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Moisture Conservation Measures in Flood Prone Areas in Kenya: A Case Study of Kamukuru, Kajiado County

Practical Note

Flood-Based Livelihoods Network Foundation

Introduction

Heavy rainfall is a frequent phenomenon in different parts of Kenya especially during the occurrence of long rains running from March to May. This often results in flash floods which cause havoc to humans, livestock and farmlands especially in the floodplains. However, these floods can be harnessed and used for flood based farming in crop production, agro-forestry and rangeland management, domestic and livestock water supply and even recharging groundwater (Embaye, 2015). This farming system depends on flood events that may last a few hours to a few months and can take different forms which include: spate irrigation which is the diversion of flashy floods in to the downstream command area; flood inundation and recession in which the rivers overflow their embankment and flood adjacent areas; flood spreading weirs and road water harvesting. Kajiado is one of the many counties in Kenya that face frequent flooding.

To introduce and demonstrate flood-based farming techniques, a site was identified in Kamukuru-Kajiado where the effectiveness of spate irrigation in optimizing sorghum yield was assessed. Kamukuru area is a communal ranch that is mainly faced with floods. Despite the occurrence of the floods, the area is very dry with very little vegetation. Much of what can be seen is the dust up in the sky. The main inhabitants of the area are the Maasai who are mainly pastoralists. To understand the moisture conservation dynamics, the study was conducted in three block replicates of 10 m by 10 m area with each block subdivided in to four plots. Each plot was treated with different moisture conservation measures. The first plot was under the farmers practice, the second under ridges, the third on mulch and the fourth under a combination of both mulch and ridges. To understand the hydrologic dynamics in this research set-up, several tests and sensors were put in place. Digital moisture sensors (YL-69) were put in place to monitor the moisture content at depths of 20 cm and 40 cm below the soil surface. The percentage soil moisture content was captured every fifteen minutes and sent to the cloud. A sim card was used as the source of internet to send the data to the ThingSpeak cloud. To visualize the data in our android phones, ThingView application was installed in our mobile phones. Three different channel IDs were used for each block which were obtained during signing up. Under each block, the different moisture sensors in each treatment were under the fields category. The values in the ThingView application were observed as graphs or charts. However, all the data was recorded in the server for a later download. In this study different flood events were experienced during the growth period as discussed in the results section and they were the source of water for the growth of the sorghum crop. The plots were planted with sorghum on 7th September 2017.

Soil moisture conservation

The main aim of soil moisture conservation is to minimize the amount of water lost from the soil through evaporation and transpiration or combined, evapotranspiration. The availability of water and its retention are governed by its bulk density, hydraulic conductivity and the soil mechanical composition. For healthy crop growth, sufficient water is needed in the soil which is neither deficient nor in excess. Excessive flooding removes air from the soil hence leading to retarded growth. However, irrigation water application should raise the soil water to the field capacity (FC) level from maximum allowable depletion level.

Different soil moisture conservation measures have been developed and promoted to preserve moisture and provide additional nutrients to the soil

Figure 1: Placement of sensors

Figure 2: Connection of the moisture sensors to the board

thus increasing the irrigation efficiency (Thomas *et al.*, 1997; AHI, 2000). The most common moisture conservation measures include mulching, ridges, tied-ridges, plastic mulching, a combination of mulch and ridges or even the normal farmers' practice. Adoption of soil moisture conservation techniques such as tied ridges and mulching has shown improved soil moisture retention in a wide range of environment (Balenchew and Abera, 2010). The increase in irrigation efficiency in turn increases the crop yield. However, for proper planning, there is little information on the extent the conservation measures achieve the expected outcome. In general, soil moisture conservation practices improve soil structure and soil porosity, increases infiltration and soil hydraulic conductivity, and consequently increase soil water storage. The moisture conservation techniques applied in this study are described as follows.

