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Research Article

Impacts of Dams Construction and Water Harvesting Programs on Community Perception Red Sea in Eastern Sudan

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Abstract

The present study aimed to investigate the effect of dams constructed for providing drinking water and for irrigation in the Red Sea state of Sudan. Water harvesting programs implemented by government with assistance of international non-governmental organization were investigated for their effectiveness. The study utilized secondary data literature and some photos of the dam. The area of study is located in the northeast of Sudan latitude 16°-22°N; longitude 35°-37°E. The primary data covered both direct questionnaire and key persons discussion. The area of study constituted about 10% of the total area of Sudan. As described by reports, the topography composed of rocky hills, mountains, outcrop rocks and a network of seasonal watercourses and streams. The hilly nature of the topography and the Basement Complex formation of the base rock made surface rain run-off the only source of fresh water. Open key person discussion pointed to the limited water supply due to geologic and climatic factors. Surface run-off is provided by seasonal stream where Khor Arba' provides 60% of fresh drinking water, the amounts are affected by years of drought. Water distribution is controlled through a pipe network. Five major catchments were identified according to hydrological and morphological features and were important supply for rain-fed agriculture. The total annual groundwater recharge is 2.06×10^6 m^3. The annual discharge through underground outflow at the 'lower gate' is 3.29×10^5 m^3/year. Groundwater discharge due to pumping from Khor Arba'at basin is 4.38×10^6 m^3/year on average. Gates were designed in the dam to reduce siltation. However, sedimentation caused pipes blockage. Results of questionnaire showed that most of the respondents at Arba'at (80%) and Sinkat (92%) were aware of the concept of water harvesting. Disiltation benefit of the dams were acknowledged at both Arba'at (61%) and Sinkat (50%), while deepening of wells was expressed by 40% at Sinkat. Water conservation activities existed at Arba'at (80%) only. Most (85%) were willing to participate in water management. Associations in respondents' opinion were significant (P =.000) for both desalinization of dams and commitment to water conservation. The positive effects of Non-organization activities in the areas were expressed by participants in both areas. Significant (P =.000) associations could be obtained in respondent' opinion between the two areas. Significant (P=0.00) associations between respondents' opinion in the two areas was obtained. Also many respondents at Arba'at (98%) and Sinkat (94%) believed that traditional laws have positive effects on natural resource management.

Keywords

Dam Construction, Water Harvesting Programs, Community Perception

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1. Introduction

In sub-Saharan Africa climate variability already limits agricultural production, 95% of food comes from rain-fed farms. In South Asia, where millions of smallholders depend on irrigated agriculture, climate change will drastically affect river-flow and groundwater, the backbone of irrigation and rural economy [4]. The Red Sea Region of Sudan suffers from acute water shortage due to geologic, climatic as well as to topographic factors, where the water supply is very limited and affected by the climatic degradation. Most of the precipitation in the region is lost as surface runoff due to the high elevation of the area relative to the surroundings and the high rates of evaporation. The drainage pattern of the Red Sea Hills is structurally controlled by faults and shear zones that produced rectangular drainage pattern. Vegetation is dominated by widely scattered bushes and acacia trees, confined to the main seasonal streams. Most of the people in Red Sea State depend on rain water that collects at seasonal streams and low lands. Water resources management is normally governed under ministries for water affairs and focuses on developing and allocating water for large-scale irrigation, drinking water, and hydropower. Rainwater harvesting (RWH) has regained its importance as a valuable alternative or supplementary water resource, along with more conventional water supply technologies [4].

