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Animal Traction for Soil Cultivation, Water Harvesting and Production of Sorghum on Gurdood Soil of North Kordofan State – Sudan

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Abstract*: Animal traction is very important in rural areas of Sudan mainly for cultivation and crop production. This study was conducted to investigate the effect animal traction for cultivation and as water harvesting techniques in sandy loam "gurdood" soil of North Kordofan State for improving water conservation and production of sorghum. A field experiment was carried out in four different sites, using randomized complete block design and four treatments (animal drawn cultivator, rectangular digs, combination of cultivator and digs and control), replicated three times for two seasons. Data were collected on field performance of animal drawn cultivator, field efficiency (FE), field capacity (FC), draft power and cultivation cost, soil moisture content and soil infiltration rate. The effect of treatments plant height, leaf area index and crops residues and seeds yield was also measured. The results of the two seasons showed high field efficiency (76.25%) and high field capacity (0.19fed/hr) of cultivator. The cultivation operation cost decreased to 31% and 61% compared to hand labor and tractor, respectively. Animal drawn cultivator with digs has significantly increased the soil moisture content in the upper layer. Soil infiltration rate was increased by 59% in the cultivated soil with water harvesting digs compared to the control. The cultivator with digs increased plant height, leaf area index, sorghum grain yield and residues by 29%, 25%, 38% and 39%, respectively, compared to the control.*
The study concluded that introduction of animal traction and water harvesting techniques on gurdood soil of North Kordofan State can improve soil properties and increased the yield of seeds and residues of crops. The animal traction can alleviate the burden on the rural women, solves scarcity in hand labor and decrease cost of production.
Key words: *animal traction, cultivation, water harvesting, gurdood*

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I. INTRODUCTION

There are global interest and efforts towards reformation of small farming agricultural sector, and for promotion of its production to supply enough food security for the ever-increasing world population. Also, there is awareness raised that; much of the current level of agricultural production is being achieved against the coming generation soils [1]. Sudan is one of Sub Saharan African countries in which most of the areas used by small scale farmers are extremely degraded and productivity of land was reduced [2]. The agricultural production is also very much affected due to variability of rainfall and drought and scarcity and cost of hand labor. Agricultural production increases nowadays come though horizontal expansion which negatively affected the environment by removing of vegetation cover [3]. The State of North Kordufan lies within the semi-arid climate whereas; the rainfall is between low and intermittent. The annual rainfall, which falls in summer, ranges from about 50 mm to about 400 mm [4]. Such amount of rainfall is inadequate to meet the full water requirements of the main crops grown in the state. Water is perhaps the most important single factor that limits crop growth and production in the semi-arid zone, particularly in tradition agriculture which is heavily reliant on rainfall [5]. Productivity and production of crops are strongly influenced by climatic change during the last decades, so new strategies and interventions concerning the rain water harvesting techniques are required [6], [7]. The vertical expansion of agricultural production can be achieved through the improvement of the characteristics of the different factors that control crops productivity, such as soil, water and cultural practices. for better utilization of some types of compacted soils [8]. During the last three decades the prevalent climate has negatively changed and consequently, most of the traditional rain fed agriculture in the northern parts of the state, where most soils are sandy, has been markedly reduced and that farms are abandoned [4]. Moreover, the scarcity and inadequacy of hand labors that resulted from movement of people to other types of jobs was created an acute demand to find other source of power. The animal power might be the alternative that supposed to provide the appropriate, easy operate for cultural practices [9], [10], [11], [12]. The target soil which locally known as "Gurdud" soil, has some problems such as surface crust, compaction, slow permeability and partial truncation by wind made it hard and solid at surface, therefore, not widely used in production of both food and forage [1]. If the problems pertaining to "Gurdud" soils are solved, present and future of agriculture in the state will largely be solved, because this type of soil covered large parts of the state and have good agricultural potentiality. Attempt to such solution is introduction of water harvesting techniques which has not been practically tried in North Kordofan state, although it has been adopted in various part of the world with a view to increase soil moisture content and hence crop and forage yield [13], [14]. Therefore, the present research work was conducted to find the appropriate techniques to solve the problem under study, through investigation the effect of some water harvesting techniques with animal traction cultivation on "Gurdud" soil on sorghum crop growth and yield.

