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Intensity of Flash Rains and the Effect on Drenching and Stabilization Frequency of on-Farm Water Harvesting Systems in Matungulu Sub-County, Machakos County, Kenya

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Abstract:
Performance of the water harvesting systems depends on the farming systems, soil characteristics and hydrological factors. This study sought to determine the extent increase in frequency and intensity of flash rains affect drenching (silt removal) and stabilization frequency of on-farm water harvesting systems in Matungulu Sub-County, Machakos County in Kenya. A descriptive survey design was adopted in which some 105 randomly selected respondents were drawn from 5 sub- locations of Matungulu Sub-County. The 105 were selected from 2 Sub-County's based on livelihood of the 2086 target households that is cash crop farms and grain crop farms. 21 households for each livelihood strategy from each of the five sub-locations taking the odd-numbered items were used. A structured questionnaire was administered to obtain data on farmers' use of water harvesting systems and their performance in light of climate variability. The data was statistically analyzed and results displayed in tables, graphs and charts. The study established that the Fanya-juu system is the most practiced harvesting system in the area at (n=67, 63.81 %,) followed by Negarimsat (n=38, 36.19%).The results also show the effects of the water stress factors on silt removal for fanya-juu (r=0.1939, p=0.0571) is positive though not supported by statistical level of significance, but positive and significant on negarims (r=0.2698, p=0.0078), contour bunds(r=0.5548, p=0.0001) and contour ridges(r=0.4938, p=0.0001).Based on the climate variability effects on the on-farm water harvesting systems selected, the Fanya-Juu system is the most appropriate for use in the area. The study recommends that farmers in the area should be encouraged through awareness creation to harvest water using the fanya-juu system. Farmers also need to be sensitized and trained on monitoring and evaluation of the effects of climatic variability on the harvesting systems.

Keywords: *Rainwater harvesting, flash rains, drenching, stabilization, on-farm water harvesting*

1. Introduction

1.1. Background of the Study

Developing countries that rely heavily on agricultural production as a source of livelihood and economic growth are particularly vulnerable to the negative impacts of climate change [Kates, R. W. 2000;Kurukulasuriya, P., Mendelsohn, R., Hassan, R., Benhin, J., Deressa, T., Diop, M., . . . Jain, S. 2006]. Failure of farmers to adapt to climatic changes would likely have significant negative effects on food production [Rosenzweig, C., & Hillel, D. 1998].Promotion of water harvesting (WH) technologies has been suggested as a key strategy to alleviate growing water shortages, drought and desertification and to adapt to the negative impacts of climate change[Kurukulasuriya, P., & Rosenthal, S. 2003]. Although WH technologies are generally low-cost interventions; they themselves are susceptible to climate change impacts.

Water harvesting (WH), has supported subsistence farming in the arid and semi-arid regions of the world for a long time and proved to be one of the most promising methods of making water available for crop growth in arid and semi-arid areas Fleskens, L., Stroosnijder, L., Ouessar, M., & De Graaff, J. [2005];Ouessar, M., Sghaier, M., Mahdhi, N., Abdelli, F., De Graaff, J., Chaieb, H., . . . Gabriels, D. [2004]. Most water harvesting practices in the arid and semi-arid areas collect run-off water produced by rainfall from a catchment area and store it in tanks or soil profile for irrigation use [Abdelkdair, A., & Schultz, R. C. 2005;Huang, Z., Cheng, J., Zhao, S., Xin, X., & Liu, X. 2004]. Management and performance related to water harvesting and use has been highlighted as one of the most important adaptation requirements to ensure the development of effective adaptation strategies that are cost-effective, participatory and sustainable [Osman, E. B., Goutbi, N., Spanger, S. E., Dougherty, B., Hanafi, A., Zakieldeen, S., . . . Elhassan, H. M. 2006].