Contour ridges

Ridging is done by constructing small earth banks parallel to the contours of a slope. The water accumulates above the ridges and is thus allowed to infiltrate into the soil. It is mainly used on slopes with a gradient up to 7 % (Anschutz *et al.*, 2003). For construction purposes, clay soils are highly preferred due to their relatively stable structure otherwise the ridges become undermined by runoff and get destroyed (Anschutz *et al.*, 2003). The height of the ridges is usually 20 - 30 cm (Anschutz *et al.*, 2003) and are as wide as furrows. The distance between the ridges varies from 1.5 m to 10 m and depends on the crop grown, the steepness of the slope and the climate (Anschutz *et al.*, 2003). The main advantage of using the ridges is that they reduce both runoff and soil erosion as well as reduce nutrient loss. However, if improperly laid on the ground they can increase the risk of soil erosion and if the soils are heavy with low infiltration capacity then a lot of water might collect and in turn increase the chance of breaking. Crops are planted between the ridges and not on the ridges (Anschutz *et al.*, 2003).

Mulching

Mulches are loose coverings or sheets of materials placed on the surface of cultivated soil. They are advantageous in that they help soils retain moisture, help in control of temperature fluctuations, suppress weeds, improve soil texture and protect plant roots from extreme temperatures. Mulches can either be biodegradable or non-biodegradable.

Biodegradable mulch breaks down to release nutrients into the soil and helps improve its structure. The layers need replacing once the material has worn out. The best materials are; leaf mould, garden compost, wooden chippings and well-rotted manure. The non-biodegradable mulch does not boost the soil fertility or structure but helps to suppress the weeds, retain the moisture as well as being decorative. The main challenge of applying mulch occurs if they are placed in direct contact with the stems of the trees since they cause the stems to soften making them vulnerable to diseases.

Mulching has been widely used for soil and water conservation purposes (Sarkar & Singh, 2007; Chakraborty *et al.*, 2008). McDonald (2013), stated that mulch slows down evaporation and in turn reduces the irrigation requirement. Adeoye (1984), recorded a high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Rice husks were more superior in maintaining optimum soil moisture for crop use than transparent and black polyethylene mulch (Chakraborty *et al.*, 2008). According to the study, the residual soil moisture was minimum indicating effective utilization of soil moisture by the crop.

Plastic mulch is highly preferred because it does not decompose. This is advantageous in that it provides a permanent solution hence no need of re-applying every year to save both time and money. On the other hand, using plastic mulch is a problem in that due to its failure to decompose it causes environmental degradation. Also, there is a ban by the Kenyan government on the use of plastics. Hence, in this study the grass mulch was used in testing its effect on moisture retention on spate irrigated sorghum.

Ridge-furrow mulching technique

According to Li *et al.* (1999), mulches are used to reduce water loss through evaporation. Ridge – furrow mulching systems have been used in Kenya with good results in moisture storage. An experiment conducted in Kari-Katumani by Mo *et al.* (2016) on the effect of different mulching materials (transparent polyethylene, black polyethylene, grass-straw mulch and without mulch) showed that the mulch materials could retain moisture in the soil. Much of the moisture was retained by the transparent polyethylene.

Ren *et al.* (2016), conducted a study in Loess plateau that the ridge-furrow mulch generally improved the soil water storage with much of the increase at depths 0 - 100 cm and relatively small change from depths 100 - 200 cm. The highest levels of moisture retention were observed in the

Figure 3: Sorghum under different conservation techniques

plastic mulch. However due to the plastic ban and its effect on the environment, the grass mulch is recommended rather than the plastic mulch.

Results

Good germination and growth rates were observed all through to the end.

Different flood events of different magnitudes occurred during the sorghum growth period. The Seredo sorghum variety was planted on 7th September 2017. However, the much significant events occurred during the 18th of September 11th and 18th of October 2017. From the analysis of the data, a similar trend of flood recession was observed under the different moisture conservation measures. However, the amount of moisture retained per conservation measure varied. The moisture retained increased with an increase in the flood magnitude and the moisture content reduced with time if another flood was not observed. The moisture content was recorded every 15 minutes for the entire growth period but for analysis purposes, the daily moisture content readings were used. The YL-69 moisture sensor consists of two probes which measured the percentage volumetric water content in the soil. When the soil was wet, the soil conducted more electricity which meant less resistance and in turn high moisture content. When the soil was dry,

Figure 4: Mature sorghum crop

the soil conducted less electricity which meant high resistance and in turn low moisture content.

