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Eltigani E. Bashier Abdelgalil[1]

Sowing dates and crop replacements strategies to adapt climate change impact on traditional rain fed agriculture in semi arid regions: A case of North Kordofan in Sudan

[1] **Water Management and Irrigation Institute,** University of Gezira
P.O Box 20, Wad Medani, Sudan
Email: eltigani9@hotmail.com

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Abstract

Purpose The purpose of this paper is to develop agricultural and water management strategies to help poor traditional rain fed farmers to adapt climate change impact on agriculture in North Kordofan region in Sudan.

Methodology Historic climate data from the study area were collected and analyzed using CROPWAT model version 8.0. Reference Evapotranspiration (ETo), effective rainfall and irrigation requirements to develop different sowing dates strategys were also measured using CROPWAT model. Field visits observations and discussion with farmers also helped the author in results justifications.

Findings The study found that early sowing dates is better than late sowing in traditional rain fed sector in North Kordofan. Early sowing date secured water for almost 70 days of the crop cycle. Also under early sowing dates, soil moisture can maintain the crop at a later stage of growth. The paper investigated that drought tolerant Sesame crop replaced the millet crop for climate adaptation purposes in North Kordofan.

Value This research study is considered the first to develop agricultural and water management strategies to cope with climate change impact on traditional rain fed agriculture in North Kordofan, Sudan. The paper highlights innovations farmers are making to adjust to the changes they observe.

Keywords Climate change, agricultural strategies, traditional agriculture, semi-arid region, kordofan, Sudan

Introduction

Intergovernmental Panel on Climate Change (IPCC)(2007) predicts that during the coming decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages that will cause shifts in crop growing seasons. Climate scientists stated that adaptation is local since the most direct impact of climate change is felt locally. Consequently response measures must start at that level taking into consideration specific local circumstances. It is expected that lower income populations and marginal agricultural regions, particularly arid areas, are most vulnerable to climate change. Döll (2002) stated that two-thirds of the global area equipped for irrigation in 1995 will possibly suffer from increased water requirements. Climate change studies for Africa tend to predict a reduced potential for farming that will affect the food security situation of an already impoverished population. Parry et al. (1999) indicated that a particular example is Africa, where it is expected to experience marked reductions in yield, decreases in production, and increases in the risk of hunger as a result of climate change. Climate change scientists stated that, by 2030 climate change serious effects may lead to reduced crop yield even in tropical areas. Rosenzweig et al. (1994), stated that a global assessment of the potential impact of climate change will lead to only a small decrease in global crop production. But developing countries are expected to bear the brunt of the climate change impact problem. Climate change require strategies and actions to reduce its impact as (Burton, 2009) explained that adaptation refers to all those responses to climate change that may be used to reduce vulnerability, or to actions designed to take advantage of new opportunities that may arise as a result of climate change.

Farmers in Sudan who depend on agriculture for their livelihood are heavily influenced by climate change particularly in outskirts of Sudan. The impact of climate change will influence economic development particularly Sudan as an agricultural dependent country. The climatic conditions of Sudan described as hot and dry, arid desert and rainy season varies by region (June to November). Agriculture is and will continue to be a key sector for Sudanese farmers. However, agriculture sector is highly depreciated during oil producing time in Sudan. In addition agriculture, is more sensitive to climate change as crop, water and soil systems are strongly associated with climate change. The Sudanese agriculture is based on three farming systems, the traditional and mechanized rain-fed agriculture and the irrigated sector. Currently Sudan's inherent vulnerability to climate change is captured by the fact that food security is mainly determined by rainfall, particularly in rural areas where more than 60% of the population lives. In season 2011, rain started 30 days late in a greater part of Sudan. After separation of South Sudan, the amount of rainfall in the northern part of Sudan ranges between zero to 400 mm annually and about 40% of the country lies in the dry zone. Humid agro-climate zones shifted southwards rendering the northern increasingly desert area. The unreliable nature of rainfall together with its concentration during the short growing season increases the vulnerability of the traditional rain fed agricultural system. A trend of decreasing annual rainfall in the last 60 years (0.5%) and increased rainfall variability is contributing to drought conditions in many parts of the country particularly North Kordofan Region. A study in western Sudan conducted by Osman et al. (2007), indicated that some community–based adaptations have dramatically assisted local communities in surviving extreme drought. In the study area there is on clear and specific strategies to cope with climate change particularly in agricultural sector. This paper utilized available climate information to develop agricultural and water management strategies such as shift in crops sowing dates and crops replacement to help traditional rain fed small farmers to cope with climate change in Sudan.

