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Terrace Development Applied as a Water Harvesting Technology for Stable NERICA Production in Uganda

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Abstract: In Uganda, the greatest cause of crop damage is the shortage of rainfall due to meteorological and land structural aspects of present farming situation. The purpose of this study was to evaluate the effect of terrace development, the relationship between terrace size and efficiency of rainfall catchment, and the subsequent effects of terrace development on rice yield of the New Rice for Africa (NERICA) on sloping rainfed fields. Results revealed that terrace developments were efficient in terms of rainfall catchment which led subsequent effects on the increase of volumetric water contents and rice yield. It is suggested that narrow sized terraces are more efficient than wide sized terraces in rainfall catchment since the highest average yields of 1,568 and 1,237 Kg/ha were recorded for 0.9 m and 1.5 m terraces, respectively, while the 2.5 m terrace and non-terraced control had the least yields of 1,038 and 777 Kg/ha respectively. In addition, the average increasing rate in volumetric water content after rainfall was four times higher for banked terraces than in non-terrace plots. It was also revealed that terrace development decrease the number of missing rice plants by reducing the influence of soil erosion at inclined fields. The above study highlights that terracing is an effective water harvest technology for stable NERICA production under certain levels of unexpected and inexplicable changes in the rainfall pattern. However, because the use of terraces can prove futile in cases of severe drought, they must be applied alongside other technologies like irrigation.

Key Words: NERICA, Republic of Uganda, Technology, Terrace Development, Water Harvesting

1. Introduction

The Republic of Uganda has very favorable climatic conditions for Agriculture, notably because of bimodal rainfall pattern characterized by average annual precipitation above 1,200 mm, and average annual temperature ranging from 20.5 to 30.0 Degrees Celsius. In spite of the country's location on the equator, a majority of farmlands are at altitudes of over 1,000 meters above sea level. However there are various constraints in micro aspects such as 96.2% farmlands categorized as rainfed field and 53.1% are located on slopes that have inefficient rainfall utilization and proneness to soil erosion. In recent years, NERICA (New Rice for Africa) cultivation area has expanded in Uganda because of its liquidity and easy innovation by poor rural farmers in spite its high depletion of moisture content for growth compared with that of other upland crops. NERICA is a new group of upland rice varieties that is the product of interspecific hybridization between high yield-potential Asian species and African species that are resistant to diseases. There are 3 NERICA varieties are released in Uganda. The Government of Uganda has ranked rice as one of the important crops in its Development Strategy and Investment Plan (DSIP) from 2009 - 2014 being implemented by the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF). However, productivity has not been as high as expected due to the fact that most parts of Uganda are experiencing high erratic rainfall patterns, long-dry spells and difficulty at inclined fields that have culminated in varying degrees of crop losses.

In view of the above meteorological and land structural aspects, there is a necessity of developing water harvesting technologies that can be adopted by farmers to ensure stable NERICA production on undulating inclined fields.

Therefore, this study evaluated the relationship between terrace size and efficiency of rainfall catchment, and the subsequent effects of terrace development on NERICA rice yield when cultivated on inclined rainfed fields in Uganda.

2. Materials and Methods

2.1 Field location

Field studies were conducted at the rice research experiment fields of the National Crops Resources Research Institute (N: 00º30'46.4, E: 32º38'03.6, 1120 m alt.) under National Agricultural Research Organisation in Uganda (**Fig. 1**) during 2007B - 2010A (A and B after years stands for the 1st rainy season and 2nd rainy season respectively).

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Fig. 1. Location of experimental site at National Crops Resources Research Institute (NaCRRI) in Uganda