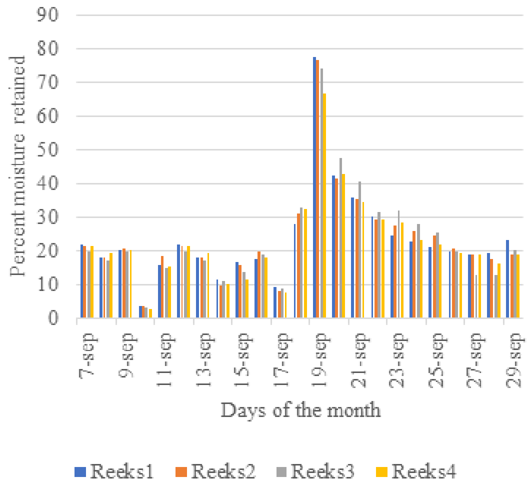
20-cm depth

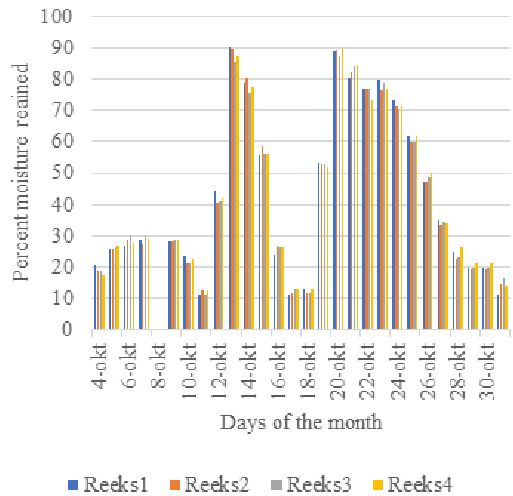
At the 20-cm depth, several flood events were observed in the month of September 2017. However, the most significant event occurred on the 18th at 4.52 pm. The moisture retained under the different moisture conservation techniques is as illustrated in Figure 5.

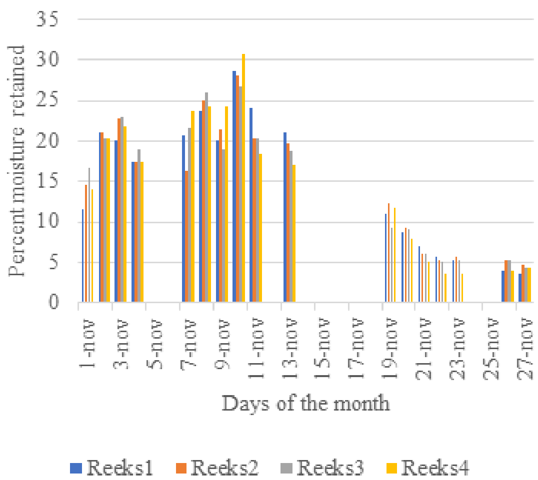
The moisture conservation measures followed the same trend where the moisture content increased with the increase in the flood magnitude and reduced with time. Different levels of moisture content were absorbed by the different treatments ranging from 66.5 % to 77.5 %. The ridges and combined ridges and mulch recorded the highest

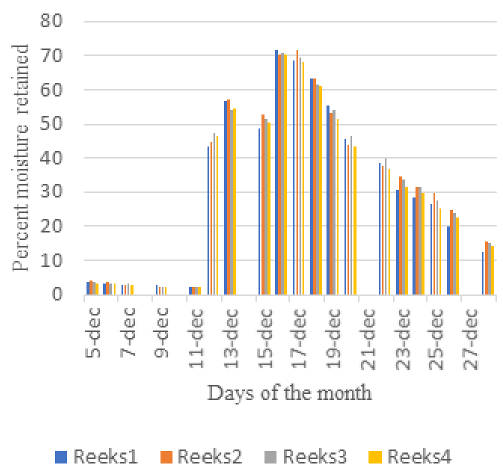
Figure 5: Moisture content retained at 20-cm depth