Kato, E., Ringler, C., Yesuf, M., & Bryan, E. [2011] investigate the impact of different soil and water conservation (SWC) technologies on the variance of crop production in Ethiopia to determine the risk implications of the different technologies in different regions and rainfall zones. Results show that SWC investments perform differently in different rainfall areas and regions of Ethiopia. These results underscore the importance of the selection of appropriate combinations of technologies and careful geographical targeting when promoting and scaling up SWC technologies for adaptation to climate change.

A case study in the loess plateau of China, a semi-arid region with rain patterns much like Kenya, examined methods of constructing compacted micro-catchments in order to increase food production [Jiang, Y., Kang, M., Gao, Q., He, L., Xiong, M., Jia, Z., &Jin, Z. 2003]. The study proposed using a mixture of locally available soils, compacted by simple rollers, in order to increase run off which would then be collected into other areas using common methods of water diversion. Although the study proved successful, soil erosion proved to be a problem during flash floods, making this solution undesirable for locations like arid regions of Kenya with existing erosional problems.

Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A., & Stroosnijder, L. [2012] did a review on rainwater harvesting and management in rain-fed agricultural systems in Sub-Saharan Africa. Their study indicates that micro-catchment and on-farm rainwater harvesting techniques are more common than rainwater irrigation techniques from macro-catchment systems. The study concludes that, rainwater harvesting techniques improves the soil water content of the rooting zone, reduces risk of crop failure during dry spells and also improves water and crop productivity. Ngigi, S. N. [2003] indicates that even though rainwater harvesting practices can yield positive results through effective increase of soil moisture for crops in water scarce areas, each system still has limited scope due to hydrological and socio-economic limitations. He proposed that many of such techniques for enhancing crop production in Arid and Semi-Arid areas of Sub-Saharan Africa and their viability, needs to be evaluated in relation to climatic conditions, apart from soil characteristics and farming systems in which they are practiced. Past studies on water harvesting have majorly evaluated soil characteristics and water management as the main determinants in performance of water harvesting systems. Hydrological limitations due to current climate variability are becoming a key determinant.

Owing to a complex and rapidly changing geography of water supply and use, a large proportion of the world population is currently experiencing water stress. Although Geographic information system (GIS) technology used to map areas where surface run-off interventions in Africa are most suited shows that the annual run-off generated in Africa if harnessed, could support the livelihoods of many people [Parry, M. L. 2007], inadequate rainwater harvesting and poor water management has led to increased water stress: too much water in the rainy season followed by water scarcity in the dry seasons. Climate change is projected to further worsen the situation. It is against this background that this study was undertaken to determine the extent increase in frequency and intensity of flash rains affect drenching (silt removal) and stabilization frequency of on-farm water harvesting systems in Matungulu Sub-County, Machakos County, Kenya.

1.2. Statement of the Problem

Water harvesting(WH) has supported subsistence farming in the arid and semi-arid regions of the world for a long time and proved to be one of the most promising methods of making water available for crop growth in arid and semi-arid areas Fleskens, L., Stroosnijder, L., Ouessar, M., & De Graaff, J. [2005]; Ouessar, M., Sghaier, M., Mahdhi, N., Abdelli, F., De Graaff, J., Chaieb, H., . . . Gabriels, D. [2004]. In Kenya some climate scenarios predict an increase in rainfall in the highland areas and decreases in others, but greater variability in cycles is expected everywhere [Ngigi, S. N., & Denning, G. 2009]. As a result, we could see more frequent occurrences of extreme weather events such as flooding and drought. Ngigi, S. N., & Denning, G. [2009] project that the challenges of water resources development in sub-Saharan Africa (SSA) will be aggravated by ensuing climate change, with serious implications on socio-economic development.