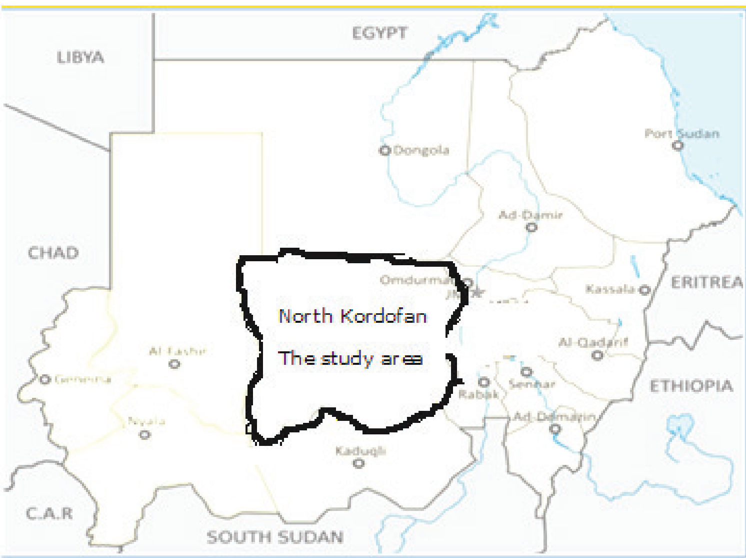
This paper is organized in six sections. Section one (foregoing) includes the introduction. Section two describes the area where the research has been conducted. Section three explains data collection methods. The results are presented in Section four. Results are discussed in Section five and Section six provides the conclusion.

Study area

North Kordofan

North Kordofan Region is situated in the mid-west of Sudan (figure 1). It is located between latitudes 14°22 and 29°32. It covers an area of about 185,302 km^2,. The region has a total population of about 2.6 million. The urban population constitutes 13% of the total population, nomads 24% and the sedentary rural population 63%. The area is semi desert, characterized by low rain fall and sandy soil with low crop productivity and successive droughts. Rains occurring between June and October. The average daily temperature ranges from 10 to 35C0 with an annual variation of 15 C0. April to June is the hottest period and December to February is the coldest. The soil in the region ranges from sandy to light soil. The sandy soils cover about 60% of the cultivated land, with organic matter, nitrogen and phosphorous comprising less than one percent. The region has a diverse vegetation with low desert and semi-desert scrub (Bashir et al., 2010). Key cereal crops grown in the region are sorghum, millet, and sesame.

Figure 1. *The study area, North Kordofan Region*



(Accessed from the internet 2014)

Methods of data collection

The study based on two types of data: that are climate data and field data. Historical climate data including maximum and minimum temperatures, relative humidity, sunshine hours and wind speed were collected from Elobied meteorological station. CROPWAT model version 8.0 was used to determine Reference Evapotranspiration (ETo), effective rainfall and irrigation requirements.

Field data were collected through four field visits conducted during 2012/2013 successive agricultural seasons. In each season, two field visits were conducted during August and September. the visits were carried out to assess the visual indicators such as farmers practices, types of crops, vegetation cover, sowing dates and crop stages of growth. Discussion with two groups including 24 representative farmers were also made. The discussion focused on current agricultural practices to minimize climate change effects and opportunities to develop local practices. Observed data during field visits were collected and used to support the obtained results. Reasons behind crops replacement were justified in terms of effective rainfall versus irrigation requirements in the study area.

Mid July has been historically practiced as fixed sowing date. Earlier and late sowing dates of mid July (1st June, 2nd June and late June 1st August) were examined in terms of available water versus crop requirements as new strategies. Successes and risks for each sowing date were carefully analyzed and taken in the consideration.

Research results

Reference Evapotarnaspiration (ETo) constitutes the base of crop water requirements and irrigation requirements (FAO, 1998). Climatic elements of temperature, humidity, wind speed and sunshine were collected from Elobied Metrological station and entered in the CROPWAT model to determine ETo in north Kurdofan region as shown in table 1. Then different sowing dates, Sorghum and Sesame crops and rainfall a mount were inserted in the model to test effective rainfall versus irrigation requirements for each sowing date as detailed in tables 2,3,4,5 and 6 bellow.