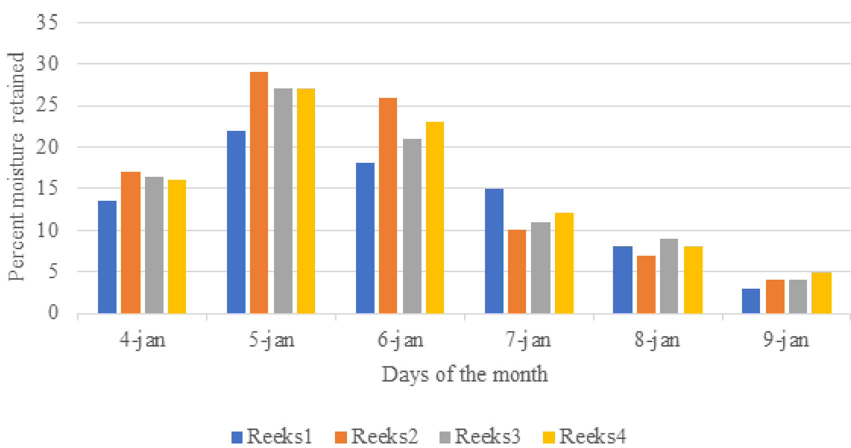
Series 1: Ridges
Series 2: Combined ridges and mulch
Series 3: Mulch
Series 4: Control











amount of moisture content of 77.5 % and 76.8 % respectively. The control treatment recorded the least moisture content of 66.5 %. With time the moisture retained was highest under the mulch followed by the combined ridges and mulch, ridges and finally the control. At the end of the month however, the combined ridges and mulch had the lowest moisture content of 18.7 % which slightly varied from the control which had 19 %. The other moisture conservation techniques, that is the mulch and ridges, had a percentage of 20 % and 23.3 % respectively. In the month of October, two significant events were observed on 13th and on 20th both at 3 pm. From both events, the conservation measures followed the same trend where the moisture levels increased with the occurrence of the floods and reduced with time. At the end of the month, the mulch retained much of the moisture content at 16.7 % while the combined ridges and mulch, the control and the ridges had values of 14.5 %, 14 % and 11.5 % respectively. In the month of November, small flood events were observed. At the end of the month, all the treatments had a moisture content that ranged from 0 - 5 %. During the month of December, three significant flood events were observed. The first flood event occurred on 12th December at 9.00 am. This flood event raised the moisture content of the different moisture conservation techniques to levels between 43 % to 46 %. The amount of moisture content in the soil increased with the inflow of the flood water. The second flood event occurred on 13'h at 9.00 am. The moisture content increased to 57 %. The moisture content reduced with time and in three days, another flood event was observed. The moisture content increased to levels between 70 % and 72 %. The different conservation techniques followed the same trend in which the moisture content reduced with time. At the end of the month, the moisture content recorded at the ridges, combined ridges and mulch, mulch and the control was 12.3 %, 15.7 %, 15% and 14.3 % respectively. In the month of January, the moisture ranged between 10 % to 28 % on the first seven days. The sorghum was harvested on 10th January 2018 and the moisture content recorded during harvesting was 4 % at the control and 3 % on the other conservation techniques. The low values of moisture retained in the ridges and the combined ridges and mulch could be attributed to the washed away ridges since the surface area under direct evaporation was increased.

To statistically assess the effect of different moisture conservation techniques on moisture retention, an analysis of variance (ANOVA) was done. An analysis of variance (ANOVA) was conducted to determine which conservation measure was suitable for retaining the highest moisture content in the soil. This analysis was conducted at 95 % confidence interval and results are presented in Table 1.

