Impact of Water Harvesting Techniques on Rangeland Characteristics of Butana Area, Sudan

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Abstract

Two seasons experiment of water harvesting, to evaluate the impact of water harvesting on rangeland characteristics, were conducted in Butana area in the East central of Sudan. Six sites were selected according to previous surveys in 2005, three different plots (catchments) sizes (1200, 800, 400 m^2) were designed to catch the rainfall water. The results of the study show a positive impact of water harvesting on rangeland vegetation in term of quantity and quality. The results of this study show that the production of the biomass is highly correlated with the amount of rainfall with high significance level ($P \leq 0.01$). The mean biomass of the three different plots for the six sites is 1.77, 1.63 and 0.96 ton ha-1 respectively, compared to normal conditions 1.03 ton ha-1. The study shows a highly significant difference ($P \leq 0.01$) with positive correlation between the plots area and the biomass production ($R^2 = 0.72$). Again the results showed a high significant difference ($P \leq 0.01$) but with negative correlation between the different zones (lines) and biomass production at P (0.01). The botanical survey differs from site to site and they also show a significant difference between different plots and different zones ($P \leq 0.01$) with the positive correlation with plot area and negative correlation with zones (lines) ($P \leq 0.01$).

Keywords: Water Harvesting, Rangeland Biomass, Rainfall variability, Runoff

Introduction

Dry lands cover about 5.2 billion hectares, a third of the land area of the globe (UNEP, 1992). Roughly one fifth of the world population live in these areas. Drylands have been defined by FAO on the basis of the length of the growing season, as zones which fall between 1-74 and 75-199 growing days to represent the arid and semi-arid dry lands respectively, and receiving rainfall between 0 – 600 mm annually (FAO, 1978).

The main feature of "dryness" is the negative water balance between the annual rainfall (supply) and the evaporative demand. Many of the world's drylands are grazing rangelands and characterized by the need to manage and cope with erratic events of rain that constrain opportunities for development.

In dry-lands, production is possible only when additional water is made available for cultivation. With declining investments in irrigation in developing countries, alternative methods, such as soil and water conservation, have become more important in recent decades (Turral, 1995). Water harvesting is one such technology and is based on the collection and concentration of surface runoff for cultivation before it reaches seasonal or perennial streams (Reij *et al.*, 1988).

Water harvesting is a broad umbrella definition including all methods for concentrating, storing and collecting surface runoff water in different mediums, for domestic or agricultural uses. A common straight-forward definition of water harvesting is the collection of runoff for productive use (Siegert, 1994).

Runoff can be collected from roofs or ground surfaces (rainwater harvesting) as well as from seasonal streams (flood water harvesting) (Agromisa, 1997). The harvested runoff can involve different forms of surface runoff (sheet, rill, gully and stream flow) and the storage is either done above ground, in different systems of tanks, reservoirs or dams, or below ground in the soil. Methods for harvesting runoff water can be distinguished after (i) source of the surface water (external or within-field catchments from sheet, rill, gully or stream flow), (ii) the method of managing the water (maximising infiltration in the soil, storing water in tanks/dams, inundating crop fields with storm floods) and (iii) the use of water (livestock, households, crop production and erosion management).

Water harvesting systems can be either passive or active. Passive systems are simple modifications to the existing landscape to utilize gravity for redirecting rainwater. Such systems require only minimal attention and direct water to the area of immediate use. Active systems redirect rainwater and also incorporate the collection and temporary storage of water. These systems require additional maintenance and active involvement both after a rainfall has occurred and during water applications. Either system, or a combination of the two systems, can be very simple to install if certain principles are followed and designs are carefully planned.

Water harvesting is practised in nearly all African dry-lands either in its indigenous form, or as technique introduced by international donor programmes (Van Dijk, 1995). Its scope as a low-cost alternative to irrigation is increasingly recognised in developing countries in other parts of the world (Napier *et al.*, 1994; Tabor, 1995; Gupta, 1995). Rain water harvesting techniques have been developed for various types of water collection from domestic rain water harvesting schemes through the micro to the macro flood control levels.

