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Determinants of Adoption of Rainwater Harvesting Technologies, A Case Study of Ponds in Masongaleni, Makueni County, Kenya.

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Abstract: *Adoption of new technology is critical for food security and economic development especially in developing countries. For a technology to be successfully implemented in an area, the priorities and concerns of farmers should be taken into consideration. This report seeks to evaluate the socio-economic and biophysical factors that determine adoption of ponds for rainwater harvesting. The study area was based in Masongaleni location Kenya where 65 households were randomly sampled from 16 villages. The survey captured both adopters and non-adopters of ponds. Questionnaires were administered in each household for data collection. CSPro software was used for data entry and the data exported to Microsoft Excel 2016 for descriptive statistical analysis. The results showed that high education level, male household heads, large family size, labour availability, funding/subsidies received in pond construction, training on rainwater harvesting, membership to farmer chamas and large farm sizes positively influenced adoption. On the other hand, the major factors that inhibited adoption included labour and financial constraint. Female household head negatively affected adoption. The results also indicated that age, distance to water source and distance to market do not significantly determine adoption of the rainwater harvesting ponds.*

Keywords: *Lined Ponds, Unlined Ponds, Rainwater Harvesting Technology, Masongaleni, Adoption, Makueni County.*

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I. INTRODUCTION

Water is a very critical resource and is also considered invaluable as it is the driving force of nature. It however can cause devastation if not properly managed. One of the world's leading problems is water scarcity, sub-Saharan Africa being the most affected (UN-Water, 2013). About 1.1 billion people live in areas of *physical scarcity*[1], and another 500 million people are heading towards this state. Furthermore, almost one quarter of the world's population is experiencing *economic water scarcity*[2] (UNDP, 2006). Kenya population is approximately at 38.6 million (2009) and 80% of Kenya is classified as ASALs which is home to an estimate of 30% (~12 million) of the Kenyan population, 50% of livestock and 75% of wildlife (KIPPRA, 2013). Among the ASAL regions is Makueni County and therefore water scarcity is prevalent.

One of the methods to ensure water security is by harvesting and conserving rainwater (Prinz, 2002). Rainwater harvesting involves capturing, diversion and storage of rainwater for later use. RWH helps in reducing the demand on conventional water supply, reduces run-off, erosion, and contamination of surface water (Kloss, 2008). RWH systems in the absence of reliable potable water are one of the foremost methods of achieving water security and therefore food security in ASAL regions where water is scarce.

Ponds can be used as a way of harvesting runoff and storing water. A well designed pond can collect significant amounts of water for domestic use, livestock and for irrigation to supplement rainfall. For this study an adopter was defined as one that had an operational pond at the time of the study, lining and presence of water in the pond notwithstanding.

Masongaleni area is characterized by harsh climatic conditions resulting from inadequate and erratic rains hence chronic water and food shortages. This has led to the introduction of ponds by several agencies who have constructed pilot ponds in the area with a view that the farmers will uptake the technology. However this has not been the case, some farmers have adopted the technology while many have not. The reasons behind the choice of adoption or non-adoption vary widely hence necessitating a full study on these factors that determine adoption.

A study conducted by Anand (2000) in Bidar District reported that the main challenges that affected non-adoption or partial adoption of watershed technology were inadequate capital for land levelling, lack of knowledge regarding these technologies and rocky subsurface which made it difficult to open up ridges and furrows.

Naik (2000) revealed that the major causes for non-adoption of water harvesting structures in Kanakanala and Indawar-Hullalli watersheds include inaccessibility to credit facilities and high interest rates of 69% each, followed by long conception period (68%) then high hiring rates of superior implements (65%) and small land capacity (61%) in the non-watershed area.

Findings from a study conducted by Nirmala (2003) revealed that farmers were more likely to uptake technologies if they would benefit them in the form of increased income with a percentage of 58.33%, followed by increased moisture (51.66%) and increased productivity (48.33%) as well as increased employment creation. She also observed that the major reasons for non-adoption of the technologies in non-watershed areas include lack of capital (51.6%), lack of technical expertise (46.6%), scarce land (45%), limited labour supply, inadequate extension services and poor land quality.

