to create general awareness of that particular technology. There are many possible sources of knowledge in RWH. Table 2 shows the sources of knowledge as identified by the respondents.

The overall results from the study reveal that most of the farmers are applying RWH through their own initiatives or through the use of indigenous knowledge (Table 2). In the villages surveyed, about 60% of the respondents indicated that they apply RWH using their own initiative or indigenous knowledge.

Table 1: RWH Techniques used by Farming Systems

Farming system	RWH technique	Extent of use
1.Hedaru		
i) Maize-Lablab-bean	• Rill/sheet flow (CWR) • Deep tillage (DT)	Limited
ii) Maize-Bean-Cowpea	• Rill/sheet flow (CWR) • Deep tillage (DT)	Limited
Iii) Maize-lablab bean-livestock	• Rill/sheetflow (CWR) • 'Ndoroto' (RWH for livestock)	Moderate
iv) Livestock-maize-rice	• Diversion from rivers (DWR) • 'Ndoroto'(RWH for livestock) • 'Lang'ata'(RWH for livestock) • 'Makono'(RWH for livestock)	High
Maize-vegetable	• Diversion from rivers (DWR) • Diversion from rivers (DWR)with storage • Terraces (Infield structure)	High
Rice-Maize-Vegetable	• Diversion from rivers (DWR) • Terraces (Infield structure)	High
2. Kiruru-Ibweijewa		
Maize-beans	• Deep tillage (DT)	Limited
Maize-cowpeas-livestock	• Diversion from gullies (DRG) • Rill/sheet flow (CWR) • 'Ndoroto' (RWH for livestock)	Moderate
Beans-maize-vegetables	• Diversion from rivers (DWR) • Diversion from rivers (DWR) with storage • Deep tillage (DT) • Stone bunds/terraces (Infield structure)	High

Source: Survey data 1999

Table 2: Sources of information in RWH techniques

Source	Senkondo *et al.* (1998)	This study
	% of respondents	
Indigenous knowledge/own initiative	60 (42)	60 (52)
SUA RWH project	49 (34)	10 (9)
Fellow farmers/neighbours	17 (12)	10 (9)
Non-governmental organisation	3 (2)	13 (12)
Extension workers	3 (2)	0 (0)
Visit to other areas	0 (0)	6 (5)

Source: Survey data, 1999 and Senkondo *et al.* (1998)
Number in parentheses represents the number of respondents. Note that there are multiple responses

The impact of the RWH project (in the WPLL) as a source of information in RWH was moderately felt in the study area. However, the study by Senkondo *et al.* (1998) showed that the impact of the RWH project was highly felt (34% of respondents). This might have been influenced by the presence of RWH trials by Sokoine University of Agriculture (SUA) at Kisangara village (which is near Lembeni) and in Kifaru village. The current (1999 survey) study has low score because one of the villages (Hedaru) is far away from the trial site at Kisangara and Kifaru. However, some influence has been due to the presence of Same Agricultural Improvement Project (SAIPRO), an NGO at Hedaru village. The relatively high score on non-governmental organisations in this study also supports this.

There was little evidence of farmers learning RWH techniques from extension workers. This might have been due to the absence of RWH extension package in the district agricultural offices, poor training of extension workers in RWH techniques and the extension workers' orientation to soil and water conservation rather than in RWH.

Extent of adoption of RWH

The study examined adoption of RWH techniques by looking at the rate of adoption of RWH techniques. This implies the proportion of farmers who have adopted at least one of the RWH techniques. Table 3 compares the extent of use of RWH by the respondents. The table shows that there has been more adopters of RWH as compared to the earlier results of Senkondo *et al.* (1998). This may be attributed to the existing traditional supplementary irrigation/RWH in Hedaru village. In addition, Kiruru village has had more contact with RWH project site at Kisangara compared to Kifaru village (surveyed by Senkondo *et al.* 1998), which has had less contact.

Table 3: Extent of use of RWH

	Senkondo *et al*.(1998)	This study
	% of respondents	
Adopters	49 (35)	76 (56)
Non-adopters	51 (37)	24 (29)

Source: Survey data, 1999 and Senkondo *et al*. (1998)
Number in parentheses represents the number of respondents

Table 4: Constraints in the use of RWH (percent of respondents)

Reason	Senkondo *et al*. (1998)	This study
Lack of technical knowledge in RWH	46.2 (12)	48.0 (11)
Requires a lot of labour	9.8 (5)	17.3 (4)
Location of the farm versus the catchment	9.8 (5)	-
Fear of erosion	7.8 (4)	13.0 (3)
Lack of cash/capital	3.9 (2)	-
Too much runoff	3.9 (2)	-
Soil not appropriate	-	13.0 (3)
Rain is not enough	-	8.7 (2)
Farm flat no runoff	2.0 (2)	-

Source: Survey data, 1999 and Senkondo *et al*.(1998)
Number in parentheses represents the number of respondents

Constraints in the use of RWH

Various reasons were given as to why some farmers did not adopt RWH (Table 4). Among the reasons, the most frequently mentioned is lack of technical knowledge regarding rainwater harvesting. This was also identified from an earlier study by Senkondo *et al*. (1998). The specific knowledge they lack is in the designing of water canals for diverting water from ephemeral streams, as well as knowledge in control of runoff.