In Sudan, where the major part of it falls within the arid and semi-arid zones, different traditional water harvesting techniques and systems are being practiced since long and are still referred to in the literature by their traditional names, e. g. Haffir and Teru (Oweis et al., 1999).

The Butana area considered one of the best grazing areas in the country but, at the same time the least developed area of rural Sudan. In the central part, permanent settlements have been established around wells, based on a combination of animal husbandry and rainfed sorghum cultivation. Camels, cattle, sheep and goats are all kept in this area (Gunnar 2003), big and small communities live in the area and they share in the overall country economic by their contribution in livestock and agricultural products. Butana is very rich in its natural resources, but had no permanent sources of water except haffirs (artificial ponds) which last for only a few months after the rains. When these haffirs dried up, the visiting tribes had to leave the Butana. In some years, due to rain variability and uneven distributions of rains, the area suffer from severe shortage of water which reflects on quality and quantity of biomass production, drinking water and later has a great impact on the available biomass utilization because all of the herders concentrate their movements around water points and left the area soon after the rainy season, although the rangeland vegetation is still rich. In 1993 Akhtar stated that the southward drift of the isohyets during the last 15 years has led to a shift of vegetation formation towards the south. This was accompanied by southward migration of the nomads who did not find sufficient fodder supply for their animals in the North, mainly due to the drought-caused degradation of the natural vegetation approximately north of the latitude 15°. As a result of this movement the carrying capacities of the rangeland in centre and South of Butana experienced a significant reduction. Water harvesting emerges as promising techniques to overcome the rainfall variability and problems of water shortage in arid regions through its role in harvesting the appreciable runoff potential and keep it in the root zone. Many attempts have been done on the effect of water harvesting on crop production, but in this paper the main objective is to test the effect of water harvesting on rangeland biomass or dry matter production and diversification of species variety in central and south of Butana.

Material and Methods

The study was conducted in central Butana, between latitude 14° 32 and 15° 17 N and longitude 32° 21 and 34° 18 E as shown in Figure (1).

A preliminary survey was conducted in this area in the rainy season of 2005 and showed that there were two main vegetation units which highly depend on the type of the soil and climate variability. The first type dominates in the high red sandy clay soil (Goz) with much different types of Acacia species mainly *Acacia tortilis* and the second dominates in the black clay soils.

The Butana region is a flat clay plain in east-central Sudan, receiving annual rainfall ranging from less than 100 mm in the North up to 600 mm in the South with the maximum temperature reaching 40° C in April and minimum temperature about 17° C in January. Generally rainfall is characterized by uneven distribution and long dry spells that affected crops and range vegetation at their critical growth and filling stages which leads immediately to a significant reduction in production.

Six experimental sites namely, Wad nail, Camp1, Camp2, Elsial, Sobohab and Sangir were selected by their coordinates. The first three sites were chosen for clay soil and the last three for sandy clay soil. Rectangular plots (Fig. 2) were selected as the layout of the experiment and designed to be parallel to the direction of flow, four different size of plots given the numbers 1, 2, 3 and 4 with the surface area 60x20 m^2, 40x20 m^2, 20x20 m^2 and 20x20 m^2(control) respectively. The first three plots were consider as a separate catchments and totally closed in all sides by earth embankment while the last plot was left open as a control. Each of the first three plots was divided in two main units representing the runoff area and the harvesting area.

The experiment was run for two seasons (2006 & 2007) to estimate the primary production which includes the aboveground part of all vegetation produced during a single growth year, regardless of accessibility to grazing animals (USDA, SCS 1976). The samples for biomass had been taken from each line from1 m^2 from different five locations along each line (5 samples/line and 25 samples/plot). The biomass had been taken at maturity stage and taken to the laboratory for dry matter determination (Faichney *et al* 1983).

Soil samples for soil moisture determination were taken in the middle of the rainy season from two depths 0 -15 cm and 15 - 30 cm in the harvesting area. The samples were taken to the laboratory for soil moisture determination as in (Rowell 1994).