In Sudan, in 2003, a first demonstration of the water-harvesting technique was carried out in five villages with the collaboration of 25 previously trained farmers, each of whom had adopted it on plots of two feddans (0.84 hectares). The project provided improved sorghum varieties and covered the costs of ploughing, whereas the farmers built the shields and did other tilling operations. Following the success of the experiment, the project's results were disseminated through one-day field demonstration with farmers from more than ten villages, and through farmers' field schools. As a consequence, the number of farmers who adopted the water harvesting technique increased from 402 in 2004 to 1,349 in 2005 and 1,448 in 2006, with final total of 3,344 farmers (115 of whom were women). Average productivity increased as much as eleven times, while average cultivated area decreased by more than two-thirds – thus saving other natural resources such as trees and pastures that used to be cut down to expand crop cultivation.

2. Material and Methods

The methodology of the present work utilized secondary data depending on published literature and government reports; that included dam construction and drawbacks, water catchment and run-off, water resources and demands. The primary data included open key person group discussion included government administrations as soil soil and water management, academia from faculty of earth science, university of Red Sea. A questionnaire targeted communities at Arab'at and Sinkat to investigate to what extent had water harvesting programs executed by government supported by international non-governmental organization had improved their livelihood in some parts of the state. The main purpose was to assess the impacts of constructed dams and NGO programs on water resources improvement which affected community life.

3. Results

3.1. Secondary Data

3.1.1. Area of Study (General Description)

The Red Sea state is located in the northeast of Sudan latitude 16°-22°N; longitude 35°-37°E. It is bordered by Egypt in the north and Eritrea in the south. Within the country, it is bordered by Kassala State in the south and River Nile State in the west. It covers an area of 218.887 km^2 constituting about 10% of the total area of Sudan and 63% of the Eastern State. There are two sea ports, Port-Sudan and Suakint which provide vital links to the rest of the world. The Red Sea region consists of three distinct morphological zones: (i) Coastal, (ii) Mountainous range and (iii) Inland zone. The topography is composed of rocky hills, mountains, outcrop rocks and a network of seasonal watercourses and streams. Most of the soils in the region are sandy, sandy clay The inland flat lands are filtered with running valleys and isolated pockets of mountains and rocky hills. Loamy and alluvial deposits, confined to numerous natural depressions areas, offer good grazing ground for the livestock and rainfed farming on flood residual moisture during the rainy season [3]. The hilly nature of the topography and the Basement Complex formation of the base rock made surface run-off the only source of fresh water in the Red Sea area [1]. The rocky and compact nature of soils, the steep slope, the pattern of rainfall in the area (thunderstorms) and the poor vegetation cover, all contribute to the high rates of run-off in the Red Sea area [2].

3.1.2. Water Resources

The Red Sea Region suffers from acute water shortage due to geologic, climatic as well as to topographic factors, where the water supply is very limited and affected by the climatic degradation. Most of the precipitation in the region is lost as surface runoff due to the high elevation of the area relative to the surroundings and the high rates of evaporation. The drainage pattern of the Red Sea Hills is structurally controlled by faults and shear zones that produced rectangular drainage pattern. Vegetation is dominated by widely scattered bushes and acacia trees, confined to the main seasonal streams.

Khor Arba'at (a seasonal stream) is the largest and most important source of fresh water in the whole of the State and upon which over 60% of the population (Port Sudan dwellers) depend for drinking. Because of that value, attention by the State authorities was turned to it since early 1920s to supply fresh water to Port Sudan town and support agriculture on the fertile land of Arba'at Though seasonal in nature and small in terms of volume of its waters, Khor Arba'at supply has been for decades sustained as an all-year supply, except under very extreme and long drought conditions. This has been realized through measures of control: the damming of the Khor at its entrance to Arba'at on the foot of the hills, creating an artificial reservoir and controlling distribution through a piped network.