II. MATERIALS AND METHODS

2.1 The study site location and soil

The research was conducted in North Kordufan state in the central of the Sudan marked between latitudes 12°40´N and 14°20´ north; and longitudes 28°10´East and 31°40´east. The soil of study area is sandy loam which locally called "Gurdud" and covers about 30% of the state land ([4]MOA, 2005). The soil of the study area is hard, non-cracking sandy clay with low water infiltration rates and represents one of the main types of soil in the north, centre and the southern parts of North Kordufan region. Table 1 below shows some soil physical and chemical properties [15].

Table 1. Some soil physical and chemical properties of North Kordufan region

Soil depths (cm)	Particle size distribution %			Soil chemical properties		
	Sand	Silt	Clay	SAR	EC	PH
0 - 10	68	12	20	1.9	0.5	6.8
10 - 20	70	13	17	1.8	0.6	7.6
20 - 30	66	12.9	21.1	1.3	0.5	7.8
30 - 40	68	11.6	20.4	1.4	0.4	8.2
Average	68	12.4	19.6	1.6	0.5	7.6

2.2 Implements & equipments used

The modified Nubian plough (cultivator) is an animal drawn plough used for land preparation, land cultivation land reclamation with the specifications of weight 30 kg, width 80 cm. and set on one front wheel and has five flexible springs to minimize the impact of the collision with solid objects and five blades on three rows fixed on the main shaft of the plough. The tines are adjustable horizontally and vertically. Two of the tines are on the back and middle rows while one is in the front row (Plate 1). The digging machine (plate 2) composed of moldboard blade, hand and connecting fount shaft used for connecting the implement to the plough. It's also can be draft alone but this will add addition cost.

Plate (1) Plough (cultivator)

Plate (2) digs (barriers) maker

Plate (3) digs (barriers) maker attached to the cultivator

Other materials used are, five meters length tape for measuring the blocks areas, two stopwatches for time recording and sensitive weight balance for weighting crops seeds and residues.

2.3 Experimental design and layout

The experimental design adopted for this study was randomized complete blocks design in four sites with four factors; animal cultivator with water harvesting techniques (digs) (AC+WT), animal cultivator only (AC), water harvesting techniques (digs) only (WH) and control plots without any intervention. Each site composed of twelve plots in three blocks, each of an area of $60m^2$. The different treatments were distributed randomly in each block. Land preparation was carried out in early rainy season, on the four experimental sites, by removal all plants, shrubs and trees residues. The modified Nubian plough used as cultivator in each of the four sites.

2.4 Water harvesting technique

The digs designed as single open ends structure (Fig.1), however, the storage capacity of this type is less than that of closed system, but it's simple and practical for small holders and can easily maintained manually during the rain season. The digs made at the field with ploughing process by attaching digs maker to the plough Plate (3).