The challenge facing the ASALs ecosystem now is how to enhance communities' resilience whose livelihoods depend entirely on climate-sensitive resources [Kenya Agricultural Research Institute. 2000]. Generally, developing countries are investing on several adaptation activities to address impacts of climate change in the agricultural sector. Water harvesting techniques are already being used in many areas to adapt to the drier, degraded conditions brought on in part by changes in climate. In Arid and semi-arid regions of Kenya, major stakeholders are increasingly looking into rain water harvesting as a decentralized solution to water needs. Despite this heightening interest, water harvesting and storage capacity remains dreadfully low in most parts of Kenya and is declining [Government of Kenya. 2010]. Exacerbating water stress further in Kenya is the negative impacts of climate change to the adaptation measures already underway.

1.3. Objectives of the Study

- To determine the main on-farm water harvesting systems used by households in Matungulu Sub-County, Machakos County, Kenya.
- To determine to what extent increase in frequency and intensity of flash rains affect drenching (silt removal) and stabilization frequency of on-farm water harvesting systems in Matungulu Sub-County, Machakos County, Kenya.

1.4. Significance of the Study

The study provides insight to planners and policy makers across the water sector on how best to confront the challenges of water stress in the ASALs in light of climate variability. The study also elicits interest for academicians in the interactions between performance of water harvesting systems and climate variability with a view to finding out further how they affect each other. This increases the body of knowledge and forms a basis upon which further studies can be done.

2. Methodology

2.1. Area of Study

Matungulu district in Machakos County formed the study area. It's located between latitudes1^{o}S to2^{o}S and between longitudes 37^{o}to 38^{o}E.It borders Kangundo to the south, Yatta to the north, Mwala to the East and Kathiani to the south west. The District is divided into three administrative Sub-County's namely Matungulu, Tala and KyeleniSub-County's (figure 3.1). The area is in a semi-arid region in Kenya, already experiencing water stress and highly susceptible to climate variability impacts especially on water resources. No similar research had been done in the past in the same region hence more relevant for such a study. Matungulu Sub-County has a population of 21725[Kenya National Bureau of Statistics. 2009], area size of 40km^2.divided into Katheka, Matheini, Kingoti, Kambusu and Mwatati sub-locations, with 2086 households. The main activity for their livelihood is small scale grain farming in the low and rather dry areas and a mixture of grain farming and cash crop farming in the high-altitude areas of gently sloping terrain.

2.2. Research Design

The research design used was descriptive survey of on-farm water harvesting systems being used by households within the Sub-County. This design was considered for this study because it involves specific predictions, with narration of facts and characteristics concerning the particular technique performance [Kothari, C. 2004].Descriptive survey studies are designed to obtain pertinent and precise information concerning the status of a phenomenon and whenever possible to draw valid conclusion from the facts discovered.

2.3. Sampling Design

According to Mugenda, M. O., &Mugenda, A. G. [2003], population refers to an entire group of individual's events or objects having common observable characteristics. The target was all households using on-farm water harvesting systems in Matungulu Sub-County. Since the population targeted was large and its members scattered all over the Sub-County, purposive sampling was used in this study to generate the data needed. Purposive sampling used ten percent (10%) of all the 2086 households. Two sub-Sub-Countys based on livelihood of the target population, that is cash crop farms (coffee) and grain crop farms (maize and beans) were used, 21 households for each livelihood strategy from each of the 5 sub-locations were sampled taking the odd-numbered items. This was designed to gather information from each and every representative member of the population [Valdo, P. 1992].

2.4. Data Collection

Primary data was collected using a structured questionnaire. The questionnaire contained both closed ended questions and a few open-ended questions. Part I of the questionnaire included a short demographic questionnaire. Part II of the questionnaire included factors that influence performance of water harvesting as conceptualized in this study. The components included per factor were considered to be indicators of the impact on the performance.

2.5. Data Analysis

Before analysis, the data was checked for completeness and consistency. Standard statistical tools-frequency, distribution, measures of central tendency was used. Inferential statistics such as coefficient of correlation were used to assess the relationship between the climate variability parameters (flash floods, droughts, erratic rainfalls) and the performance of the water harvesting systems (*Fanya-Juu*, Contour bunds, Contour ridges and Negarims). Descriptive Statistics were arrived at using the SPSS statistical computer packages and the results presented in terms of tables, percentages and co-relation matrixes.