3.1.3. Catchments and Seasonal Streams (khors)

Surface water hydrology of the area comprises mainly surface runoff and drainage during the wet seasons, with expectation of some springs found in mountain areas such as Erkowit and Arba'at. Such springs are a typical feature of arid lands (Taha *et al*., 2006). Perennial watercourses are absent, while surface drainage of ephemeral streams and lowlands are numerous. It is mainly shaped by the undulating and elevated surfaces, seasonality and variability of rainfall, which are prone and conducive to some favorable runoff in the lieu of steep slope, rocky surface and sparse vegetation cover. The Red Sea Hills that run parallel to the Red Sea coast serve as a water divide between watersheds of the Red Sea to the east and the Nile to the west. Based on these hydrological and morphological features, five major catchments can be identified in the region, namely; Khor Baraka, Arab, Arba'at–Odrus, Gowb and Diib catchments these khors play an important role in the livelihood of the Red Sea Region people. The region depends entirely upon them as a source of both domestic and agricultural water supply, for production of millet and sorghum crops as rain–fed in the flood receding moisture, and irrigated vegetables and forage production where shallow ground water exists.

(i). Khor Arba'at Catchment Areas and Dam Construction

Khor Arba'at basin is the main source of potable water supply for the more than 750,000 inhabitants of Port-Sudan. Arba'at area is one of Sahelian area which located in north Port Sudan 30km north Port Sudan, water flow from Red Sea hills to cross Arba'at area to pour in the Red Sea. Khor Arba'at lies about 20 km to the north of Port Sudan, on the coastal plain of and comprises some 54,850 feddans (23,040 ha) formed on a largely silty, sandy and gravelly textured laid down where the Khor Arba'at drainage system debouches from the Red Sea littoral [4]. Khor Arba'at drains a catchment area of about 4200km^2 through the upper gate 30m wide in to alluvial basin of the lower gate. The stat of the basin lies at 30km NNW of Port Sudan and extend over 12 km upstream (Figure 1). Including Khor Odrus, which has a total length of about 160 kms (between the upper catchment "lower gate") up to the coastal plain therefore covering a total area of some 4,750 km^2 (Taha *et al*., 2006). The Khor flows in a northern direction for most of the first half of its upper course (90 km), then turning into a north-eastern direction for 40 Km before turning sharply east towards the sea. In this last sector, the Khor bed width ranges between 1500-2000 meters. The Khor splits in to nine minor tributaries before discharging into the Sea (Soil Conservation and land Use Dept., 1999).

(ii). Ground Water

Ground water resources are mainly hand-dug wells located in or beside seasonal wadis. These wadis flow only after rain, so the quality and quantity of water in wells varies in space and time. The total annual groundwater discharge is about 4.7 × 106 m^3. A deficit of 2.6 × 106 m^3/year is calculated. Although the total annual discharge is twice the estimated annual recharge, additional groundwater flow from the fractured basement probably balances the annual groundwater budget since no decline is observed in the piezometric levels [4].

The water table rises during the summer and winter rainy seasons; it reaches its lowest level in the dry season. The storage capacity of the Khor Arba'at aquifer is estimated to be 21.75 $\times 10^6$ m^3. The annual recharge through the infiltration of flood water is about 1.93 $\times 10^6$ m^3. The groundwater recharge, calculated as underground inflow at the 'upper gate', is 1.33 × 10^5 m^3/year. The total annual groundwater recharge is 2.06 × 10^6 m^3. The annual discharge through underground outflow at the 'lower gate' (through which groundwater flows onto the coastal plain) is 3.29 × 10^5 m^3/year. Groundwater discharge due to pumping from Khor Arba'at basin is 4.38 $\times 10^6$ m^3/year on average [4].

3.1.4. Water Supply and Demand

Most of the people in Red Sea State depend on rain water that collects at kors and wadies waters, the contribution from each varied significantly, most contribution come from Khor Baraka (560,000,000,), then Arba'at (18,540,000), the lowest came from Wadi Amoor (6,416,000), Durdaib (3,500,000). Sources of surface water per locality is shown in Table 1. For the Red Sea State net water additional supply is expected to increase from 2007 to 2027 for urban, semi-urban, rural and livestock. It was found to increase progressively from 49,343, 86,05, 134,849, 201,199 m/D^3 for the years 2007, 2012, 2017, 2027 respectively (Table 2). For the demand it was found to increase for 110,430, 141,589, 179,360, 227,516, 286,545 m/D^3 for the same years (Table 3). Construction of the dams at the Red Sea region was expected to increase water potentially to 30–50 percent with the capture and spreading of streams runoff.