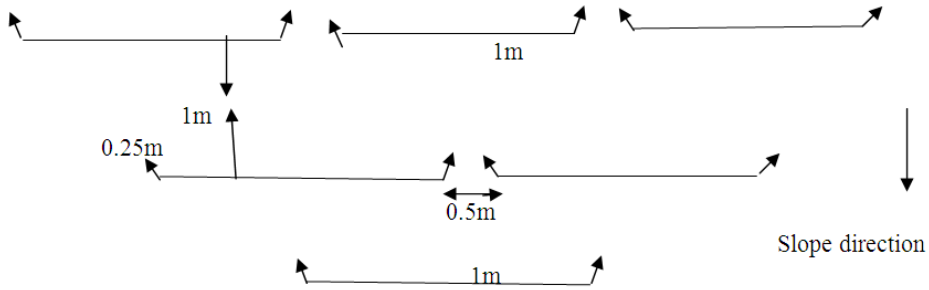

Fig.(1) Digs structure and layout

2.5 Animal traction description

Horses were the animals used for drafting the modified Nubian plough for cultivation. The implement tided to the animal at the harness in two linking points by using two thick ropes of 2.5m long linkage to yoke of wood 50cm on the front part of the plough and of 1m length. The harness made by local craftsmen from materials which locally available includes wood, leather and metal which made it cheap and easily maintained [16]. The cultivation process done by two trained labors, one to lead the animal and the other for adjusting the plough and pulling the plough hands at the turning points (Plate 4).

Plate (4) the draft animal with two labour and the cultivator

2.6 Animal drawn cultivator field performance measurements

Field efficiency (FE)

Field efficiency is an important criterion for making important machinery management decisions. The field efficiency measured by the following equation as stated by [17].

$$FE = \frac{Tt - Tw}{Tt}$$

Where: Tt = Total time (min), Tw = wasted time

Rate of work (Field capacity - FC)

The rate of work calculated by using the following equation, as mentioned by [16].

$$\text{Rate of work (FC) (fed/hr)} = \frac{\text{Area covered in } m^2 \times 60 \text{ min}}{\text{Total time in the field (min)} \times 4200}$$

Draft power

Draft force was taken as percentage of the animal body weight (10 to 12 percent of the animal body weight as stated by [18]. The domestic horse weight in the study area was 250kg [4]. The draft power can be calculated by the following equation as mentioned by [19].

$$\text{Draft power} = \frac{\text{draft force x distance}}{\text{Time/sec.}} \quad \text{or} \quad = \text{draft force (kg)} \times \text{speed (km/hr)}$$

It was stated that the speed of draft animal was 1m/sec or 3600m/hr =3.6km/hr in fine and medium soils [20].

Cost of operation

The cost of operation includes the cost of ownership and operation. 10% of the plough price as annual depreciation, cost of animal feeding and health care, cost of hiring labors, cost of accessories and the cost of repair and maintenance of the implement [21]. Cost of operations was determined as average of the two years, because some items were fixed such as plough annual depreciation and animal health care, while other items were changed during the two years.

Soil Infiltration rate measurement

The double-ring infiltrometer is often used for measuring infiltration rates, as described by [22] and [23]. The double-ring infiltrometer test is a well-recognized and documented technique for directly measuring soil infiltration rates. The measurements done three times; at the soil preparation, at the peak of vegetative growth and at harvesting.

Soil Moisture contents (MC %)

The soil samples were from four depths (0-10, 10 -20, 20-30 & 30 -40cm), dried at of 105C° for 24 hours and the soil moisture contents (MC) determined according to the following equation;

(MC %) = W2-W3/W3-W1 X 100

Where:

W 1 = Weight of tin (g)

W 2 = Weight of moist soil + tin (g)

W 3 = Weight of dried soil + tin (g)

Plant height measurements

The plant samples were selected in each site by using steel frame (1x1 m). The plants in the one-meter square were measured once at harvesting and the measurement made from the ground surface to the tip of the plant using measuring tape of 5m (Plate 5). The records are average of three randomly selected area plants and measurements for all treatments, as described by [24].

Plate (5) Sorghum plant height.

Plate (6) Sorghum (grain) seeds.

Crops grain yield and residues weight measurements

At crop maturity, yield samples were taken by steel frame of ($1x1m^2$). The spikes of plants within each frame were carefully collected in bundles, labeled and left to dry for seven days and clean grains were weighed (Plate 6). The yield per unit area determined, by the following equation.

$$\text{Grain yield (kg/fed)} = \frac{\text{grain sample weight(kg)} \times 4200}{\text{unit area } (m^2)}$$

The crop residues (stems + leaves) within per unit area was also determined as follows:

$$\text{Crop residues yield (kg/fed)} = \frac{\text{plant residues weight(kg)} \times 4200}{\text{unit area } (m^2)}$$

Statistical Analysis

statistical analysis was carried out for the collected data using Analysis of Variance table (ANOVA) and means were separated using Least Significant Difference (LSD) at 5 % and 10% level of probability.