3. Data Analysis and Discussions

3.1. The On-Farm Water Harvesting Systems Used by Households

The number of respondents from the randomly selected sample who stated that they practice water harvesting to supplement rain fed agriculture in their farms was 100 out of the total 105 respondents interviewed. This represented 95.24 per cent of the sampled farmers indicating that most of the farmer's supplemented rain fed agriculture through water harvesting. Further analysis of the data revealed that male and female farmers comprised 51 (48.57 per cent) and 54 (51.43 per cent) of all the respondents interviewed. The males who practiced water harvesting in supplementing rain fed agriculture in their farms were 47 representing 44.76 per cent of all the respondents while female farmers practicing water harvesting were 53 (51.43 per cent).

Farmers using on-farm water harvesting	Frequency	Per cent
Yes	100	95.24
No	5	4.76
Total	105	100

Table 1: Farmers Who Practice Water Harvesting to Supplement Rain Fed Agriculture in the Farm

The data was further disaggregated by the highest level of education of the farmers interviewed with a view of establishing whether education level was related to supplementing rain fed agriculture with water harvesting. The surveyed data revealed that 21 (20.00 per cent) of the sampled respondents had attained primary education level, while those who had attained secondary and post-secondary education were 65 (61.90 per cent) and 19 (18.10 per cent) respectively. All the farmers who had attained primary education practiced water harvesting to supplement rain fed agriculture, while those who had attained secondary education practicing water harvesting were 63 (60.00 per cent) of the 105 farmers interviewed. Farmers who had attained post-secondary education practicing water harvesting were 16 representing 15.24 per cent of the total number of farmer's interviewed. None of the farmers who had attained primary education did not practice water harvesting compared to two and three with secondary and post-secondary education respectively. Hence, failure to practice water harvesting increased with the level of education attained, irrespective of the number of farmers at each level of education.

The on-farm water harvesting system practiced by the farmers in the area are Fanya-juu, Negarims, contour bunds, contour ridges and damming. The farmers who practiced Fanya-juu were 67 representing 63.81 per cent of all the farmers interviewed. This system of Fanya-juu was practiced by 29 (27.62 per cent) and 38 (36.19 per cent) males and females respectively. This shows that a greater percentage of female farmers practiced this system of Fanya-juu compared to the male farmers practicing it. Farmers with primary education level who practiced Fanya-juusystems were 20 (19.05 per cent), with 37 (35.24 per cent) and 10 (9.52 per cent) practicing Fanya-juu system having attained secondary and post-secondary education level respectively.

On-farm system	**Males**		**Females**		**Total**	
	Freq	(%)	Freq	(%)	Freq	(%)
Fanya-Juu	29	27.62	38	36.19	67	63.81
Negarims (v-shaped bunds)	15	14.29	23	21.90	38	36.19
Contour bunds	14	13.33	8	7.62	22	20.95
Contour ridges	7	6.67	14	13.33	21	20.00
Dams construction	0	0.00	2	1.90	2	1.90

Table 2: On-Farm Water Harvesting System Practiced by Sex

Negarim system of water harvesting was practiced by 38 (36.19 per cent) of the farmers interviewed. The male and female farmers who practiced Negarim system were 15 (14.29 per cent) and 23 (21.90 per cent) respectively. Negarim system of water harvesting was practiced by eight (7.62 per cent) of the farmers with primary education, with 29 (27.62 per cent) and one (0.95 per cent) of the farmers who had attained secondary and post-secondary education using the system.