Floral survey was conducted in each line and the numbers of dominant species were identified.

Rainfall readings for the two season was taken from temporary installed rain gauges at each site

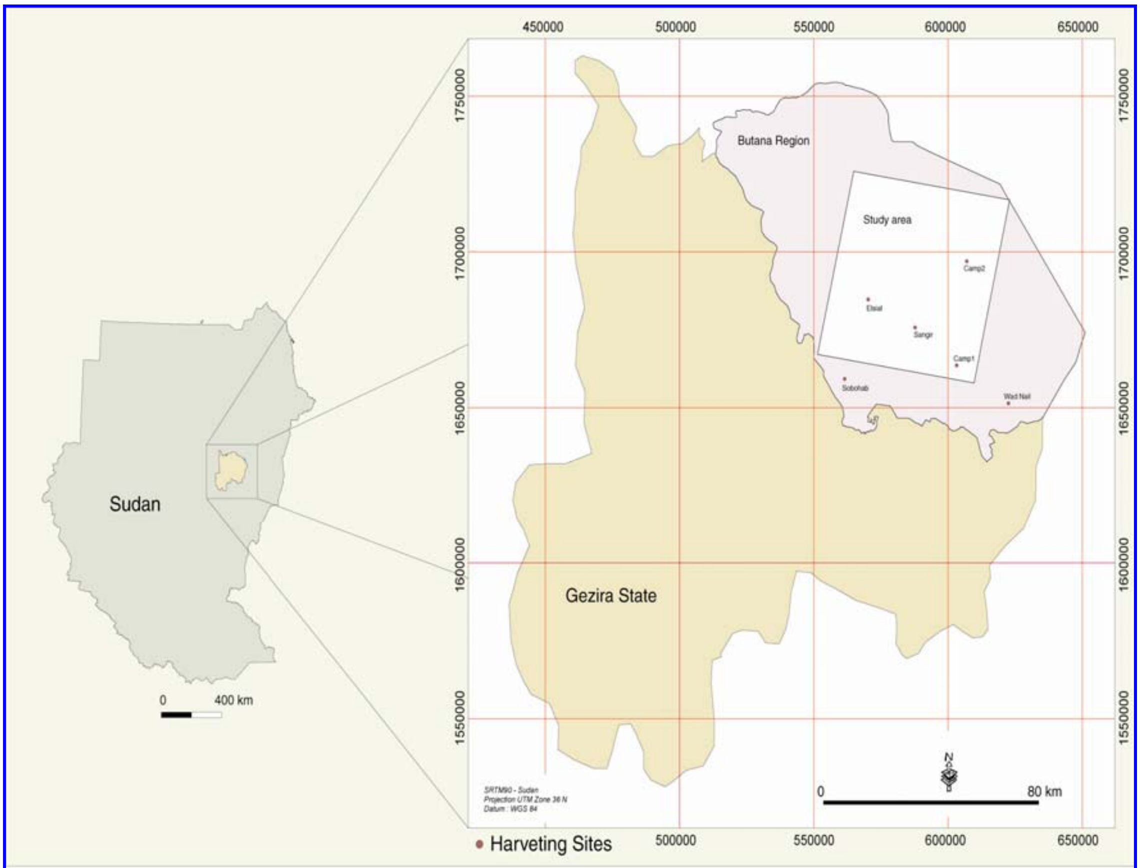

Figure 1: The location of the Butana Region and Harvesting Sites

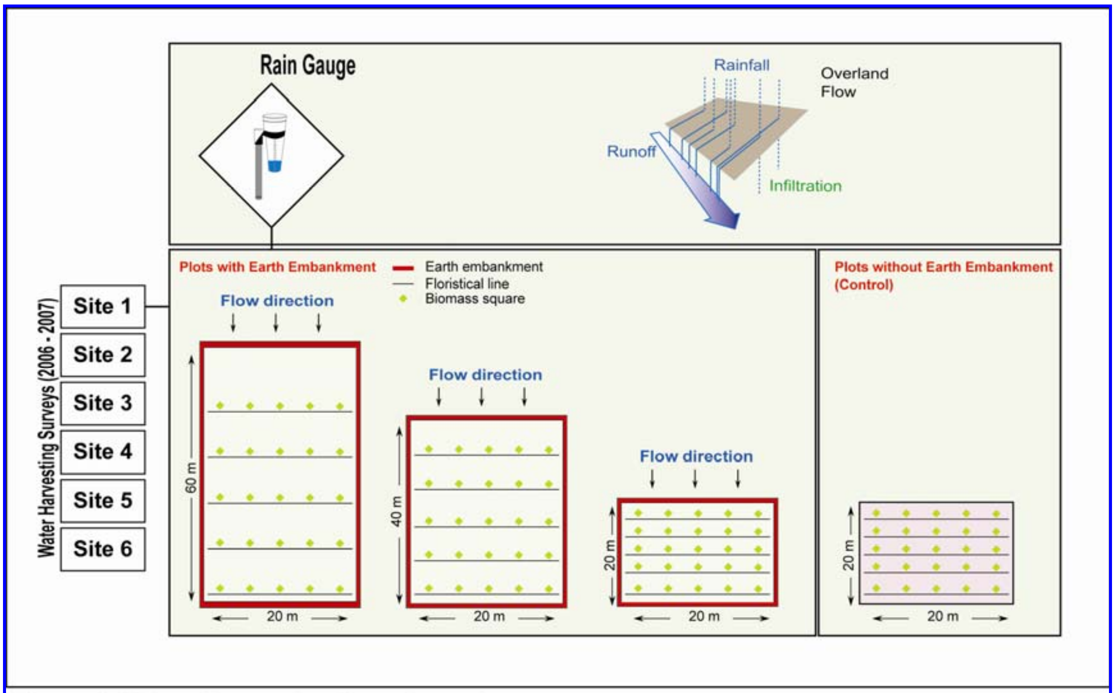

Figure 2: Water Harvesting Experiment Layout

Results and Discussion

The results of this study proved that there is great potential of water harvesting as a methodology to overcome the problem of water shortage due to the long dry spells occurring from the high variability of rainfall in the arid and semi arid regions of Butana area in Sudan.

The production of rangeland biomass differs from site to site as it's greatly affected by the amount of rainfall, type of soil and vegetation cover. The last site (Wad nail) shows a very high biomass production compared to other five sites and this due to the fact that this site is located in the southern heavy clay soil part of the area as in (fig. 3), hence receiving the highest amount of rainfall and also the dominant grass in this site is the Nal (*Cymbopogon nervatus*) which is relatively very high and dense grass.

Both seasons show high biomass production (Table 1) as a result of water harvesting technique, however the biomass is less in season 2007 because most of the rainfall occur in the beginning of the rainy season, 71% of rainfall from late June to late July, followed by long interval showers in August, September and October.

The effect of plot area on biomass, harvested water, soil moisture and number of species in both seasons is clearly explained in Figure (3), table (1 & 3). The mean value of biomass, harvested water, soil moisture and number of species show a very high significant difference between different plots areas ($P \leq 0.01$) with a positive high significant correlation ($P \leq 0.01$) except for the number of species which was unlikely found with negative correlation with biomass ($P \leq 0.05$), however the difference is not significant between plot (1 & 2) and (3 & 4). In five sites from six sites, it was found that the normal condition represented by control plot produce higher biomass than plot (4) with a surface area of 400 m², this result showed that the water harvested in this plot is not sufficient to grow more vegetation compared to the control plot which receives more water by runoff from adjacent areas.