Synthesis of data derived from this study could help generate information that can be used by Government and Non-governmental organizations to develop policies and strategies that will enhance successful implementation of ponds as a method of RWH. This study is intended to identify circumstances, incentives, and support framework that affect the decision of adoption by farmers of RWH ponds in Masongaleni-Kibwezi.

II. METHODOLOGY

2.1 Study Area

The project site was based in Masongaleni, Kibwezi Sub County, Makueni County Kenya. Masongaleni is situated in Kibwezi Division, approximately 200km south east Nairobi. It lies within longitude 38° 2' 60E and latitude 2° 28' 60S and elevation of about 852 metres above the sea level. Actual location is at the southern portion of Makueni County. Its watershed runs from Chyullu Hills in the West to Athi River on the East, which is the second longest river in Kenya, covering an area of approximately 280 km^2.

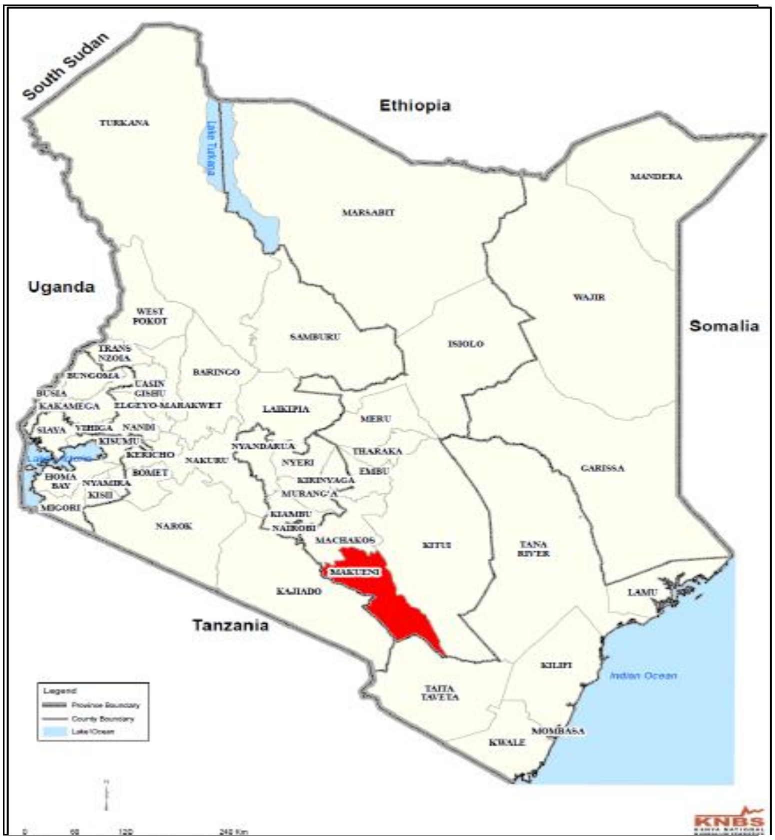

Figure 1: Map showing the Location of Makueni County in Kenya

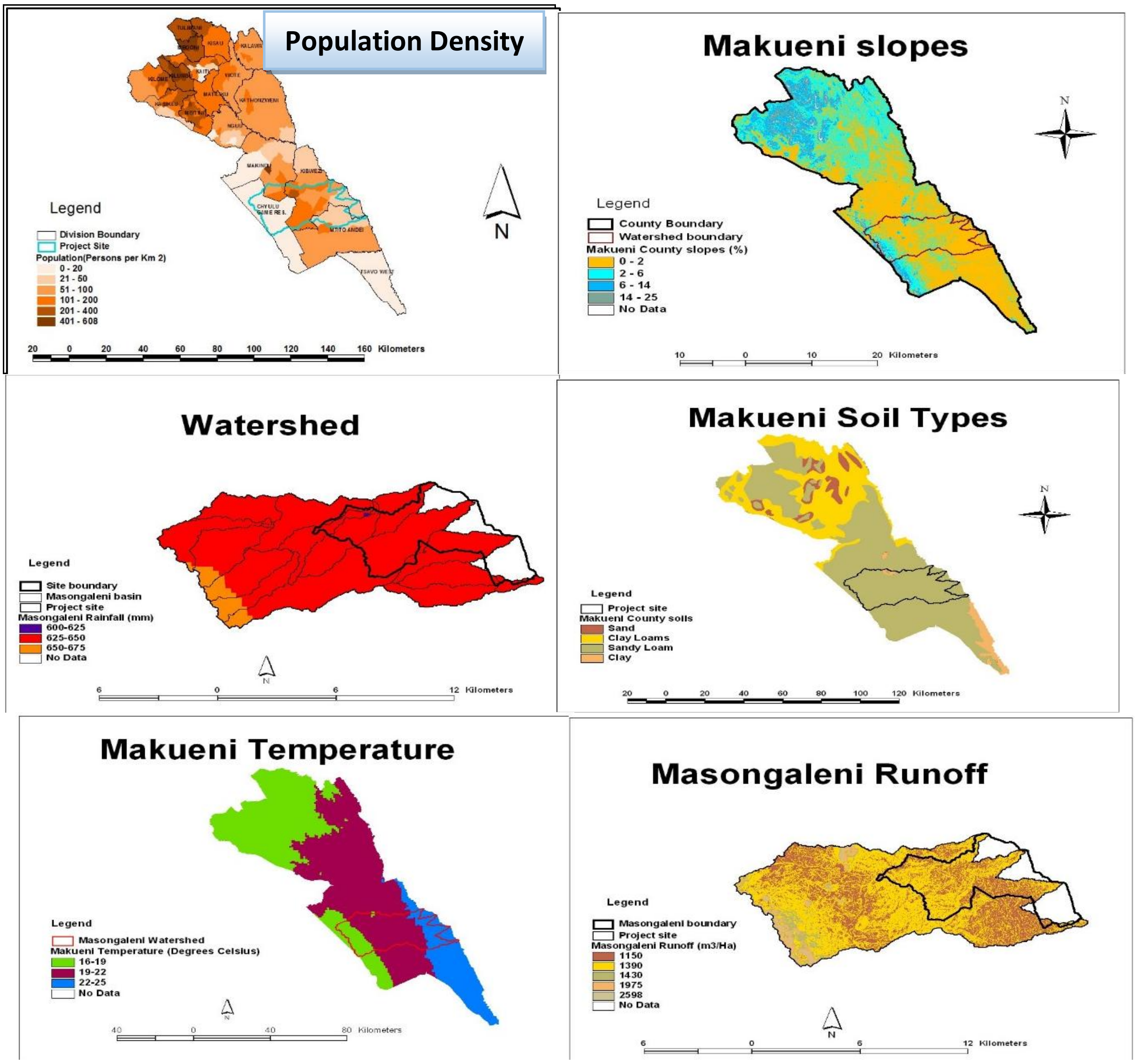

Figure 2: Maps of Makueni County with different study site parameters

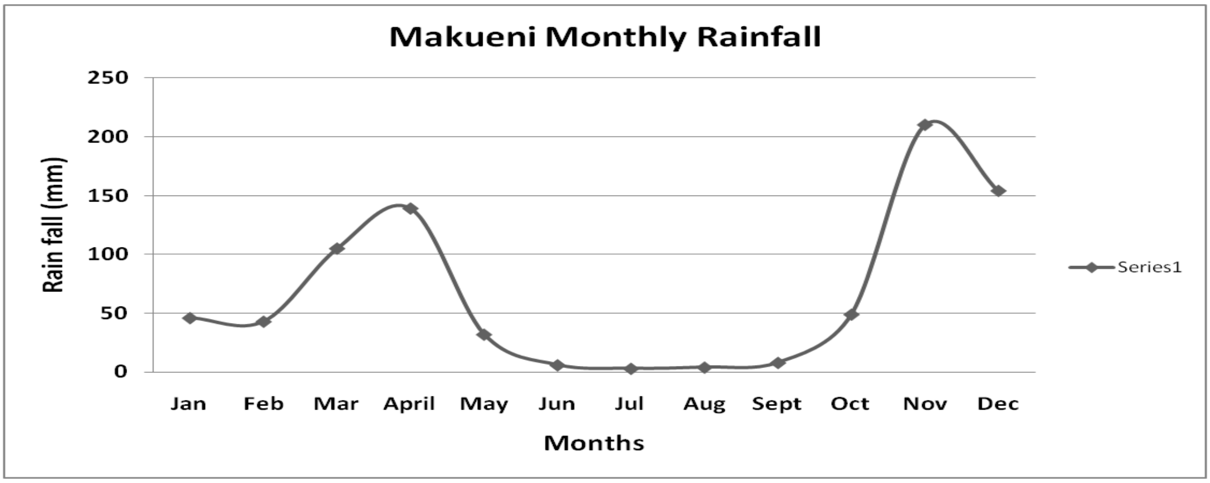

Figure 3: Monthly Rainfall for Makueni County

Masongaleni is a water scarce location. It has 2 main rivers namely River Kibwezi which is permanent and River Thange which is seasonal. Some households obtain their water from these rivers though some stay further away hence have to walk long distances in such of water. There are water kiosks in some markets, however this water is not always available. People can spend a whole day just making long lines waiting for water which eventually fails to come. Many projects involving water management and rain water harvesting technologies in this case