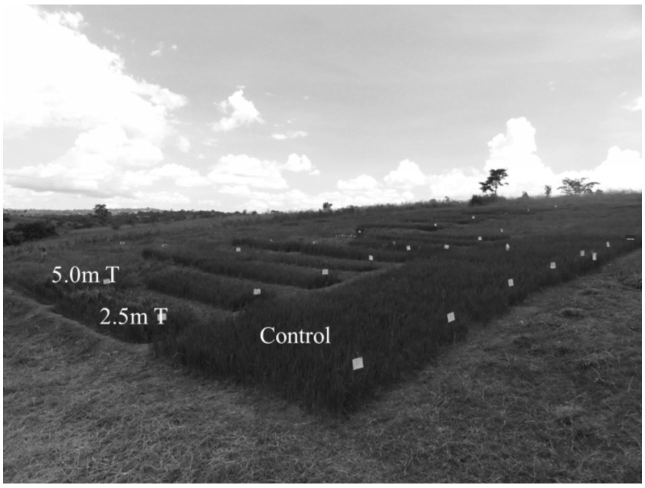

Fig. 2. Experimental design and treatment allocation. The experimental field was divided lengthways and treatments were set within each plot without randomization.

2.2 Experimental design and Treatment allocation

Terraces were developed on a field inclined at 10 degrees. During terrace development, top soil was initially removed aside and put back after terraces were developed to ensure the even distribution of nutrient-rich topsoil on each terrace.

The experimental plots were arranged across the slope gradient without randomization, otherwise treatments could influence each other with regards to the amount of run-off water. The control (non-terraced) plots were located alongside treatment plots, so that run-off water from the control would not affect results of treatments in the lower parts of the slope. Since the experiment was aimed at assessing the efficiency of rainfall catchment by different sized terraces, the field was initially divided lengthways and treatments were assigned within each plot (**Fig. 2**).

2.3 Cultivar and Yield survey method

The cultivar used for the experiments was NERICA-4 which is the most widely adopted and stable upland rice variety in Uganda. Yield survey was conducted at physiological maturity using yield components to determine rice yield per hectare.

2.4 Terrace development and Rice yield

In 2007B and 2008A, the efficiency of rainfall catchment and subsequent effect of terracing on the yield of NERICA-4 was assessed using different terrace sizes, 0.9, 1.5, and 2.5 m respectively. The terrace treatments were replicated 3 times in 2007B and 4 times in 2008A.

In 2009A and 2009B, the shapes of the terraces were modified by banking with soil alone (**Fig. 3**) and with soil-filled sacks (**Fig. 4**) since terraces developed in 2008A were not able to restrain run-off water of rainfall. The experiment was replicated 7 times.

In 2010A, 2 sized terraces namely 2.5 m and 5 m both banked with soil only experimented in comparison to control to further confirm the effect of rainfall catchment on yield. The experiment was replicated 4 times.

Fig. 3. 2.5m-Terrace banked with soil (left) and control (right) during a downpour. Terraces retain rainfall but water escapes down the control field.

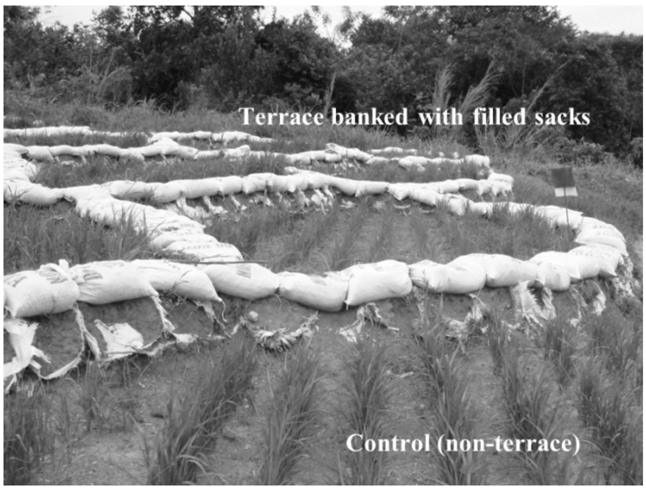

Fig.4. Terraces banked with soil-filled sacks.