Table 1. *Sources of surface water per locality.*

Average annual Surface water m^3	Main Khors and wadis
18,540,000	Arba'at
4,667,000	Khor saloom
6,416,000	Wadi amoor
18,313,000	Khor arab
1,200,000	Gadamy
3,500,000	Durdaib
560,000,000	Khor Baraka
4,512,000	Ashat
10,134,000	Khor Gob

Source: RSS water sources, Salah Bashier Musa, Khartoum University, 1995.

Table 2. *Water Supply in Red Sea State 2007.*

Sector	Water supply coverage %			
	Current converge	2012	2017	2022
Urban	40	55	70	80
Semi urban	40	50	60	70
Rural population	47	55	60	70
Livestock	63	65	70	75
Net additional water required m/D^3		49,343	86,050	134,849

Table 3. *Water Demand in Red Sea State 2007.*

Sector	Water demand coverage m/D^3				
	Current converge	2012	2017	2022	2027
Urban sector	67,525	88,217	114,299	147,065	188,103
Semi urban centers	7,586	10,301	12,329	15,776	18,812
Rural population	7,806	10,448	13,960554	17,029	20,960
Live stock	27,513	32,623	39,178	47,646	58,670
TOTAL	110,430	141,589	179,360	227,516	286,545

Source: RSS water sources, Salah Bashier Musa, Khartoum University, 1995. State strategies plan

3.1.5. Dam Construction Drawbacks

The government established dams to harvest water for benefit people lives that areas especially Port Sudan town and villages that surrounding dam area. The dam was designed to store about $16Mm^3$ at a head of 24m. The variation in hydraulic conductivity and storage capacity is due to the heterogeneity of the sediments, which ranged from clay and silt to gravely sand and boulders. Besides provision of water by surface storage, the dam may augment ground water recharge by downward water seepage from the reservoir in spite of the contradicting views undermining the deficiency of such dams in researching groundwater downstream, positive result, in this respect, were obtained by construction of earth embankment for recharge purpose in Arba'at. Three constructed dams are existing, the first one is Alwali dam; which is of small drainage area (12,000,000m^2), constructed in fractured metavolcanics rocks which is the main reason behind the loss of its stored water. Tawai dam has relatively bigger catchment area (30,000,000m^2). It was built in fractured granitic rocks intruding the meta-volcano sedimentary rocks. Though of its relatively larger watershed, it has lesser water storage capacity, since the stored water is lost through the open fractures trending in the NW-SE direction [4]. During the months of May-October, the inter-tropical convergence zone (ITCZ) moves northward to run parallel to the Red Sea coast, causing rainfall, which reaches its peak in August. There is very little rainfall along the coast at this time. During the winter months of November-January, low pressure system moving eastwards across the Arabian Peninsula draws in northerly winds which pickup moisture as they cross the Red Sea. These winds produce local showers along the coastal plain and foothills when they collide with the Red Sea Hills [4].

The design of the dams faced problem of maintenance and reappearance, however, the gates which responsible of filtration of silt was closed due to the deepness of it and inability to repair, siltation highest fill about 10 m of the dams. The siltation affected the capacity of water in dam from 26 m^2 to 10m^2 and huge amount of water lost as a flood and flow eastern direction to destroyed agricultural land in Delta Arba'at resulting in soil erosion, and loss of a huge amount of water going to the Red Sea without benefiting people [4].