have been implemented to boost both domestic water supply and agricultural production. These include structures like: sand dams, ponds and earth dams. Women are the key managers of such projects and usually form committees for efficient operation and maintenance of the systems.

2.2 Study Design

A literature review was conducted to obtain background information regarding the study area including the biophysical aspects, socio-economic aspects and institutional factors. Through this research, the variables to be tested were identified and listed to be used in developing the questionnaire. The questionnaire covered a broad range of aspects comprising the household characteristics, land size, RWHT, adoption and risk, training, membership in chamas, sources of water, income and expenses. The level of income was put last in the questionnaire since people are usually reluctant to disclose this kind of information.The household heads were assumed to be the sole decision-makers in cases concerning adoption.

2.3 Mathodology

2.3.1 Farm Household selection

A total of 65 households were randomly sampled from a list of farmers at the Ministry of Agriculture-Kibwezi district office. This list consisted of farmers from Masongaleni location capturing a total of 16 villages. The sampled households consisted of farmers with ponds (lined and unlined) and those without ponds. The determined sample size was regarded as adequate for inferences to be made about the entire population considering the time available and the costs involved in the survey as well as the homogeneity of the target population in the study area.

2.3.2 Data collection technique

Objectives of the survey were clearly defined to the farmers including both direct and indirect benefits likely to accrue from the study .The farmers were also assured of confidentiality in order to gain their trust. Structured questionnaires containing both close-ended and open-ended questions were administered to individual households to gather primary data. The purpose of the household survey was to collect data on socio-economic and physical characteristics of the respondents i.e. age, educational background, land size, labour force size, off-farm activities, types of rainwater harvesting technologies, income level, expenditure. Other factors which were covered in the questionnaire included the extent of adoption, reasons for non-adoption, and uses of the pond. For the purpose of this study, the heads of the selected were implicitly assumed to be the sole decision maker in adoption studies. In order to reduce linguistic problems at village level, guides who doubled up as translators were selected. The researchers asked questions and the guides translated where necessary. An average of 45 minutes per household.

GPS software was used to indicate the location of each household. This included getting the latitude, longitude and altitude of the specific household. Field observation was also conducted during the survey which helped in cross-checking data from other instruments. Data from both published and unpublished materials including journals, reports, and theses from the library were collected and used to design the questionnaire. A template questionnaire was created in the Census and Survey Processing System (CSPro) for data entry. This program was particularly chosen as it allows double entry to minimize errors, and the data can easily be exported to other statistical programs for analysis. Data collected was analyzed Microsoft office excel 2013. The analysis involved the use of descriptive statistics of the various components in the sample.