Labour constraint was mentioned as the second major problem hindering the adoption of RWH. The use of RWH practices requires a substantial amount of labour and/or capital/cash to use and manage runoff, as a result lack of labour and or capital, affects the capability of the households to undertake RWH.

Farmers were also asked to mention the problems they encounter when using RWH (adopters). The main problem encountered is the difficulties with water distribution. This is especially for those farmers who use diversion channels from ephemeral streams or rivers. In some cases the water may not be enough thereby causing conflicts. The second problem is related to soil erosion and water losses.

Sometimes the speed of water in gullies is so high that farmers fail to control it.

Empirical determination of factors influencing adoption of RWH techniques in WPLL

Many of the adoption studies (for example Ayuk, 1997 and Adesina and Zinnah, 1993) try to group the factors affecting adoption of technologies into three categories namely technology, biophysical/farm and farmer characteristics. Technology characteristics examined included the potential for availing water at critical times, easiness of constructing the structures, construction costs and maintenance, risk of erosion and accessibility.

Together with technology characteristics, adoption of RWH technologies is also influenced by biophysical/farm characteristics. Farmers consider two important farm characteristics. These are location of the field in relation to the source of runoff and the soil type. The former may be a source of conflict if upstream farmers deny downstream farmers enough water or if they do not manage water properly thereby causing flooding in downstream farms.

Important farmer characteristics considered in adoption of RWH techniques are labour availability (especially family labour) and farmers' perception of the RWH technologies.

Results of the logit model are presented in Table 5.

The results of the estimated logit model show that farmers with larger numbers of plots are less likely to adopt RWH techniques. In this case the farm size was conceptualised as different plots that are owned by the farmers, as a result farmers have already taken risk against crop failure by diversification. They expect some harvest (large volume of harvest in good year) during the season and thus may not be adopters of RWH techniques. This is why these results appear to contradict the findings by Senkondo *et al.* (1998), which showed that farmers with large farm size are likely to adopt RWH compared to those with small sizes.

According to the results of the logit model (current study), family labour seems to have no significant influence on adoption of RWH techniques. Fifty five percent of adopters have family labour of two people or less. While 59% of non-adopters have also labour of 2 or less people. These results contradict the earlier study in RWH by Senkondo *et al.* (1998). The differences may be due to the small number of family labour available as explained above. Another reason for this may be that there are other sources of labour e.g. hired labour and exchange labour. A study by Senagalawe (1998) found that participation in labour sharing groups increased the probability of using

Table 5: Estimated results of logit model

The dependent variable is: RWH Discrete variable indicating whether the respondent adopted RWH or not

Variable	Estimated coeff.	Std error	Wald statistic	Significance	R	Exponential(β)
PLOTNUM	-1.1069	0.5331	4.3107	0.0379	-0.1501*	0.3306
SEXCOD	-1.6209	0.5438	8.8862	0.0028	-0.2595**	0.1977
CONSTANT	2.0294	0.5069	16.0261	0.001		

Source: Survey data 1999

Model Chi-square 14.204 sign. 0.0008

Model prediction 70%

** Significant at p=0.01

* Significant at p=0.05

improved soil conservation measures by 11%. Another explanation is that for most techniques, labour requirements are a long-term input. As such cross-sectional data collection may not be appropriate for assessing the effect of labour on adoption of RWH technique.

Where sex of head of household change from male to female, the chance of adoption of RWH decreases (Table 5) (The odds of adoption of RWH are decreased by the value of β i.e. 0.1977). The odds of an event occurring are defined as the ratio of probability that it will occur to the probability that it will not occur.

Comparison of results from WPLL with other similar studies in Tanzania

There are relatively few adoption studies in SWC and RWH in Tanzania. Three studies, Kalineza *et al.*, (1999); Senkondo *et al.*, (1998) and Semgalawe (1998) are reviewed (Table 6). Kalineza *et al.*, (1999) investigated factors influencing adoption of soil conservation technologies in Gairo Tanzania, using logistic regression.

The study by Senkondo *et al.* (1998) investigated the factors affecting adoption of RWH techniques using probit model, and defined the dependent variable as intensity of adoption (proportion of total land committed to RWH). The study by Semgalawe (1998) aimed at explaining household adoption behaviour towards the use of improved soil conservation measures to reduce land degradation (soil erosion) and reverse declining soil productivity and attain sustainability in land use. The study was conducted in Pare and West Usambara Mountains. The study findings are summarised in Table 6.

The results of the above studies do not show similarities to the results reported in this paper. However there are similarities among the three studies reviewed. Despite the differences in models used, the study by Kalineza *et al.* (1999) and that of Senkondo *et al.* (1998) indicated technical knowledge as the main factor affecting adoption of SWC/RWH. Similarities were also noted in the study by Semgalawe, (1998) and Senkondo *et al.* (1998). Both studies indicated that labour and farm size are important factors in the adoption decisions of farmers.