From the analysis results summarized in Table 1, it becomes evident that there was no statistical difference at the 20-cm depth in terms of moisture retention from the different treatments. However, there was a statistical difference in terms of the percentage amount of water retained per block. The highest amount was retained in block 3 with a mean of 35.23 followed by block 1 with a mean of 32.74 and finally block 2 with a mean of 31.69. In spite the blocks having significant statistical difference, the treatments were observed to have different means with the highest recorded under the mulch conservation at 33.37 %. This was followed by the combined ridges and mulch which had a value of 33.31 %, then the ridges with a

Table 1: ANOVA test at 20 cm depth

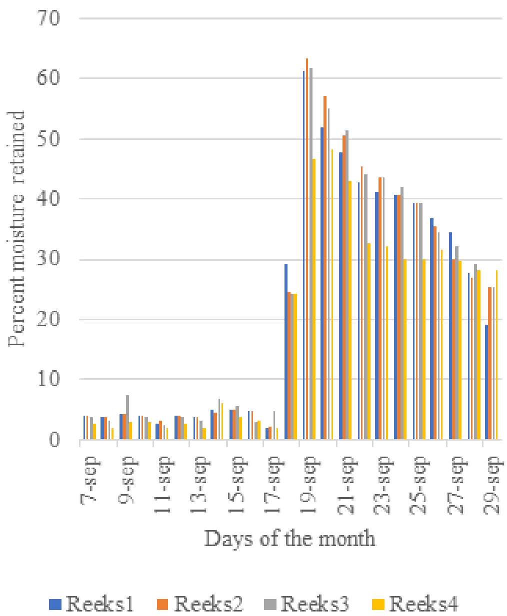
Moisture conservation technique	Count	Sum	Average	Variance
Combined ridges and mulch	3	99.93578	33.31193	4.099747
Mulch	3	100.1117	33.37055	0.537386
Control	3	98.99893	32.99964	6.979055
Ridges	3	99.60964	33.20321	3.625096
Block 1	4	130.9514	32.73785	0.177708
Block 2	4	126.7681	31.69203	0.65849
Block 3	4	140.9365	35.23412	0.572826

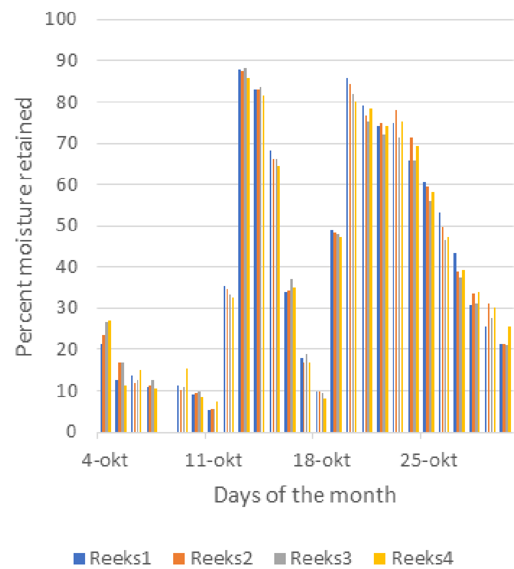
Source of variation	df	SS	MS	F	Fcritical	P-value
Treatments	3	0.239843	0.079948	0.120305	4.757063	0.944814
Blocks	2	26.49534	13.24767	19.93515	5.143253	0.002238
Error	6	3.98723	0.664538			
Total	11	30.72241				

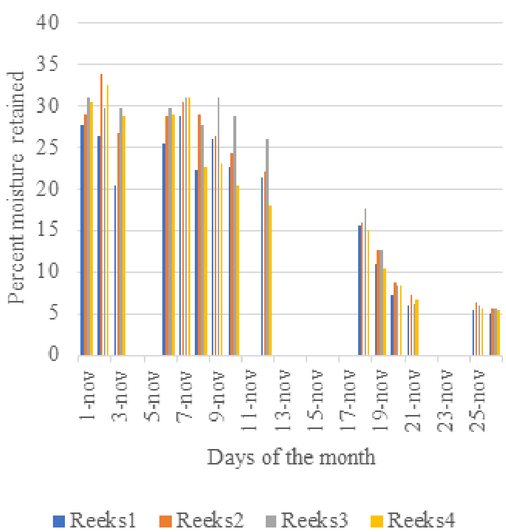
value of 33.20 % and finally the control which had a value of 32.99 %. The observed p-value was 0.94. This value was high in comparison to the level of significance of 0.05 hence the lack of significant difference in how the treatments retained moisture content. A study conducted by Salifu (2015), that assessed the effect of soil and water conservation measures on cowpea cultivation in Ghana confirmed the same; contour ridges conserved soil moisture better than the normal farmer's practice (Salifu, 2015). Like in this study, the results of the study