Table 1: Description of variables

Acronym	Description	Type of measure
Dependent variables		
ADOP	Whether a farmer has adopted or not	Dummy (1 if yes, 0 if no)
Explanatory variables		
AGE	Household head's age	Years
EDUC	Educational background of the household head	0 = Never attended, 1 = Preschool, 2 = Primary/Basic, 3 = Secondary, 4 = Post-secondary, 5 = Don't know
GEND	Gender of the household head	1.Male 2.Female
FSIZ	Household in number of people	Numbers
MMSIZ	Number of male in the house	Numbers

FFSIZ	Number of females in the household	Numbers
FLABE	Full time household labour	Numbers
PLABE	Part time household labour	Numbers
OFFA	If Farmer has any off-farm activity	Dummy (1 if yes, 0 if no)
RISK	Level of household head's risk preference	1. Risk averse, 0. Risk love
ASSI	Assistance or Subsidy received for pond	Dummy (1 if yes, 0 if no)
TRAI	Training on rain water and harvesting	Dummy (1 if yes, 0 if no)
MEMB	Membership in Chamas/Group/SACCOs	Dummy (1 if yes, 0 if no)
WDIST	Distance to the water source in Kilometres	Total distance in Kilometres
LSIZE	Land size in acres	Total land size in acres
MDIST	Distance to the market in Kilometres	Total distance in Kilometres

III. RESULTS AND DISCUSSIONS

A total of 65 households were randomly selected and surveyed. Out of these, 21 households which accounts for 32.3% of the sample size were found to have either lined or unlined ponds in their farmsteads. Variables tested were 17 including: Age, educational background, risk preference and gender of the household head, household size in terms of the numbers of males and females in the household, full time and part time farm labour , off farm activity of the household , assistance or subsidy received for pond construction , training received on rain water harvesting ,membership to chamas, Sacco's or farmer group, distance to the nearest water source, land size in acres and the distance to market.

3.1: Sample variables

The minimum number, maximum number, mean and standard deviation were calculated for each variable. Mean was the major statistic used for comparison. The mean was used to show the central tendencies of the data obtained so as to judge the general characteristics of the variables tested. Standard Deviation (SD) was used to show how much variation from the average exists in the tested variables; a low standard deviation indicated that the data was very close to the mean hence homogeneous while a high standard deviation indicated that the data points are spread out over a large range of values. Minimum values of the variables were used to indicate the least possible value in the factor being tested while the maximum value indicated the largest possible value in the factor being tested.

Table 2: Characteristics for all households sampled.

Variables	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
ADOP	0	1	0.32	0.47
AGE	27	85	53.72	12.77
EDUC	0	4	2.11	1.12
GEND	0	1	0.78	1.12
FSIZ	2	21	6.95	3.18
MMSIZ	1	15	3.40	1.97
FFSIZ	1	8	3.55	1.78
FLABE	0	7	2.28	1.41
PLABE	0	6	1.63	1.73
OFFA	0	1	0.69	0.47
RISK	0	1	0.77	0.42
ASSI	0	1	0.43	0.51
TRAI	0	1	0.52	0.50
MEMB	0	1	0.66	0.48
WDIST	0	5.5	1.40	1.50
LSIZE	0.5	20	5.76	4.03
MDIST	0	5.5	1.40	1.50

Table 3: Characteristics for households with and without ponds

	With ponds				**Without ponds**			
Variables	**Minimum**	**Maximum**	**Mean**	SD	**Minimum**	**Maximum**	**Mean**	**S.D**
AGE	35	77	54.75	10.67	27	85	53.25	13.71
EDUC	0	9	2,476	1.67	0	4	2.1	0.77
GEND	0	1	0.81	0.40	0	1	0.77	0.42
FSIZ	1	15	3.83	2.40	2	16	6.61	2.76
MMSIZ	1	15	4.04	2.82	1	8	3.1	1.34
FFSIZ	1	7	3.62	1.96	1	8	3.5	1.7
FLABE	1	7	2.76	1.76	0	5	2	1.16
PLABE	0	6	2.38	1.96	0	5	1.27	1.5
OFFA	0	1	0.71	0.46	0	1	0.68	0.47
RISK	0	1	0.22	0.43	0	1	0.67	0.47
ASSI	0	1	0.48	0.51				
TRAI	1	2	1.26	0.46	0	1	0.41	0.5
MEMB	0	1	0.86	0.36	0	1	0.57	0.5
WDIST	0	5.5	1.64	1.36	0	5	1.32	1.54
LSIZE	2	20	7.46	4.74	0.5	16	4.95	3.4
MDIST	0.3	13	5.46	3.18	0	15	3.97	3.57