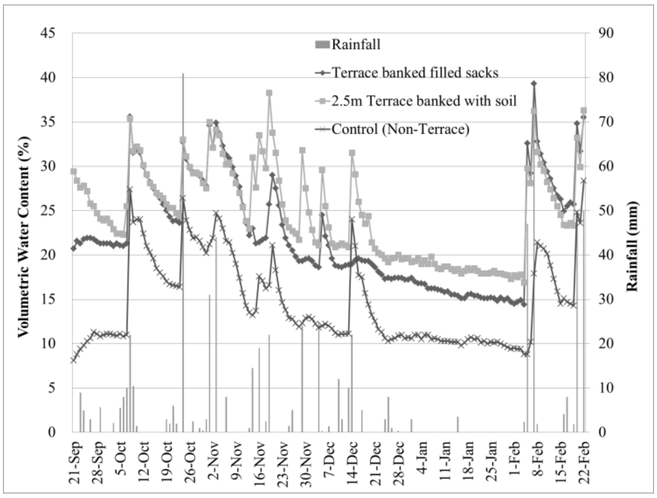

Fig. 5. Movement of volumetric water contents at terraces and no-terrace.

Table 1. Total rainfall (mm) in each season. Season A and B stand for March to July and September to January, respectively.

Year	2007	2008	2009	2010
Season A	439.9	543.1	289.7	566.1
Season B	552.3	591.3	511.4	

The analyses were performed using *F*-test followed by T-test in Microsoft Excel to know statistical reliability.

2.5. Measurements of Volumetric Water Contents and Rice yield

In 2009A and 2009B, the variations of Volumetric Water Contents (hereinafter VWC) in the 15 cm soil-depth were monitored using soil moisture sensors (EC-5, Decagon Devices Inc., Pullman, WA, USA) and data loggers (Em50, Decagon Devices Inc., Pullman, WA, USA). The equipment was set to automatically collect VWC data on an hourly interval at 2 types of terraces in comparison to control (**Fig. 5**). In addition, VWC data immediately after receiving rainfall were surveyed and evaluated (**Table 1**).

2.6. Terracing size and Number of existing rice plants

In 2010A, the number of existing rice plants in 3 m length in row was counted with 2 replications to ascertain the degree of soil erosion in each treatment. The data is analyzed using mean difference *t*-test probability to know statistical reliability.

3. Results and Discussions

3.1. Effect of terrace development and its size on rice yield

The total rainfall was adequate in both seasons as 552 mm and 543 mm for 2007B and 2008A, respectively (Table 1). Results of terrace experiments conducted in 2007B and 2008A revealed a significant effect of terrace development on the yield

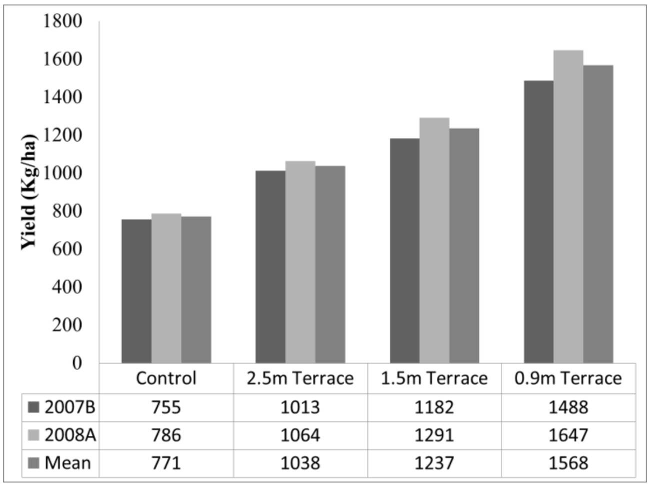

Fig. 6. Yield of NERICA-4 at treatments in 2007B and 2008A.

of NERICA-4 cultivated in an inclined field. The highest and lowest average rice yield of 1,568 and 777 Kg/ha were recorded for 0.9 m terraces and the non-terraced controls ($P<0.00003$), respectively (**Fig. 6**). The above results imply that terrace development apparently decreases the erosive effect of slope gradient and improves rainfall catchment. Moreover, 0.9 m terraces have significantly high yields than those of 1.5 m terraces ($P<0.027$) and 2.5 m terraces ($P<0.0024$). This suggests that narrow sized terraces are more efficient in rainfall catchment than the wide sized terraces (1.5 m and 2.5 m).