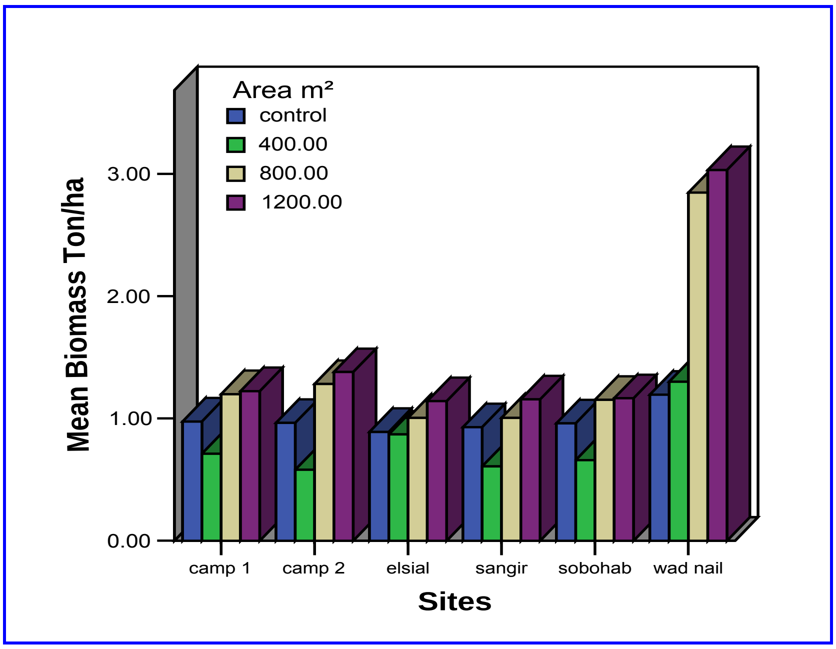

Figure 3: Average Biomass Production in Different Sites and Different Plot Areas

Within each plot the biomass show a gradient increasing from the top of each plot to the bottom due to the large amount of soil moisture in the root zone resulting from water harvesting, this result is shown in figure (4) and table (2 & 4), these tables show that the mean value of biomass, soil moisture and number of species between different lines (zones) along each plot have a significant differences (*P≤ 0.01*), but with negative correlation because measurement values of all the above variables are decreasing when ascending from the bottom to the top of the plot (line 1 to line 5).

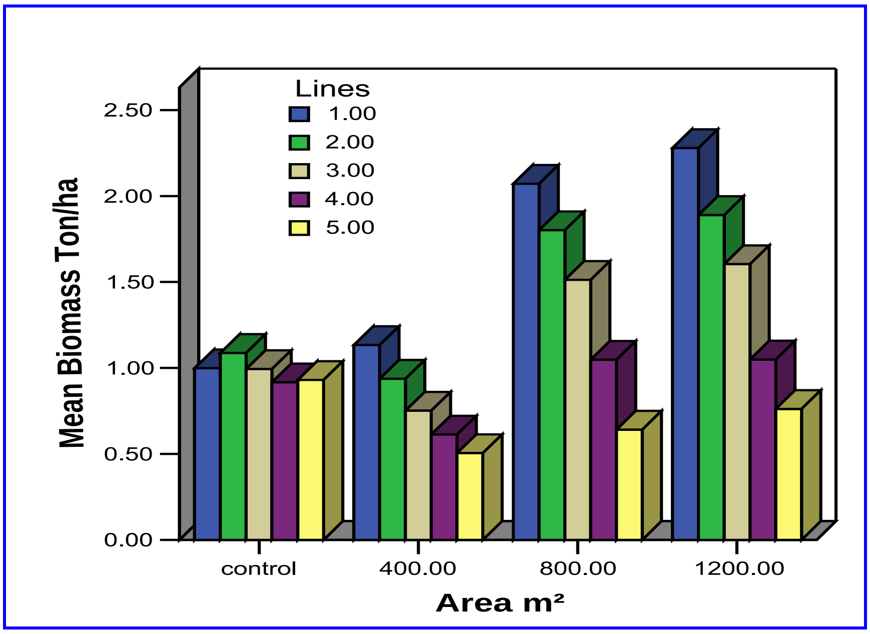

Figure 4: Average Biomass Production in Different Plot Areas and Different Lines

Since the main objective of this paper is to produce more biomass and maximize the scarce water productivity to improve the carrying capacity of Butana rangeland and gives better chance to increase the abundance of palatable species, it was found that the production of biomass is a function of harvested water as explained by the equation (1) derived from the regression curve in figure 5 ($R^2 = 0.88$).