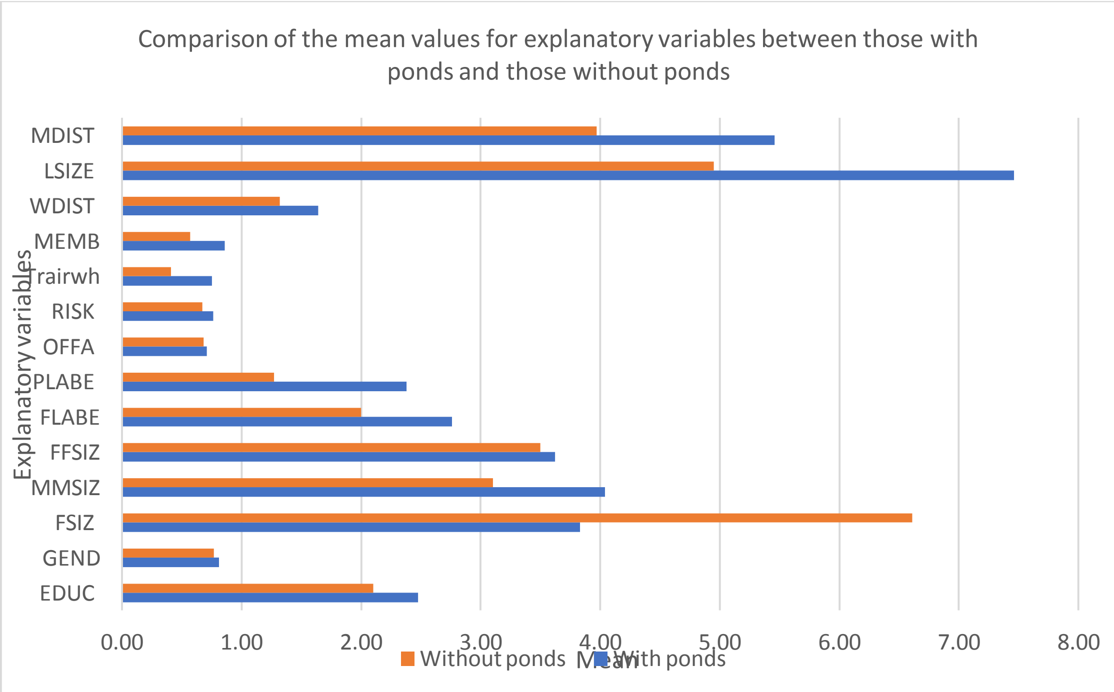

Figure 4: Graph showing the comparison of the mean values of the explanatory variables between those with ponds and those without ponds

3.1.1: Age

Age serves as a vital pointer of an individual's position in a traditional society. Farmers who are older will be in a position to gain more from traditional farming practices. Age can also determine the level of risk preference of the household head. Most studies reveal that risk averseness to new technologies increases with age (Negash, 2007).

From the table above, the mean age of the sampled household heads was found to be 53.72 with ponds had an average age of 54.75 while those without ponds had a mean age of 53.27. The results do not depict a clear cut relationship between age and decision to adopt. We therefore fail to accept the hypothesis that the decision to adopt decreases with age.