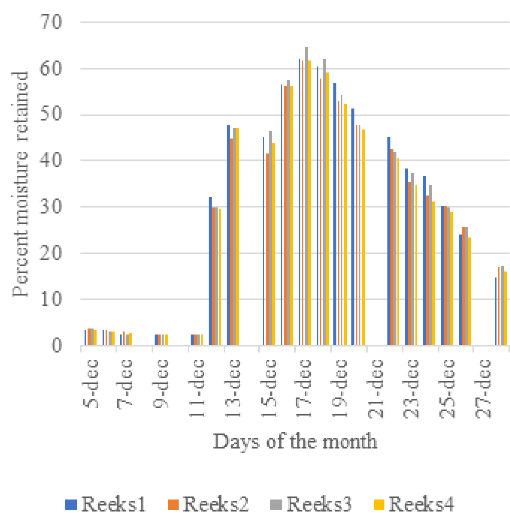
Figure 6: Moisture content retained at 40-cm depth

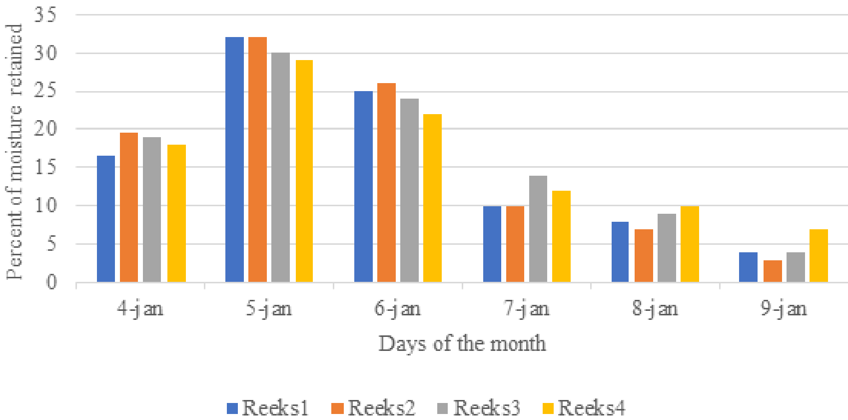
Series 1: Ridges
Series 2: Combined ridges and mulch
Series 3: Mulch
Series 4: Control











in Ghana confirmed that the farmers' practice (control) had the least moisture retention capacity (Salifu, 2015).

40-cm depth

At 40-cm depth, soils were not saturated. This was because the moisture content did not reach the field capacity at 20-cm depth hence there was little to infiltrate the soil to 40-cm depth. The moisture conservation graphs are illustrated in Figure 6.

The moisture content was at a level between 0 - 10 % before the occurrence of the significant flood event on 18th September 2017. After the occurrence of the flood on 18th, the moisture conservation techniques absorbed a significant amount of moisture content to a level between 25.3 % to 28 %. A few hours later, the moisture content under all treatments increased to values between 46.7 % to 63.3 %. Under the four moisture conservation techniques, the amount of moisture in the soil increased with the amount of floodwater and reduced with time. At the end of the month, the control recorded the highest value of 28.3 % followed by the mulch and the combine ridges and mulch with a value of 25.3 % and finally the ridges with 19 %.