$$\text{Biomass (Ton ha}^{-1}\text{)} = 0.0092\ \text{(Harvested Water (m}^{3}\text{))} + 0.0853 \quad (1)$$

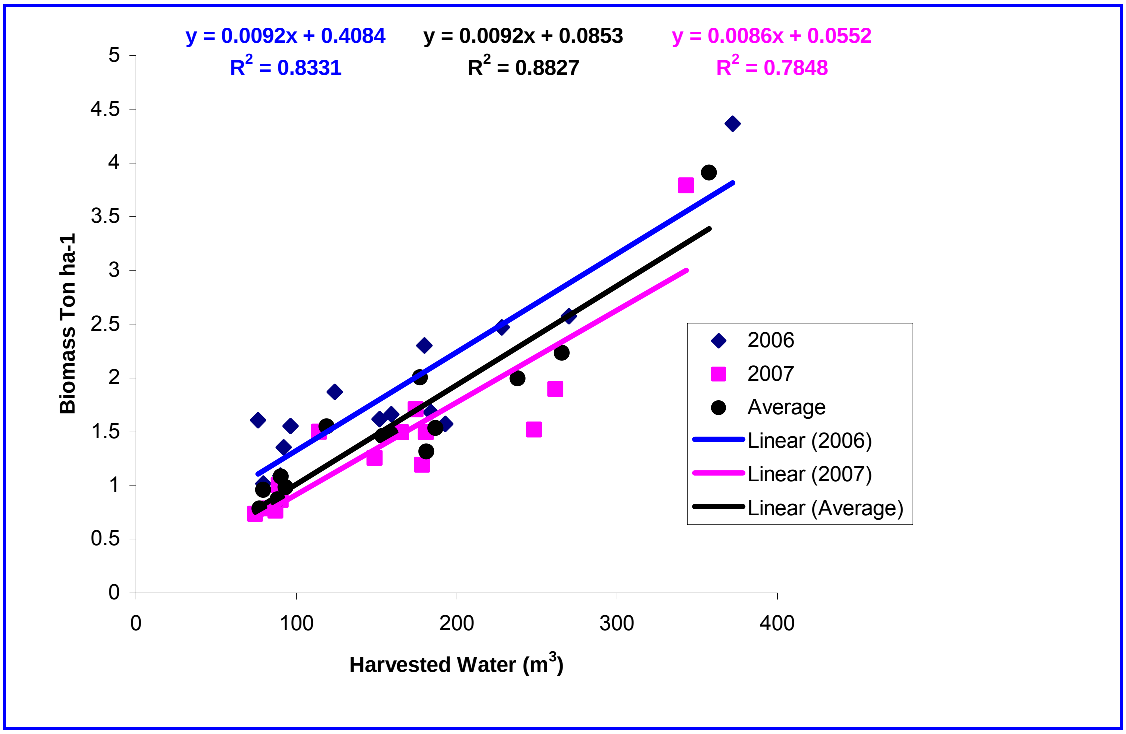

Figure 5: The Relationship Between Biomass and Harvested Water

However this two-season result will not be considered as a general model for rangeland water harvesting biomass in Butana area, but it gives a positive indicator to improve the rangeland characteristics in term of quantity and quality. The result indicate that harvesting in catchment less 400 m^2 is not recommended, however harvesting in catchment more than 800 m^2 and above gives satisfactory results, but should be put in consideration the construction works needed for large catchment area harvesting.

The potential of water harvesting for rangeland biomass in Butana could be more than was founded in these results and its application success needs further information concerning the suitable areas, soil type, rainfall map, catchment size, construction requirement, public awareness and social acceptance.