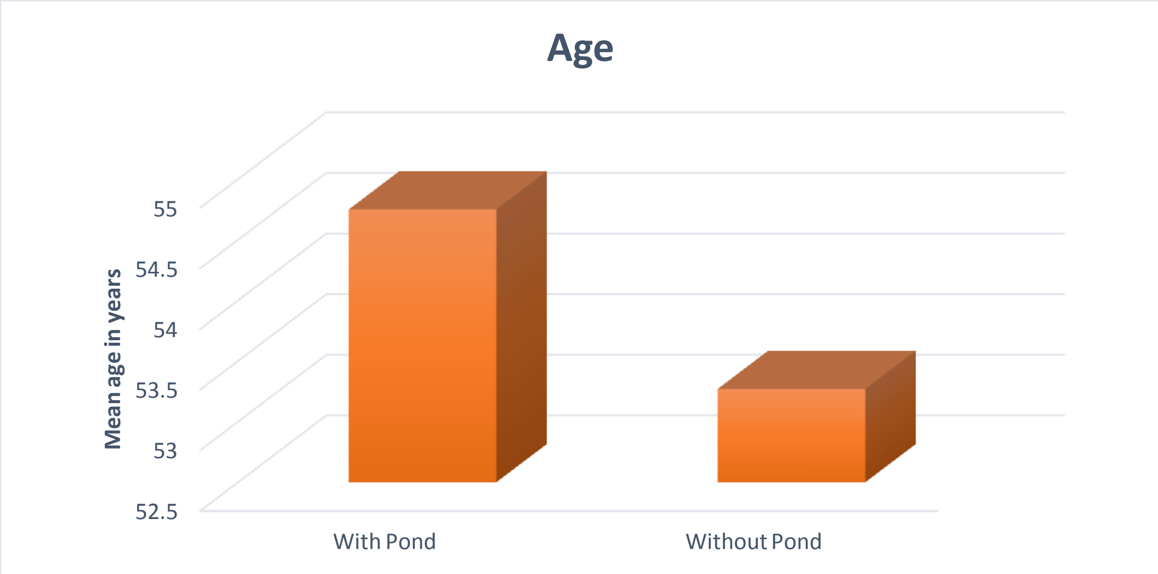

Figure 5: Graph of Ages groups with and without ponds

3.1.2: Education

From the hypothesis, it was assumed that a farmer's ability to adopt new technology increases with the level of education. It was measured by establishing the number of years a household head had been in school i.e. number of years in formal education. The result on educational status showed that the average number of years in formal education for adopters was 2.48 and for non-adopters was 2.1. These results shows that higher educational levels positively influences adoption. This finding is consistent with similar previous studies of Tesfay et al 2001 and Shikur & Beshah (2013).

3.1.3: Gender of the household

Male are head strong, more outgoing and are therefore more likely to take up challenges when it comes to technology as compared to their female counterparts (Shikur & Beshah, 2013).

Of the sampled households, 78% of the household heads were male and the remaining 22% female. For adopters, 81% were found to be male household heads as opposed to 77% for the non-adopters. These results revealed that households managed by males are more likely to adopt the technology as compared to those managed by women. However, this might not really be the case based on the following scenarios:

i. There were those women who were widows and were neither working nor stable financially hence unable to undertake the pond technology. This evidently has nothing to with gender issues.
ii. The second scenario represents women who have either separated or divorced, with many young children who cannot provide sufficient labour.

3.1.4: Family size

The study revealed that the average family size for adopters was 3.83 and for the non-adopters to be 6.81. It is expected that large family sizes with members within the range of active labour force is an indicator of labour availability. Since pond construction is labour intensive- especially for excavation, it was then hypothesized that the larger the family size, the more the labour.

The finding of the study are incongruent with the expected results and previous studies that have been done. The reason for this output may be that most of the family members for non-adopter households consisted of either children or very old individuals who are incapable of providing labour due to lack of strength.

3.1.5: Male size

From the study, the average number of males in adopter household was 4.04 and for non-adopter was 3.1. It was determined that a family with a higher number of males is more likely to adopt the technology. The reason for this is that men are more proactive when it comes to participating in activities that involve physical/manual labour. Therefore, as hypothesised, there is a positive relationship between male size and adoption.

3.1.7: Female size

In Table 4 above, it can be seen that the difference between farmers with ponds and those without ponds is only 0.12 which is too low to draw the conclusion that the number of females in a family will influence adoption.

3.1.6: Labour

Comparison of labour availability between adopters and non-adopters shows a significant difference. As can be seen in figure 14, people with ponds have on overall a larger labour force size, both for full time and part time labour as compared to their counterparts. This shows that the availability of labour can influence the decision of a farmer to adopt a pond. Building a pond manually is time consuming. From the survey we can conclude that it takes several weeks up to one year to dig the pond, depending on the time per week spent on it. This means that building a pond has high labour costs and while digging this labour cannot be used on the farm itself. This is the reason why people with limited labour supply cannot afford to build a pond, labour available is used for the farms and other daily activities.