In the month of October, clear curves of how the moisture was retained were observed after the flood event of 13th October 2017. The moisture content in all treatments increased to levels between 85 % to 90 %. After six days, the moisture content in all treatments had reduced to levels below 10 % after which another flood event was observed on 20th. The moisture content increased to levels between 80 % to 85 %. The moisture content took a while to reduce to the extremes and at the end of the month the levels were between 21 % and 25 %. In the end of the month of November, the highest values were recorded for mulch, combined ridges and mulch, ridges and control as 5.7 %, 5.7 %, 5 % and 5.7 % respectively. In December, three flood events were observed and at the end of the month the moisture content was recorded as 16 %, 17.3 %, 17 % and 14.8 % under the control, mulch, combined ridges and mulch and ridges respectively. During harvesting, the moisture content was at 4 %, 3 %, 4 % and 5 % under ridges, combined ridges and mulch, mulch and control respectively. The moisture retention curves of the sensors at this depth are illustrated in Figure 6. In determination of the most suitable technique, the statistical analysis was conducted. ANOVA was used as tabulated in Table 2.

From the analysis, it was deduced that at least one of the moisture conservation techniques was different from the others in terms of moisture retention. The treatments had a p-value of 0.02 which was less than the alpha level of 0.05 meaning there was a significant difference on at least one of the treatments. To determine the best treatment in retaining moisture content in that area an analysis of their means was done. The mulch treatment had the highest value of 31.68 %. This was closely followed by the combined ridges and mulch which had a mean of 31.61 % and then ridges which had a mean of 31.59 % and finally the control which had a mean of 30.39 %. Therefore, it was quite evident that mulch was the best in retaining the moisture content at this depth of 40 cm. Teame *et al.* (2017), confirmed similar results by conducting a study in Ethiopia to assess the effect of organic mulching on soil moisture

Table 2: ANOVA test at 40 cm depth

Moisture conservation technique	Count	Sum	Average	Variance
Combined ridges and mulch	3	94.82705	31.60901667	12.53836179
Control	3	91.1591	30.38636667	14.38646047
Mulch	3	95.05352	31.68450667	10.52128521
Ridges	3	94.77355	31.59118333	15.44408534
Block 1	4	115.24306	28.810765	0.916742648
Block 2	4	118.7029	29.675725	0.199376047
Block 3	4	141.86726	35.466815	0.377650247

Source of variation	df	SS	MS	F	Fcritical	P-value
Treatments	3	3.484762	1.161587424	6.993690866	4.757062663	0.021951335
Blocks	2	104.7838	52.39192053	315.4415144	5.14325285	8.36132E-07
Error	6	0.996545	0.166090759			
Total	11	109.2651				

yield and yield contributing factors of sesame. The authors indicated that at depth 0.21 m to 0.4 m, sudan grass conserved the highest soil moisture content of 17.3 % as compared to other materials. This coincides with the results of this study in that the experimental plots under mulch retained the highest amount of moisture content though with different moisture content values.

Analysis of the moisture content retained per block indicates that the amount of moisture retained per block is significantly different. The p-value recorded is 8.36E-07 which is way lower than 0.05 which is the significant level. Here, block 3 retained much with a mean of 35.47 % followed by block 2 with a mean of 29.66 % and finally block 1 with a mean of 28.81 %. This was a complete opposite of the results obtained at the depth of 20 cm.

Conclusion

It was observed that the mulch conservation technique was the best in retaining the moisture content in the soil with the high and severe weather conditions. The findings of this research are helpful to the community members in that they can retain the little available water in the soil for improved land productivity. By the end of the study, other farmers had picked up and started practicing flood-based farming in the surrounding areas. However, for further studies, the analysis can be conducted at higher depths to determine which is the best level for moisture retention. In addition, another material which can reduce evaporation rate better can be used.

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Practical Note #36

Colofon

This Overview Paper is prepared by Celestine Kilongosi (MetaMeta). It is mainly based on Celestine's MSc research at Egerton University, Kenya.

The Flood-Based Livelihoods Network (FBLN) supports and promotes appropriate programmes and policies to improve flood-based livelihoods systems (FBLS) through a range of interventions, assists in educational development and knowledge-sharing, creates networks and supports the implementation of projects on FBLS.

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