Effect of Water Harvesting and Re-Seeding on Forage Biomass Production from Rangelands in Sheikan Locality, North Kordofan State, Sudan

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The 22nd International Grassland Congress (Revitalising Grasslands to Sustain Our Communities) took place in Sydney, Australia from September 15 through September 19, 2013.

Proceedings Editors: David L. Michalk, Geoffrey D. Millar, Warwick B. Badgery, and Kim M. Broadfoot

Publisher: New South Wales Department of Primary Industry, Kite St., Orange New South Wales, Australia

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Abstract. This study was conducted at Sheikan Locality, North Kordofan State, Sudan. The area has a unimodal annual rainfall of 300-400 mm occurring during July-October. The main economic activities are crop and livestock production. Livestock are raised either under sedentary or migratory systems where natural grazing is practiced. The dominant livestock species are sheep, cattle, goats and camels. A main determinant of livestock production is low forage production resulting from low soil moisture due to low total precipitation and is also due to poor water infiltration rate associated with the prevalent type of sandy clay soils locally known as "gardud". These soils are widespread and are prone to excessive runoff. Water harvesting is thought to increase soil moisture content and hence pasture productivity. This study aims to investigate effect of three water harvesting techniques namely contour ridges, runoff strips and flat (control); and two planting methods specifically reseeding and natural regeneration (un-reseeded) on forage biomass production, plant density and vegetation cover. Forage biomass production in the reseeded site was 3.65, 2.25 and 0.65 t/ha for the three treatments respectively. In the un-reseeded site the values were 2.85, 1.75 and 0.55 t/ha respectively (P<0.001). A similar trend was found for plant density and plant cover. It was concluded that water harvesting and reseeding resulted in increased forage biomass production and plant cover from rangelands. The results were discussed in relation to effect of increasing soil moisture content on improving livelihoods and mitigating environmental degradation.

Keywords: Semi-arid, soil physical characteristics, range rehabilitation, gravimetric moisture, rangeland condition.

Introduction

The study was conducted in two growing seasons over two years (2009/10-2010/11) to assess the effect of water harvesting and re-seeding on forage biomass production and other parameters of rangelands condition in a semi-arid environment of North Kordofan State, Sudan. The objective of the experiment was to capture water run-off from sandy clay loam soils locally known as "gardud" for range improvement and to rehabilitate degraded environment in an area with an average annual rainfall of only 300-400 mm. These soils are characterized by hard compacted surface with high run-off potential resulting in inadequate water percolation that leads to poor establishment of natural vegetation and low forage biomass production.

Methods

Three treatments involving three methods of water harvesting were applied. These included runoff strips (ROS), contour ridges or bunds (CR) and flat as a control (C). Moreover, the effect of re-seeding was compared with natural regeneration (un-reseeded range). A split plot design was thus adopted with water harvesting practices as main factor and planting method as sub-plots with three replications. Plot size was 10 x 18.70 m, the area of each replication was 10 x 56.1 m and the total experimental area was 0.42 ha. Contour ridges were established on 6 plots at mid-June just before the onset of rains (Bancy *et al*. 2006); while ROS were established after receiving a few showers of rainfall after the soil became friable and suitable for reseeding (Hatibu and Mahoo 1999). In June 2010 and July 2011 and after the establishment of CR and ROS, seeds of rangeland species *Dactyloctenium aegyptium*, *Blepharis linarifolia*, *Crotalaria spp.* and *Aristida mutabilis* were broadcasted on 9 plots while the other 9 plots were left to regenerate naturally (un-reseeded). Forage biomass production (t/ha), plant density (plant/m^2) and vegetation cover (%) were then measured at the reseeded and un-reseeded sites to determine the effect of treatments on the various vegetation attributes.