Some of the farmers who had ponds was because they were members of a Red Cross group. Being part of this group meant that one worked 1 day per week digging a pond on someone else's farm. In return, Red Cross gave them some food supplies. The advantage of this was that even people with low labour availability could qualify for a pond. The disadvantage of this was that apart from being time consuming, the ponds were meant to be communal, however, this water was not enough to serve a whole community. The people eventually gave up as they also had other farming activities to take care of hence could not commit fully to providing labour for pond construction.

3.1.8: Off-farm activities

Presence of an off farm activity was found have no significant effect on adoption of pond.

3.1.9: Risk preference

Both the adopters and non-adopters were found to be risk loving than risk averse. Digging a pond can be seen a risk so it is logical to see that people with a pond are risk loving but people without a pond are on overall also quite risk loving. Therefore it can be concluded that risk preference doesn't significantly affect adoption of ponds.

3.1.10: Training on rain water and harvesting technologies and its effects on adoption

Farmers were asked on whether they had received any training concerning any form of rain water harvesting and 71.4% of the households with ponds responded affirmatively as compared to 38.6% of those without ponds. This shows that trainings on RWHT influences to a great extend the decision of adoption of ponds since it exposes the farmer. This finding is in accordance with the hypothesis and with the findings of He, et al., (2007) and Ahmed, et al.,(2013) in literature.

3.1.11: Membership in Chamas/Group/SACCOs

When membership of the farmers in agricultural chamas/groups/Sacco is analysed, it is found out that 85.7% of the adopters participate in these groups as compared to 51% of the non-adopters. As hypothesised, participation in farmer groups positively influences adoption. The likely reasons for this is that these groups can be seen as a form of banking where they contribute to each other and also some groups allows members to take loans and also, depending on the type, group members provide labour for pond digging.

3.1.12: Distance to the water source in Kilometres

The Distance to the nearest water source was tested to determine if it is a significant factor ,it was found out that the average distance to the nearest water source from the households of adopters was 1.6 Km while that of non-adopters was 1.3 Km. Its effect on adoption was found out to be inconclusive in this study.

3.1.13: Land size

From the sample, it was noted that the adopters average land size were bigger than that of the non-adopters. The average land size of an adopter and a non-adopter were found out to be 7.46 and 4.95 acres respectively. As hypothesized, land size positively influence adoption. The reason for this is that a larger land size allows the farmer to dig a pond and use the remaining part for other practices.

3.1.14: Distance to the market in Kilometres

A direct correlation between distance to market and adoption was not clearly depicted since adopter's average distance to market was found to be 4.1Km and those without was 3.9 Km. The difference which is not significant. Hence it can be concluded that distance too market is not a significant factor in determining adoption.

3.1.15: Assistance received for pond construction

57% of adopters received assistance in terms of labour, lining, subsidies and in other forms. The degree of assistance varied as per the households and non-adopters indicated that lack of assistance as the major contributing factor to their decision not to adopt the technology. Highly sandy soils which make unlined ponds non-feasible combined with high cost of lining materials have contributed to a large extend to non-adoption.

Lined Pond

Unlined Pond

Deteroriating Pond

Figure 6: Different types of ponds as observed in the study area.

IV. CONCLUSION

From the study, it was found out that a combination of factors rather than each factor individually determined the decision for or against adoption. Factors tested can be subdivided into those that:

i. Positively influence adoption
ii. Those that negatively influence adoption and
iii. Those that do not significantly influence adoption.

Factors that positively influenced adoption were found to be: High education level, Male household heads, Large family size, Presence of labour, Funding/Subsidies received for pond construction, Training on rainwater harvesting and Membership to Farmer chamas. Factors that negatively affect adoption were: Female household heads and small land sizes. The factors that did not significantly affect adoption were: Age, Distance to water source and Distance to market.

Conflict of interest

There is no conflict to disclose.

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