For homogenous utilization of rangeland resources, water harvesting for biomass must be accompanied by channel runoff harvesting for drinking water points.

Table 1: The Effect of Plot Area on Biomass, Harvested Water, Soil Moisture and Number of Species 2006 - 2007

	Biomass Ton ha^{-1}		Harvested Water m^3		%Soil Moisture 0 – 15 cm		%Soil Moisture 15 – 30 cm		Number of Species	
Season	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Mean	1.62**	1.18**	162.75**	134.60**	11.31**	12.24**	11.90**	12.85**	4.33**	4.25**
STDV	1.07	0.76	106.41	102.99	2.00	3.13	2.32	3.32	1.21	1.20
R^2	0.71	0.72	0.93	0.92	0.87	0.85	0.88	0.85	0.82	0.80
SE	0.05	0.03	4.86	4.20	0.11	0.17	0.12	0.18	0.06	0.05
CV%	66.05	64.19	65.38	76.52	17.68	25.58	19.50	25.84	27.94	28.23

** Difference is significant at the 0.01 level.
* Difference is significant at the 0.05 level.

Table 2: The Effect of Line Location on Biomass, Soil Moisture and Number of Species 2006 - 2007

	Biomass Ton ha^{-1}		%Soil Moisture 0 – 15 cm		%Soil Moisture 15 – 30 cm		Number of Species	
Season	2006	2007	2006	2007	2006	2007	2006	2007
Mean	1.62*	1.18**	11.31**	12.24**	11.89**	12.85**	4.33*	4.25**
STDV	1.07	0.76	2.00	3.13	2.32	3.32	1.21	1.20
R^2	0.51	0.44	0.77	0.77	0.76	0.77	0.71	0.72
SE	0.05	0.03	0.11	0.17	0.12	0.18	0.06	0.05
CV%	66.05	64.19	17.68	25.58	19.51	25.84	27.94	28.23

** Difference is significant at the 0.01 level.
* Difference is significant at the 0.05 level.

Table 3: Correlation Between Plot Area, Line, Biomass, Harvested Water, Soil Moisture and Number of Species (2006)

	Plot Area m²	Line	Biomass Ton ha^{-1}	Harvested Water m^3	%Soil Moisture 0 – 15 cm	%Soil Moisture 15 – 30 cm	Number of Species
Plot Area m²		0.32(**)	0.36(**)	0.49(**)	0.52(**)	0.91(**)	0.21(**)
Line			-0.15(**)	-0.25(**)	-0.27(**)	0.31(**)	-0.16(**)
Biomass Ton ha^{-1}				0.61(**)	0.61(**)	0.50(**)	-0.12(*)
Harvested Water m^3					0.97(**)	0.60(**)	0.21(**)
Soil Moisture 0 – 15 cm						0.60(**)	0.20(**)
Soil Moisture 15 – 30 cm							0.12(**)
Number of Species							

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.

Table 4: Correlation Between Plot Area, Line, Biomass, Rainfall, Harvested Water, Soil Moisture andNumber of Species (2007)

	Plot Area m²	Line	Biomass Ton ha^{-1}	Rainfall mm	Harvested Water m^3	Soil Moisture 0 – 15 cm	Soil Moisture 15 – 30 cm	Number of Species
Plot Area m²		N/A	0.37(**)	N/A	0.92(**)	0.58(**)	0.58(**)	0.20(**)
Line			-0.44(**)	N/A	N/A	-0.31(**)	-0.30(**)	-0.20(**)
Biomass Ton ha^{-1}				0.51(**)	0.45(**)	0.55(**)	0.56(**)	-0.09(*)
Rainfall mm					0.18(**)	0.42(**)	0.46(**)	-0.22(**)
Harvested Water m^3						0.69(**)	0.68(**)	0.14(**)
Soil Moisture 0 – 15 cm							0.97(**)	0.13(*)
Soil Moisture 15 – 30 cm								0.13(*)
Number of Species								

** Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.
N/A: Not Applicable.

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