In 2009B, the average yield of NERICA-4 at the terrace banked with filled sacks was 1713 Kg/ha, approximately 3 times higher than that of the control (615 Kg/ha). Similarly, the average yield of NERICA-4 between 2009B and 2010A at terraces banked with soil alone was 2572 Kg/ha (2.5m terraces), approximately 1.5 times higher than that of the control (1685 Kg/ha). The results support to confirm the effect of rainfall catchment on yield.

3.2. Effect of terrace development on the movement of Volumetric Water Contents

In 2009A, moisture sensors failed and no data was collected because of severe drought and the prolonged dry spell. The total rainfall in the season was 290 mm which was much lower than that of others (Table 1). Nevertheless, data collected in 2009B showed that VWC was higher for the two types of terraces than in the non-terrace field (Fig. 5), which proved the positive effect of both terrace types in improving rainfall catchment. In addition, increases in VWC rates after rainfall was 1.9, 9.0 and 9.1% for non-terraced fields (control), terrace banked with filled sacks, and terrace banded with only soil, respectively (**Table 2**). The Average of increment rate of VWC between the two terrace types is almost the same, but four-times higher than that of the non-terraced fields. The results above indicate that terracing can be an effective water

Table 2. Increasing rates (%) of soil volumetric water contents after rainfall events.

Date of survey	1st Nov	19th Nov	4th Dec	5th Feb	7th Feb	Mean
Control	1.0	0.4	0.2	0	7.7	1.9
Scale Terrace	6.8	3.8	5.9	18.2	10.1	9.0
2.5m Terrace	7.5	8.5	8.5	12.9	8.1	9.1
Rainfall	40mm	22mm	25mm	47mm	70mm	N/A

Table 3. Number of existing rice plants in 3 m length in row.

	No. of sample	No. of rice plants existed
Control versus 2.5m Terrace		
Control (Non-Terrace)	6	29.3
2.5m Terrace banked with soil	6	43.3
Mean difference t-test probability		**0.0003**
Control versus 5.0m Terrace		
Control	6	29.3
2.5m Terrace banked with soil	6	40.3
Mean difference t-test probability		**0.0044**
2.5m Terrace versus 5.0m Terrace		
2.5m Terrace banked with soil	6	43.3
5.0m Terrace banked with soil	6	40.3
Mean difference t-test probability		**0.2415**

harvesting technology against a certain level of unexpected and inexplicable changes in the rainfall pattern. However, because the use of terraces will prove futile in cases of severe drought, they must be applied with other accompanied technologies like irrigation that can bolster crop performance during periods of severe drought or long dry-spell.

3.3 Terracing size and Number of existing rice plants

Our investigation revealed that the average number of existing rice plants in 3 m length in row are highly significant between control and 2.5 m terrace banked with soil ($P<0.0003$), control and 5 m terrace banked with soil ($P<0.0044$). However there is no significant difference between the above terraces ($P<0.2415$) (**Table 3**). The result suggests that terrace development helped in decreasing missing plants which was caused by intensive rainfall.

4. Conclusions

Our result revealed that there are significant benefits in terrace development in terms of rainfall catchment resulting in high soil VWC and high yield of rice. In addition, the results of rice yield showed that narrow sized terraces are more effective than wide sized terraces in terms of rainfall catchment. This result was considered as there is the movement of water in wide sized terraces when the field received intense deluges and water cannot be distributed evenly within the terraces.

Narrow sized terraces have advantages of high yields and less labor requirements in comparison to wide sized terraces. However it has disadvantages such as larger margin area, where crops cannot be planted, created by banks than wide sized terraces. Therefore it is important to conduct further research to propose the best practice of terrace development in terms of the size. In addition, other rice varieties such as early rice should be studied to know variety response to the water harvesting in inclined fields.

In this paper, the authors tried to highlight the benefits of terrace development on inclined rainfed fields in terms of rainfall catchment. They would like to further suggest that terrace development alone is not a perfect measure against severe droughts as shown in the result of 2009A in which rice was destroyed completely. To develop comprehensive technologies to withstand severe drought, terrace development should be applied with other water harvesting technologies such as supplemental irrigation technology using consecutive irrigation reservoir system as proposed by Kitanaka *et al.* (2008).

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