At each of the 3 treatments in the water harvesting experiment 6 plots were located making 18 plots in all. Three quadrants of 1×3 m area were taken from each of the 6 plots making 18 quadrants/ treatment. Herbaceous vegetation within the quadrants was cut at 3 cm above ground level. Samples were dried at 105 ºC to constant weight. Plant density was measured in 18 quadrates from each treatment (Holecheck *et al.* 2004). Plant cover was estimated by 3 observers in each quadrate covered by vegetation. Total vegetation cover within each of the 54 quadrates from all treatments was recorded over two seasons. Soil moisture samples were taken from each experimental unit (18 plots) at different depths (0-15, 15-30 and 30-45 cm) by an auger, at wet condition (2 days after rain) and after a long dry spell (15 days after rain). Samples were covered and taken to laboratory for gravimetric moisture analysis (Michael 1978). Gravimetric moisture contents were calculated by expressing the percentage moisture on dry mass basis.

$$\text{Soil moisture content } \% = \frac{(a) - (b)}{(b)} \times 100$$

where: (a) = Mass of moisture sample and (b) = Mass of oven-dry sample.

An analysis of variance was conducted as a mixed model with water harvesting as main treatments and planting methods as sub-treatments in a split plot deign with Duncan's multiple range test for variable of SAS 1988.

Results

Rainfall pattern

Total annual rainfall was 304.5 and 297.8 mm in 2010 and 2011 respectively. Rainfall distribution was more even in 2010 (18 rainy days in 5 months) compared with 2011 (16 rainy days in 3 months). In 2010 rainfall was 18.0 mm in June, 121.1 mm in July, 108.6 mm in August, 28.0 mm in September, and 28.8 mm in October. In 2011 there were 58.9 mm in July, 160.0 mm in August and 78.9 mm in September.

Soil moisture content (%) two days after rainfall

During the 2010 season, gravimetric soil moisture content in CR, ROS and Flat was 15-25%, 10-21% and 2-5% respectively (Fig. 1). Differences between treatments in gravimetric soil moisture content were highly significant (P<0.001) suggesting that more water was retained by the terracing structures. This agrees with Elwaleed (2005) and Ahmed (2008) who reported significant differences in soil moisture content between water harvesting and control treatment.

At CR, soil moisture content was higher at depths of 0-15 and 15-30 cm than at a depth of 30-45 cm probably due to the concentration of water at the upper layers of soil (Fig. 2). Runoff strips showed higher soil moisture content at 15-30 and 30-45 cm depths than at 0-15 cm depth. This may be because chiselling improved the physical characteristics of "gardud" soil such as soil porosity thus permitted more water to infiltrate into the soil. Similar results were reported by Ahmed 2008 who found an increase in soil moisture content under the chisel and ridge systems presumably due to surface modifying effect of these tillage practices, which had improved the bulk density and increased soil porosity.

There were highly significant differences (P<0.001)

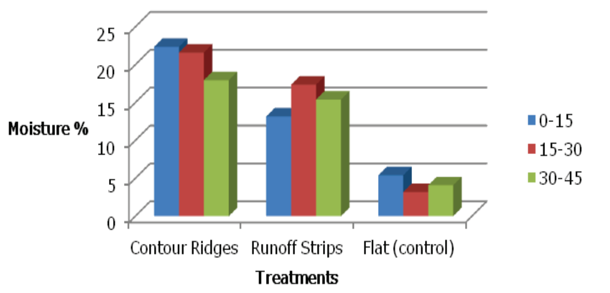

Figure 1. Soil moisture content two days after rainfall (12.6 mm) under three depths (cm)

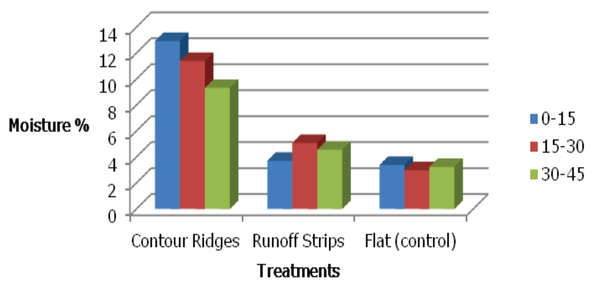

Figure 2. Soil moisture content at dry spell after 15 days of rainfall under three depths (cm)

between treatments fifteen days after rainfall, CR showed the highest soil moisture % which ranged between 9-13 % compared with ROS and flat which ranged between 3-5% and 2-3 % respectively. At CR the upper layer 0-15cm had higher soil moisture % than the 15-30cm and 30-45cm layers probably due to the concentration of water at upper layer of "gradud" soil. The second stratum of soil (15-30 cm) at ROS had higher soil moisture than the layers 0-15 cm and 30-45cm probably because of infiltration of water into the soil due to chiselling practice. Soil moisture content was lowest at flat (control).