Table 1. *ETo of Elobied, North Kurdofan using CROPWAT Model*

Country Sudan Altitude 574		Latitude 13.16 N			Station Elobied Longitude 30.23 E		
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	Min Temp	Max Temp	Humidity %	km/day	hours	MJ/m²/day	mm/day
January	13.5	29.9	41	311	9.2	20	6.17
February	15.4	32.2	33	346	9.4	21.9	7.53

Country Sudan Altitude 574	Latitude 13.16 N			Station Elobied Longitude 30.23 E			
Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	Min Temp	Max Temp	Humidity %	km/day	hours	MJ/m²/ day	mm/day
March	19.1	35.7	25	311	9.8	24	8.54
April	21.9	38.6	26	268	9.2	23.7	8.59
May	24.6	39.4	32	268	8.6	22.6	8.47
June	24.5	37.5	43	346	7.5	20.6	8.34
July	23.1	33.9	61	346	6.4	19	6.33
August	22.4	32.7	71	268	6.2	18.8	5.16
September	21.8	34.8	57	233	7.5	20.6	6.02
October	22.4	36.4	38	268	8.5	20.9	7.37
November	18.3	33.6	34	311	9.3	20.4	7.33
December	14.1	30.5	36	311	9.5	19.8	6.47
Average	20.1	34.6	41	299	8.4	21	7.19

Shift in sowing dates strategy
Mid July sowing date

Historically, Farmers grow sorghum in mid July under a higher risk of water stress for more than 60% of the crop live period as shown in table (2). The water stress occurs at the critical stages during September. At this stage the crop is being at the mid season which relatively requires a greater amount of water because this is the period of flowering and creation of seeds. Also mid-July match the higher rate of effective rainfall which is greater than the water needed by the crop at sowing date.

Table 2. *Irrigation requirements vs effective rainfall for Sorghum crop sown in mid-July in North Kordofan*

Month	Decade	stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irri. Req. mm/dec	surplus or deficit
Jul	2	Init	0.3	1.9	15.2	24.1	0	24.1
Jul	3	Init	0.3	1.78	19.6	30.2	0	30.2
Aug	1	Deve	0.39	2.13	21.3	30.8	0	30.8
Aug	2	Deve	0.6	2.98	29.8	32.4	0	32.4
Aug	3	Deve	0.82	4.34	47.8	27.8	20	7.8
Sep	1	Mid	1	5.75	57.5	22.6	34.9	-12.3
Sep	2	Mid	1.02	6.16	61.6	18.8	42.8	-24
Sep	3	Mid	1.02	6.63	66.3	14.1	52.2	-38.1
Oct	1	Mid	1.02	7.16	71.6	8.5	63.1	-54.6
Oct	2	Late	1	7.5	75	3.5	71.5	-68
Oct	3	Late	0.87	6.45	71	2.3	68.6	-66.3
Nov	1	Late	0.72	5.3	53	0.4	52.6	-52.2
Nov	2	Late	0.62	4.56	18.2	0	18.2	-18.2

Water stress

First June sowing date

Shift sowing to first June will secure water for the crop for 60 days after sowing time. At this sowing date effective rainfall is quite enough particularly during critical stages of development and mid season for the crop, table 3.

The risky point is, in the first June there is fewer effective rainfall but farmers have an experience to plant sorghum on dry soil. They told that seeds can be stored in the dry soil up to 20 days.

Table 3. *Irrigation requirements vs effective rainfall for Sorghum crop for 1stJune Strategy in North Kordofan*

Month	Decade	stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irri. Req. mm/dec	surplus or deficit	
Jun	1	Init	0.3	2.56	10.2	1.7	8.1	-6.4	Water stress
Jun	2	Init	0.3	2.56	25.6	5	20.6	-15.6	
Jun	3	Deve	0.32	2.5	25	12.5	12.5	0	
Jul	1	Deve	0.49	3.44	34.4	22.5	12	10.5	
Jul	2	Deve	0.69	4.39	43.9	30.1	13.8	16.3	
Jul	3	Deve	0.91	5.38	59.2	30.2	29	1.2	
Aug	1	Mid	1.01	5.45	54.5	30.8	23.7	7.1	
Aug	2	Mid	1.01	4.99	49.9	32.4	17.5	14.9	
Aug	3	Mid	1.01	5.35	58.8	27.8	31.1	-3.3	Water stress
Sep	1	Late	1.01	5.76	57.6	22.6	35	-12.4	
Sep	2	Late	0.91	5.49	54.9	18.8	36.1	-17.3	
Sep	3	Late	0.77	4.97	49.7	14.1	35.6	-21.5	
Oct	1	Late	0.63	4.41	39.7	7.6	31.2	-23.6	

Mid June strategy

Mid June sowing date will keep the crop under secured water for almost 70 days. With mid-June strategy it is possible to maintain the crop with soil moisture at the end of season. Also it is possible to harvest surplus water during first season to supplement the crop during the end of season, table 4. This strategy has lower risk in terms of the difference between effective rainfall and water needed by the crop particularly during the end of season.