On-farm system	Primary		Secondary		Post-secondary		Total	
	Freq	(%)	Freq	(%)	Freq	(%)	Freq	(%)
Fanya-Juu	20	19.05	37	35.24	10	9.52	67	63.81
Negarims (v-shaped bunds)	8	7.62	29	27.62	1	0.95	38	36.19
Contour bunds	2	1.90	20	19.05	0	0.00	22	20.95
Contour ridges	5	4.76	11	10.48	5	4.76	21	20.00
Dams construction	0	0.00	0	0.00	2	1.90	2	1.90

Table 3: On-Farm Water Harvesting System Practiced by Education Level Attained

The sampled farmers who practiced contour bunds were 22 representing 20.95 per cent of all the farmers interviewed. This system of contour bunds was practiced by 14 (13.33 per cent) and 8 (7.62 per cent) males and females respectively. This shows that a greater percentage of male farmers practiced this system of contour bunds compared to the female farmers practicing it. Farmers with primary education level who practiced contour bunds system were two (1.90 per cent), with 20 (19.05 per cent) and none who had attained secondary and post-secondary education level respectively practicing contour bunds system.

Contour ridges system of water harvesting was practiced by 21 (20.00 per cent) of the farmers interviewed. The male and female farmers who practiced contour ridges system of water harvesting were seven (6.67 per cent) and 14 (13.33 per cent) respectively, showing that the female farmers practicing this system of contour ridges doubled the males carrying on the contour ridges system. Contour ridges system of water harvesting was practiced by five (4.76 per cent) of the farmers with primary education, with 11 (10.48 per cent) and five (4.76 per cent) of the farmers who had attained secondary and post-secondary education practicing contour ridges system.

Thus, the Fanya-juu system followed by Negarims systems of water harvesting were most reportedly being practiced by the farmers in the area irrespective of their gender and level of education attained. More males preferred the contour bunds systems compared to females, while a greater proportion of female farmers opting for contour ridges system in relation to male farmers. Two female farmers, who had attained post-secondary education reportedly, practiced damming as a way of harvesting water to supplement rain fed agriculture.

Livelihood strategy practiced in your farm	Frequency	Percent
Cash crop farming	33	31.43
Grain farming	43	40.95
Both	29	27.62

Table 4: Livelihood Strategy Practiced by the Farmers in Their Farms

In regards to the livelihood strategy practiced by the farmers in their farms, 43 (40.95 per cent) of the farmers reported that they practice grain farming, 33 (31.43 per cent) said that they practiced cash crop farming while 29 (27.62 per cent) practiced both grain farming and cash crop farming. This shows that 72 (68.57 per cent of the farmers did practiced grain farming while 62 (59.05 per cent) were occupied in cash crop farming.

Reasons given for water management by the respondents varied. The reason for practicing water harvesting system by 30 (28.57 per cent) of the respondents was to trap water for crop irrigation. This is in line with the suggestion byAbdelkdair, A., & Schultz, R. C. [2005]; Fleskens, L., Stroosnijder, L., Ouessar, M., & De Graaff, J. [2005]; Huang, Z., Cheng, J., Zhao, S., Xin, X., & Liu, X. [2004];Ouessar, M., Sghaier, M., Mahdhi, N., Abdelli, F., De Graaff, J., Chaieb, H., . . . Gabriels, D. [2004] that rain water can be used to irrigate. Inaddition,40 (38.10 per cent) reported that it was to check, control and minimize soil erosion, while 37 (35.24 per cent) reported that it was intended for increasing moisture conservation and take water to the roots. Similar views were given by[Vohland, K., & Barry, B. 2009] who said that the availability of water in the root zone is increased by water harvesting.Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A., &Stroosnijder, L. [2012] established the same findings that rainwater harvesting techniques could improve the soil water content of the rooting zone. These reasons were similar to those established byParry, M. L. [2007] on adoption of water-efficient technologies to 'harvest' water, conserve soil moisture and improve water management to prevent water erosion.

3.2. Extent intensity of flash rains affect drenching and stabilization of on-farm water harvesting systems

Regarding the increment in the number of times drenching has to be done under different on-farm water harvesting systems due to flash rains, 61 (58.10 per cent) and 29 (27.62 per cent) of the respondents strongly agreed and agreed respectively that flash rains increase the frequency of drenching under Fanya-juu system. Only four (3.81 per cent) and three (2.86 per cent) respectively disagreed and strongly disagreed.