III. RESULTS AND DISCUSSION

3.1 Field efficiency (FE) and capacity (EFC) measurements

The field efficiency was calculated as an average of cultivated plots in each site, for the four sites and for the two seasons through measuring the average time for ploughing in all blocks. Table 2 showed that, the average field efficiency was high hence the wasted time was less than quarter (23.75%). Time factor is of a vital importance in agricultural production, so the high field efficiency which may be attributed to the short time spends in repair and maintenance. This indicates that using of animal drawn plough for Gurdud soil cultivation ensures better utilization of time. These results agreed with that recorded by [25] and [26].

The average rate of work (EFC) in each of the four sites was high (table 2), when considering the time used for work on daily basis was 6hr/day therefore the daily performance of the draft animal was 1.14 fed/day. Therefore, this rate of work is satisfactory for small farmers whose annual cultivated land was 18 fed/year. This result agreed with what had been recorded by [27]. On the other hand, when the average annual time for plowing is 30 days, the annual plowed area will be 26.1 fed, which is more than the annual average cultivated area by the household which was estimated as 18 fed/year [8]. Therefore, farmers who owned draft animal with plough can get income from hiring to other farmers besides ploughing their own farm as stated by [4]. This can improve the life standard of rural people by creation new source of income. The average draft power of the animal was found suitable for drafting the implement and land cultivation in this type of soil. This is in line with that reported by [28].

Table 2. Average field efficiency, Field capacity and draft power of the animal draft cultivator in the four sites

Sites	Total time (min)	Wasted time (min)	FE (%)	FC (fed/hr)	Draft power (kW)
1st Site	2.50	0.66	75	0.16	0.26
2nd Site	2.74	0.56	80	0.18	0.27
3rd Site	2.87	0.6	79	0.19	0.27
4th Site	3.09	0.9	71	0.23	0.28
Average	2.80	0.68	76.3	0.19	0.27

3.2 Effect of animal traction & water harvesting techniques (digs) on infiltration rate and soil moisture content (Average of two seasons)

Table (3) showed highly significant differences between treatments effect on the infiltration rate, white between the differences was insignificance. The cultivated with harvesting technique recorded the highest infiltration rate as 0.7 cm/min) compared to 0.44 cm/min of the control. Therefore, the infiltration rate by 59% which is due to the improvement of soil physical properties and minimizing the runoff and the rain water will increase the soil conservation percentage and avoid loses of water from the run off and evaporation. These results agreed with [29] and [30]. Animal cultivator alone and water harvesting technique alone were also increased the infiltration rate by 27% and 18% compared to control.

Table 3. Effect of animal traction and water harvesting techniques (digs) on infiltration rate (cm/min) (Average of two seasons)

Site	Treatments				Mean
	AC+WH	AC only	WH only	Control	
1st site	0.54	0.52	0.48	0.46	**0.50**
2nd site	0.63	0.50	0.52	0.46	**0.52**
3rd site	0.69	0.45	0.48	0.44	**0.52**
4th site	0.95	0.75	0.56	0.37	**0.66**
Mean	**0.70**	**0.56**	**0.52**	**0.44**	
S.E. ±	**0.135**				
P- Value	**0.091****				

* AC+WH= Animal traction with water harvesting techniques. * AC= Animal traction only
* WH = Water harvesting techniques only * control= No animal traction and water harvesting

It was observed that, soil moisture content was generally higher in the upper two depth, 0 –10cm, 10-20 cm (table 4). These depths represent the growth zone of sorghum roots. Animal cultivator with water harvesting digs treatment recorded the highest moisture content compared to other treatments. There is highly significant difference at 1% in soil moisture content between depths and treatments. These results agreed with what was found by [31].