Table 4. *Irrigation requirements vs effective rainfall for Sorghum crop for 20th June strategy in North Kordofan*

Month	Decade	stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irri. Req. mm/dec	surplus or deficit
June	2	Init	0.3	2.56	2.6	0.5	2.6	-2.1
	3	Init	0.3	2.34	23.4	12.5	10.9	1.6
Jul	1	Deve	0.3	2.11	21.1	22.5	0	22.5
	2	Deve	0.43	2.73	27.3	30.1	0	30.1
	3	Deve	0.65	3.83	42.2	30.2	12	18.2
Aug	1	Deve	0.86	4.65	46.5	30.8	15.7	15.1
	2	Mid	1	4.98	49.8	32.4	17.4	15
	3	Mid	1.01	5.37	59.1	27.8	31.3	-3.5
Sep	1	Mid	1.01	5.79	57.9	22.6	35.3	-12.7
	2	Mid	1.01	6.08	60.8	18.8	42	-23.2
	3	Late	0.96	6.21	62.1	14.1	48	-33.9
Oct	1	Late	0.82	5.71	57.1	8.5	48.6	-40.1
	2	Late	0.67	5.04	50.4	3.5	46.9	-43.4
	3	Late	0.59	4.37	8.7	0.4	8.7	-8.3

Late June first August strategy

This sowing date is good at the beginning of season and there is possibility for the crop to match winter season in December however, water stress is possible for 70 days (table 5). This sowing date is practically impossible because the crop cannot be maintained by soil moisture for more than two months under semi-dry conditions.

Table 5. *Irrigation requirements vs effective rainfall for Sorghum crop 1st August strategy in North Kordofan*

Month	Decade	stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff. Rain mm/dec	Irri. Req. mm/dec	surplus or deficit
Aug	1	Init	0.3	1.62	16.2	30.8	0	30.8
Aug	2	Init	0.3	1.49	14.9	32.4	0	32.4
Aug	3	Deve	0.43	2.26	24.9	27.8	0	27.8
Sep	1	Deve	0.65	3.71	37.1	22.6	14.4	8.2
Sep	2	Deve	0.86	5.16	51.6	18.8	32.8	-14
Sep	3	Mid	1.02	6.62	66.2	14.1	52.1	-38
Oct	1	Mid	1.04	7.24	72.4	8.5	63.9	-55.4
Oct	2	Mid	1.04	7.74	77.4	3.5	74	-70.5
Oct	3	Mid	1.04	7.7	84.7	2.3	82.3	-80
Nov	1	Late	1	7.33	73.3	0.4	72.9	-72.5
Nov	2	Late	0.86	6.32	63.2	0	63.2	-63.2
Nov	3	Late	0.72	5.09	50.9	0	50.9	-50.9
Dec	1	Late	0.63	4.27	12.8	0	12.8	-12.8

Successes and risks of the developed strategys

From the above mentioned results, the table below has been build to summarize the success and risk points for each strategy.

Table 6. *Sowing dates strategys: successes and risks*

Sowing date	Successes	Risks
Mid July	Secure water for 50 days	50 days Water stress at critical time. Zero water and Less soil moisture at the end of season
1st June	Secure water for 65 days Possibility to maintain the crop with soil moisture Possibility of dry sowing	40 days Water stress at critical time. No water at sowing date
Mid June	Secure water for 70 days Good moisture at sowing date Possibility to maintain the crop with soil moisture at the end of season Possibility to supplement the crop at the end of season using accessed water at the beginning of the season (water harvesting)	Effective rainfall lower than water needed but by lower amount compared with other strategys
Late June, 1st August	Planting under available water Possibility to reach winter season	Possible water stress for 70 days

Source: Developed from tables (1,2, and 3)