		Strongly agree	Agree	Disagree	Strongly disagree	Not sure
Fanya-juu	Freq (%)	61 (58.10)	29 (27.62)	4 (3.81)	3 (2.86)	8 (7.62)
Negarims	Freq (%)	37 (35.24)	53 (50.48)	5 (4.76)	1 (0.95)	9 (8.57)
Contour bunds	Freq (%)	28 (26.67)	43 (40.95)	12 (11.43)	6 (5.71)	16 (15.24)
Contour ridges	Freq (%)	27 (25.71)	35 (33.33)	6 (5.71)	6 (5.71)	31 (29.52)

Table 5: Flash Rains Increase the Times Drenching Has to Be Done on the Harvesting System

Under the Negarims system of water harvesting 37 (35.24 per cent) and 53 (50.48 per cent) strongly agreed and agreed respectively that flash rains do indeed increase the number of times drenching has to be done. Only five (4.76 per cent) disagreed while one (0.95 per cent) strongly disagreeing. This shows that there exists a similar response by the farmers on the Fanya-juu and Negarim systems.

Similar trend was also observed from the farmers' responses pertaining to the effect of flash rains on drenching under contour bunds and ridges systems. In the case of contour bunds system 28 (26.67 per cent) of the respondents strongly agreed while 43 (40.95 per cent) agreed that flash rains increase the frequency of drenching. The farmers who disagreed with the assertion were 12 (11.43 per cent) and six (5.71 per cent) strongly disagreeing. Contour ridges system was not an exception as the farmers who strongly agreed were 27 (25.71 per cent), while 35 (33.33 per cent) agreed to the increment of drenching as a result of flash rains. The farmers who disagreed were six (5.71 per cent) with an equal number of farmers also strongly disagreeing with the claim that flash rains led to increase in the number of times drenching has to be embarked-on, under the contour ridges system of water harvesting.

According to most of the farmers interviewed, flash rains do increase the frequency of drenching under the different water harvesting systems thus affecting their performance. The report shows that flash rains necessitates silt removal for both the Fanya-juu and Negarim systems, according to 90 (85.72 per cent) of the farmers interviewed, followed by contour bunds system and finally the contour ridges system, since 71 (67.62 per cent) and 62 (59.04 per cent) of the farmers respectively, concurred that the increment in the number of times drenching had to be done was attributed to flash rains.

		Drenching	Fanya-juu	Negarims	Contour bunds	Contour ridges
Drenching		1				
Fanya-juu		0.1939	1			
	p-value	0.0571				
Negarims		0.2698*	0.3407*	1		
	p-value	0.0078	0.001			
Contour bunds		0.5548*	0.2506*	0.1974	1	
	p-value	0.0001	0.0215	0.0719		
Contour ridges		0.4938*	-0.0792	0.2709*	0.3345*	1
	p-value	0.0001	0.5117	0.0223	0.0036	

Table 6: Correlation Matrix for the Number of Times Drenching Has to Be Done
*Note: * Indicates 5 % Level of Significance*

The correlation matrix in Table 6 gives a correlation coefficient in relation to the number of times drenching has to be done of 0.1939 for fanya-juu, 0.2698 for negarims, 0.5548 for contour bunds, and 0.4938 for contour ridges. The associated probability values (p-values) for fanya-juu, negarims, contour bunds and contour ridges are 0.0571, 0.0078, 0.0001, and 0.0001 respectively in relation to the number of times drenching has to be done due to increase in flash rains. Thus, the results show that drenching frequency and bund stability effects due to increase in flash rains is positively and statistically significantly correlated to negarims, contour bunds and contour ridges at the five per cent level of significance. Table 6 further shows that flash rains increase effects on drenching is positively correlated to the fanya-juu system though not supported by statistical test of significance. These analysis reveals that flash rains increase the number of times drenching has to be done under all the on-farm harvesting systems except the fanya-Juu. The worst affected by flash rains is contour bunds (r=0, 5548, p=0.0001), followed by contour ridges (r=0.4938, p=0.0001) and finally the negarims at (r=0.2698, p=0.0078). The statistical test of significance shows that the fanya-juusystem drenching frequency and stability is not affected by flash rains since its probability value (p-value) exceeds 5%.