Table 4. Effect of animal traction & water harvesting techniques (digs) on soil moisture contents (average of the two seasons).

Soil depth Treatments	0 - 10 Cm	10- 20 cm	20- 30 cm	30- 40 Cm	Means
AC+WH	11.50	11.48	11.34	11.63	11.49
AC only	11.48	11.48	11.36	11.53	11.46
WH only	11.38	11.40	11.42	11.53	11.43
Control	11.36	11.38	11.37	11.39	11.38
Means	11.43	11.44	11.37	11.52	
CV %	0.40%				
P-Value	0.000**				

3.3 Total cost of field cultivation operation

Table 5 showed the total cost of operation was 1655 SDG per year, while the cost per feddan was 92.0 SDG/fed. In the area around the experiments sites, the costs of using hand tools and tractors was found 300 SDG and 150 SDG per feddan respectively, although it's not accessible for all farmers to get tractors due to the farms size and distances between farms at one community as stated by [14]. It can be observed that using animal drawn plough decreased the cost of ploughing operation by 69% and 39% compared to hand tools and tractors respectively. This is in line with the findings of [32]. The animal draft will also help in early and better performing of ploughing practice which considered one of most difficult and labour consuming operation, as stated by [4], [33] stated that using of animal drawn implements for ploughing was decreased the cost by 58% compared to the hand tools.

Table 5. Cost components of land ploughing by animal drawn cultivator

Item	Cost SDG
Implement annual depreciation 10%	50
Animal feeding and health care	200
Accessories	115
Repair and maintenance	90
Hiring of two labors 30days x40SDG	1200
Total	1655

3.4 Effect of Animal traction and water harvesting techniques on plant height (cm), LAI and weight of sorghum residues and seeds (kg/m^2)

Table 6 showed that animal drawn cultivator and water harvesting techniques increased the sorghum plant height, leaf area index, by 29% and 25% respectively, compared to control. This may be due to the suitable growth environment. However, the vegetative growth is one of most important factors of the crop yield. These results agreed with that of [34]. Highly significant differences were observed between the treatments effect on weights of sorghum residues and seeds in kg/m^2 (table 6). The animal drawn cultivation with water harvesting digs treatment recorded higher average sorghum residues and seeds weight by 39% and 38% respectively compared to control.

Table 6. Effect of Animal traction and water harvesting techniques on, LAI, plant height (cm) and weight of residues and seeds of sorghum (kg/m^2)

Treatments	LAI	Plant height	Wt. of residue	Wt. of seeds
AC+WH	6.41	195.08	0.97	0.65
AC only	6.04	185.02	0.87	0.53
WH only	6.25	186.30	0.85	0.54
Control	5.14	151.07	0.70	0.40
Mean	**5.96**	**179.37**	**0.84**	**0.53**
P-Value	0.000**	0.074*	**0.033 ****	**0.026****

These findings were in line with what obtained by [35] and [36]. Therefore, it was important to consider the added values of increasing both sorghum seeds and residues yield, which are commonly used for human and their animals feed as well as cash income. All these improve the living standards of the farmers in rural communities**.** This agreed with reports of [37].

IV. CONCLUSIONS

The following conclusions may be drawn from the results of this study:

1-The high rate of work of draft animal (0.19fed/hr) with the high field efficiency (76.25%) was appropriate for small-scale farmers whereas the annual cultivated land is less than 20fed.

2- The cost of operation was decreased by 69% and 39% compared to hand tools and tractors respectively, so it was added value to the crops production in the study area. Animal draft-power is the source of power in the rural areas as solution of scarcity of hand labor,

3- Water harvesting techniques and animal traction ploughing increased the yield of sorghum seeds and residues by 38% & 39% respectively, which improve the living standards of the farmers in rural communities

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