Crop replacement strategy

Farmers who live close to farms often observe the activities around them and are the first to identify and adapt to any changes. Hagmann et al. (1996) stated that, farmer experimentation is the major element to improve development and spreading of innovations. In Kordofan, farmers observed the change in vegetation covers which was shifted from humid in 1950s to recent desert vegetation. Farmers mentioned that, long lived trees were killed and there is a general reduction in the vegetation cover, leaving land more vulnerable to overgrazing and erosion. Historically, North Kurofan is the region of millet crop in Sudan. But recently millet has been replaced by Sesame. Recently, Millet has been affected by water stress at the end of season as shown in table 7 bellow. This situation has been repeated seasonally for the last 15 years. Therefore, farmers in North Kordofan replaced millet by Sesame. Because Sesame(Sesamumindicum L.) is drought tolerant crop and it has shorter growing season compared by Millet . It is considered one of the cash crops in Sudan. As shown in table 7, sesame can be maintained by rain throughout the season. It requires sufficient water during the early stages of growth, but once the plant has emerged it is tolerant to dry weather conditions and soils. The table below indicate that Sesame has shorter period of two months and requires water for only one month compared with Millet.

Table 7. *Irrigation requirements vs effective rainfall for Millet crop in North Kordofan*

Month	Decade	Stage	Eff. Rain mm/dec	Millet Irr. Req. mm/dec	Sesami Irr. Req mm/dec
Jul	2	Init	18.1	0	0
Jul	3	Deve	30.2	0	0
Aug	1	Deve	30.8	0	9.3
Aug	2	Deve	32.4	7.3	16.9
Aug	3	Mid	27.8	31.1	28.6
Sep	1	Mid	22.6	35.5	0
Sep	2	Mid	18.8	42.3	
Sep	3	Mid	14.1	51.6	
Oct	1	Late	8.5	55.2	
Oct	2	Late	3.5	43.5	
Oct	3	Late	1.5	17.7	

Discussion

Climate change impact is expected to be harder on poor farmers who are traditional rain fed agriculture dependent, because, climate change will influence poverty and food security status. Abdelmoneim et al. (2012) stated that a yield loss of 5–25 percent is expected between 2000 and 2050 over most of the Sudan's sorghum harvest area, and, in the marginal cultivated areas of the semi-dry zone. Food and Agriculture Organization (FAO) (2006) documented that climate change adaptation measures need to focus on crop insurance, and incentives to adopt better agricultural practices. Change in sowing date is one of the strategies and considered cost effective technique that can be applied by poor farmers to adapt climate change as Rounsevell et al. (1999) found that the use of good management practices, provides the best strategy for adaptation to the impact of climate change.

Among four sowing dates strategies, the paper found that early sowing is better to adapt climate change impact in North Kordofan. Historically farmers sown in mid July but this paper found that mid June sowing date is the best option because effective rain fall can secure water for the crop for 70 days. Also there is possibility to harvest a huge amount of water at the beginning of season to supplement the crop during water stress periods. Availability of soil moisture because of mid June sowing date can also maintain the crops. This result is in line with Tubiello et al. (2000) which stated that early planting for spring-summer crops succeeds in maintaining crop yields.
In terms of crop replacement strategy, it has been observed that farmers making major shifts in crops as another mechanism to cope with climate change. Schimmelpfennig (1999) stated that adaptation at the farm level, through changes in crops, is another adaptation mechanism. Sesame has extensively replaced Millet crop in the pure Kordofan sands outside El Obeid in Sudan. Farmers replace millet with sesame because sesame is drought tolerant crop (Julian et al., 2012). FAO(2009) promotes the use of indigenous and locally-adapted plants as well as the selection and multiplication of crop varieties to adverse conditions. It is observed that sesame has been intercropped with Water Mellon. Economically, farmers preferred sesame because it has lower production costs and higher net benefits compared with sorghum.

Conclusion

Climate change impact on traditional rain fed agriculture in Kordofan is harder particularly on poorer farmers. Early sowing date strategy will help traditional rain fed farmers in semi dry areas to adapt climate change impact on agriculture through effective utilization of rainfall. Shorter rainy season in the region can effectively be utilized through early sowing of crops. Tolerant crops like sesame can be planted to cope with drier conditions and changing climate.

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About the author

Eltigani Elnour Bashier Abdelgalil is an Assistant Professor of Water Management at the Water Management and Irrigation Institute of the University of Gezira. He holds a PhD on Water Management at the University of Gezira 2009, a MSc on Economics of Water Resources, 2003 and a BSc on Agricultural Science of the Faculty for Agriculture and Natural Resources at the University of Gezira. 1999. Currently, he is the Dean of Water Management and Irrigation Institute