4. Conclusions and Recommendations

4.1. Conclusions

The number of respondents who stated that they practiced water harvesting to supplement rain fed agriculture in their farms represented 95.24 per cent of the farmers indicating that most of the farmer's supplemented rain fed agriculture through water harvesting. The males who practiced water harvesting represented 44.76 per cent of all the respondents while female farmers practicing water harvesting were 51.43 per cent. This shows that only one female farmer compared to four male farmers did not supplement rain fed agriculture by harvesting water.

None of the farmers interviewed, who had attained primary education did not practice water harvesting to supplement rain fed agriculture, compared to two and three with secondary and post-secondary education respectively. Hence, failure to practice water harvesting increased with the level of education attained, irrespective of the number of farmers at each level of education which could be attributed to those well-educated having other sources of livelihood apart from farming hence not very keen on farming.

Two-thirds of the farmers interviewed practiced Fanya-juu. This system of Fanya-juu was practiced by 27.62 per cent and 36.19 per cent males and females respectively. This shows that a greater percentage of female farmers practiced this system of Fanya-juu compared to the male farmers practicing it. A greater percentage of male farmers practiced the system of contour bunds compared to the female farmers practicing it. Female farmers practicing the system of contour ridges doubled the males carrying on the contour ridges system. The Fanya-juu system followed by Negarims systems of water harvesting were most reportedly being practiced by the farmers in the area irrespective of their gender and level of education attained. A greater percentage of the farmers view Fanya-Juu as the best suited for the gently sloping terrain of the study area. More males preferred the contour bunds systems compared to females, while a greater proportion of female farmers opted for contour ridges system in relation to male farmers. Two female farmers, who had attained post-secondary education reportedly, practiced damming as a way of harvesting water to supplement rain fed agriculture, with no male being said to practice dam construction. Damming limited use was attributed to the resources required to set them up and expertise.

Reasons provided on water management by the respondents varied. The reason for practicing water harvesting technique by 28.57 per cent of the respondents was to trap water for crop irrigation. In addition, 38.10 per cent reported that it was to check, control and minimize soil erosion, while 35.24 per cent reported that it was intended for increasing moisture conservation and take water to the roots.

Most of the farmers interviewed reported that flash rains do increase the frequency of drenching under the different water harvesting systems. The correlation matrix analysis shows that effects of flash rains is both positive and significant for all on-farm water harvesting systems except the Fanya-juu systems (r=0.01939,p=0.0571).Occurrences of flashfloods(r=0.4090, p=0.0011)droughts(r=0.4610,p=0.0005),erratic rainfalls(r=0.4610, p=0.0018) and high temperatures at(r=0.45011,p=0.0009) emerged influential on the water stress levels in the area both statistically and significant. Hence, thefanya-juu system and negarims systems of water harvesting were most reportedly being practiced by the farmers in the area irrespective of their gender and level of education attained. In addition, thefanya-juu system is not significantly affected by flash rains hence no drenching has to be done under this on-farm water harvesting system.

4.2. Recommendations

Based on the findings of the study, the following recommendations were made;

- Farmers need to be more sensitized and trained on use of contour bunds and contour and on how to monitor and evaluate their performance.
- To alleviate water stress exacerbated by erratic rainfall, high temperatures and droughts, farmers in the area should be encouraged through awareness creation to harvest water using the fanya-juu system, since it is positive in effectiveness and statistically significant under different water stress factors.

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