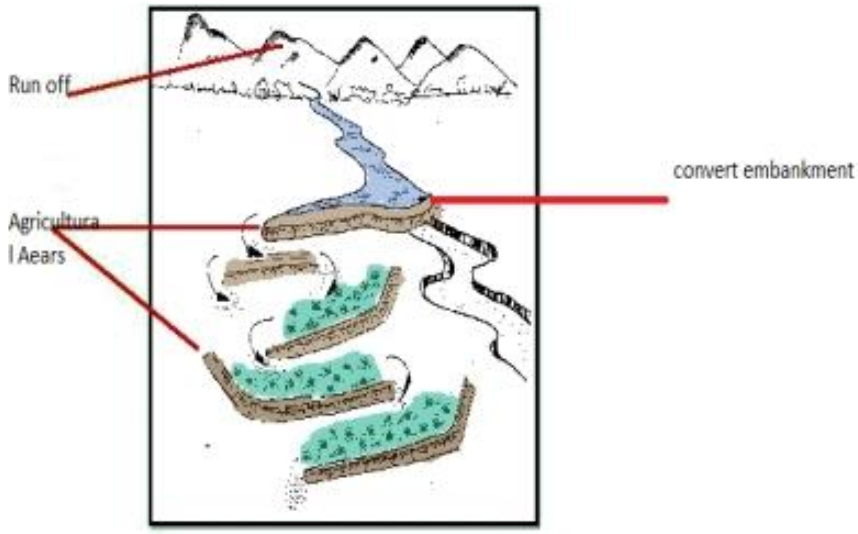
Improvement of Dam Construction for Water Harvesting

Upper Gate Dam established since 2005 with the purpose of harvesting rain water that flows from Odrus Mountains 160k West, (the highest of dam is 28m and the storage Capacity 16 million m^3. Gates were designed in the dam to reduce siltation, the construction of this dam to reduce water loss and benefit surrounding people to cultivate irrigated lands and give them other activities chances and income earning resources. Also it creates new habitats before dams such as the appearance of animals (Deer and wolves) [1].

Resilience building measures started with strengthening of old earth-bunds and the construction of new ones. The bunds have contributed considerably to harness the Khor water and allow for its maximum utilization [4]. According to farmers in the area, that was the first maintenance of the bunds since the early 1970s. The nine small tributaries of the Khor have helped in the appropriate distribution of water over the whole area, through a network of pipes, thus raising substantially the efficiency of the water harvesting (Figures 1, 2, 3).

Figure 1. *Araba'at dam WH at non-hill side.*

Figure 2. *At rocky side.*



Source: Red Sea state, Ministry of house planning and public utilities, water corporation, Khor Araba'at development (final report 2003)

Figure 3. *Water floods diverted towards farm fields.*

3.1.6. Impact of Water Harvesting Program

An agriculture program started in the valley of mekheiry at Arba'at for cultivation of fruits, vegetables and animal fodder. This project attracted people of Gabait to settle in dam area in order to benefit from this program as income earning source. However, farmers did not benefit from this dam as catchment areas were not established. At Sinkat the constructed dam did not satisfy the people demand due to the huge number of migrant's people from surrounding villages searching for water and work. However, the valley of dam was used as grazing area. In Sinkat several agricultural schemes trained farmers (males and Females) on water harvesting techniques, soil conservation and seed plantation.

Khor Arba'at Rehabilitation Project (KARP) project came in response to the Sahelian drought in the 1980s by SOS Sahel (UK). Khor Arba'at delta (Arba'at Zira'a) was chosen as an area where it was felt that rehabilitation of the somewhat degraded agriculture farming system could provide considerable benefits to the local community and that the people of Arba'at and their agricultural system had been rather bypassed and neglected by government services in recent years, but people were eager to participate in a broad ranging programme designed to improve their livelihoods. One of the first results observed by farmers was that high floods became no longer a threat to the cultivated crops, while small quantities of water has also been of use when efficiently managed. Thus, farmers have learned how to cope with the fluctuating amount of flow [4]. Soil erosion control activities have been concentrated in the Erkawit (east of Red Sea) area. The Programme included contour lining, gullies filling, steel cages dams, dry stone dams and grass seeds scattering. Training of inhabitants to undertake soil erosion control as a daily activity, the result was the great improvement in crops yields.