Whereas the study by Kalineza *et al.* (1999) estimated the logit model to identified SWC techniques separately, the other studies (including this paper) lumped together the techniques and estimated a single model. Despite the difficulties of the technologies

Table 6: Summary of adoption studies in SWC and RWH in Tanzania

Study	Methodology	Sample size (n)	Model	Factors affecting adoption
Kalineza et al. (1999)	Survey approach (questionnaire)	114	Logistic regression	Knowledge* (+) Secure land tenure (+)
Results of this study	Survey approach (questionnaire)	86	Logit	Number of farming plots (-) Sex of the head of household (-)
Senkondo et al. (1998)	Survey approach (questionnaire)	70	Probit	Knowledge* (+) Farm size* (+) Experience in farming (+) Labour* (+) Perception of the technology (+)

* Indicates that the factor is similar to other studies

(+) and (-) show the direction of the relationship between adoption and the independent variables

Despite the difficulties of the technologies studied, the approach adopted by this paper and the studies by Semgalawe (1998) and Senkondo *et al.* (1998) may be a limitation in studying adoption of SWC and RWH technologies.

Limitation of the studies in understanding factors affecting adoption

All the studies summarised in Table 6 used similar methods of data collection. All the approaches depended to a large extent upon the reliability of the information provided by the farmers. Accurate and reliable information from farmers using questionnaire is always difficult because of reliance on memories of the farmers. All the studies tried to counteract this by combining informal discussion and actual field observations.

Adoption of technologies is an exogenous scenario that affects production, consumption and marketing decisions. The household is thus trying to maximise the utility of production, consumption and marketing (as a result of new technology) subject to a set of constraints. It follows therefore that assessing the adoption of a new innovation and its effects on the household/farmer production, consumption and marketing are important. However, modelling of the whole system is inherently difficult. In modelling the household decision making as represented by utility maximisation, most often the decisions affecting production, consumption and marketing are made simultaneously, with each decision affecting the other. Modelling household decision-making is thus very complicated and time consuming.

The reported studies used static rather than dynamic adoption models. This may not represent the true case because adoption of SWC/RWH is a continuous process, which requires the models to consider the time element. The following advantages of dynamic adoption models need to be considered.

- Experience and information about the technology accumulated over time tend to update the parameters, the farm households use in decision making, and thus resulting to high adoption rates.
- Changes in household effectiveness in the technology over time can be captured.
- Changes in prices over time can be accommodated. Changes in prices can also be as a result of adoption of a particular technology which occurred over time
- Perceived risk and uncertainty associated with a new technology is assumed to decline over time as a result of learning by doing and the accumulated technical information over time. For example, farmers may decide to use part of the technology in the initial stages towards full adoption or rejection of the technology.
- Adoption is also looked at as a gradual process, which involves sequential stages e.g. awareness, trial, evaluation and adoption. These normally occur over time.

Finally, as already mentioned, the use of discrete dependent variable where adopters =1 and non-adopters = 2 as used in Kalineza *et al.*(1999), Semgalawe (1998) and in this study need great care because in practice it is difficult to accurately distinguish between adopters and non-adopters in SWC and RWH

Conclusions

The paper has analysed and presented the results and experiences of adoption of RWH in WPLL. The paper shows that many farmers are interested in RWH through the use of external catchments and infield water management and distributions. The findings of the studies show that there is relatively high adoption rate of RWH techniques in the survey areas.

The limited extent of knowledge in RWH by farmers was identified as the main constraint in RWH adoption in this study. In a study by Senkondo *et al.* (1998), knowledge in RWH techniques was significant in explaining the intensity of adoption of RWH techniques and this was supported by empirical evidence. Implications of this finding include the need for imparting RWH skills among the extension agents. This is mainly because the source of innovations in RWH techniques has been the farmers' own initiatives/indigenous knowledge and the RWH project in Kisangara and Kifaru. The contribution of extension workers in knowledge dissemination on RWH techniques was low.

Constraints in the adoption of RWH technologies were noted including constraints facing those who are already using the RWH technologies. Problems facing the users include difficulties with water distribution. This is especially for those farmers who use diversion channels from ephemeral streams or rivers. In some cases the water may not be enough thereby causing conflicts. The second problem is related to soil erosion and water losses. Sometimes the speed of water in gullies is so high that farmers fail to control it.

Given the identified constraints, farmers choose to use or not to use any of the RWH techniques. Any support to encourage the use of RWH needs to address these constraints. Minimum external support in the form of technical advice and financial assistance can have a substantial impact in technology adoption.

The analysis of the adoption studies shows that two factors are important in designing adoption studies. These are time and location. The time at which the studies are conducted since the introduction of the technology affect the results obtained. This is because adoption rate changes with time. Depending on the acceptability of the technology, the adoption rate may increase or decline with time. As a result there is a need for continuous data collection in order to monitor adoption of a particular technology. Empirical models should also include time element.

The location also affects adoption because of the distance from the source of technology. Areas located far away from the source of technology (for example far way from on-farm trial sites) may reduce the adoption rate.

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