Vegetation cover % at different water harvesting techniques

Differences between treatments in vegetation cover were highly significant (P<0.001), flat being significantly lower than CR and ROS at both sites (Table 1, Fig. 3). At the reseeded site mean cover for CR and ROS was 85.9% and 86.9% respectively; as compared to 38.9%for the flat. At un-reseeded site CR and ROS also produced higher vegetative cover than flat. This suggests that water harvesting has improved the vegetation cover by capturing and conserving more soil water compared with flat.

Plant density (plant/m²)

At reseeded range site plant densities were 262, 292 and 162 plant /m² for CR, ROS and flat respectively (Table 1). At the un-reseeded site densities were 223, 236, and 124 plant /m² respectively. In both range sites CR and ROS resulted in higher plant density compared with flat.

Forage biomass production (t/ha) at contour ridges, runoff strips and flat

Highly significant differences were observed between

Table 1. Vegetation cover (%) under contour ridges, runoff strips and flat

Treatments	Management system	1st season	2nd season	Mean	Probability
CR	Reseeded site	88.3	83.5	85.9a	
	Un-reseeded site	83.3	76.7	80.0a	(P<0.001)
ROS	Reseeded site	88.3	85.6	86.9a	
	Un-reseeded site	80.0	73.3	76.7a	(P<0.001)
Flat	Reseeded site	46.7	31.1	38.9b	
	Un-reseeded site	33.3	18.9	26.1b	(P<0.001)

Table 2. Forage biomass production (t/ha) at CR, ROS and flat at reseeded and un-reseeded sites

Treatments	Management system	1st season	2nd season	Mean	Probability
CR	Reseeded	4.1	3.2	3.65a	
	Un-reseeded	3.5	2.2	2.85a	(P<0.001)
ROS	Reseeded	2.6	1.9	2.25b	
	Un-reseeded	1.9	1.6	1.75b	(P<0.001)
Flat	Reseeded	0.7	0.6	0.65c	
	Un-reseeded	0.6	0.5	0.55c	(P<0.001)

Figure 3. Vegetation cover on CR (left), flat (centre) and ROS (right).

treatments; CR resulting in highest yields followed by ROS, Flat gave lowest yields (Table 2). The results suggest that water harvesting allowed capture and conservation of water to support plant requirements for growth while at flat water could not be captured adequately. A similar result was obtained by Elsadig *et al*. (2008) who reported that, water harvesting gives a positive indicator to improve the rangeland characteristics in terms of quantity and quality. Hani *et al*. (2011) reported significantly higher forage biomass production within contour furrows than within crescent and V- shape water harvesting techniques.

Conclusion

Application of water-harvesting techniques (CR and ROS) in soils with low water infiltration properties has improved soil physical characteristics, and increased soil moisture content. This in turn has led to capture and conservation of more soil water than in the control treatment (flat) which in turn has led to increased seed germination, higher seedling establishment and higher plant higher density which has resulted in enhanced forage biomass production.

Water harvesting and reseeding resulted in improved vegetation cover, plant density, relative density and frequency which suggest that these may be effective tools to increase forage biomass production from soils with low infiltration rate and high runoff potential, thus increasing livestock productivity and improving livelihoods in semi-arid environments.

Acknowledgments

The authors wish to thank Sudan University of Science and Technology for availing a scholarship for Ms Sahar to conduct this research as part of her PhD. Thanks are also due to Western Sudan Resource Management Programme and to El Obeid Research Station for their assistance.

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