3.2. Primary Data

Community Perception of Government and NGO Contribution to Water Harvesting Techniques

Big dam construction by the government encouraged communities in Delta Arba'at to establish earth breaks so as to slow water speed; water was allowed to pass through pipes and distributed among farmers. However, due to the flow of huge quantities of water from upper gate dam, farmers could not manage water irrigation and so their crops were damaged. Upper gate dam is a main source of water that feed Port Sudan town through pipes from Arba'at to Port Sudan. However, due to sediment the pipes were blocked and the quantity of water reaching Port Sudan town and so people suffered from scarcity of drinking water.

Most of the respondents at Arba'at (80%) and Sinkat (92%) were aware of the concept of water harvesting techniques (Table 4). While most of the respondents' at Arba'at (80%) and Sinkat (90%) thought that water harvesting techniques exist in their areas (Table 5). However, no significant associations for the respondents' opinion were obtained between the two areas for either awareness (P =0.014) or existence of water harvesting techniques (P=.048).

The government had established many water harvesting techniques for water management at Sinkat including water desilitation, water wells and water network. Some water conservation techniques for agriculture were practiced. Within this context, respondent opinions within different water management, it was shown that, nearly half of the respondents at Arba'at (61%) and Sinkat (50%) thought that desiltation of dams took place while 40% at Sinkat thought that deepening of wells was done, while very few at both areas thought that desiltation of hafirs and water shed management took place (Table 6). Water conservation activities were thought to exist at Arba'at (80%) while same percent at Sinkat did not think that water and conservation activities did exist (Figure 4) (Table 7). Most (85%) of the respondents expressed that they were committed to water resource management, while few at Arba'at (10%) expressed their commitment (Table 8). Associations in respondents' opinion were significant (P =.000) for both desalinization of dams and commitment to water conservation.

Non-organization and grass root organization activities in the areas were thought to have positive effects. For Abraat the percentages were 52 and 48% for NGOs and GOS respectively, for Sinkat they were 20 and 80% respectively. Significant (P =.000) associations could be obtained in respondent' opinion between the two areas. Most of the respondents at Arba'at and Sinkat (98%) and (96%) respectively believed that there is a positive impact of environmental institutions in their areas. Significant (P=0.00) associations between respondents' opinion in the two areas was obtained (Table 9). Also many respondents at Arba'at (98%) and Sinkat (94%) believed that traditional laws have positive effects on natural resource management (Table 10). However, significant associations of the respondents' perception were not detected (P =0.149).

Table 4. *Awareness concept of water harvesting in the study areas.*

		Areas		**df**	**P value**
		Arba'at	**Sinkat**		
yes	Count	80	92		
	% within areas	80.0%	92.0%		
no	Count	20	8	1	.014
	% within areas	20.0%	8.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

Table 5. *Water harvesting techniques in the study areas.*

		Areas		**Df**	**p. value**
		Arba'at	**Sinkat**		
yes	Count	80	90		
	% within areas	80.0%	90.0%		
no	Count	20	10	1	.048
	% within areas	20.0%	10.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

Table 6. *Activities of water resources rehabilitation in the study areas.*

		Areas		**Df**	**p. value**
		Arba'at	**Sinkat**		
Desilting hafirs	Count	20	10		
	% within areas	20.0%	10.0%	3	0.00
Desilting dams	Count	61	50		

		Areas		Df	p. value
		Arba'at	Sinkat		
	% within areas	61.0%	50.0%		
deeping wells	Count	8	40		
	% within areas	8.0%	40.0%		
water shed management	Count	11	0		
	% within areas	11.0%	.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

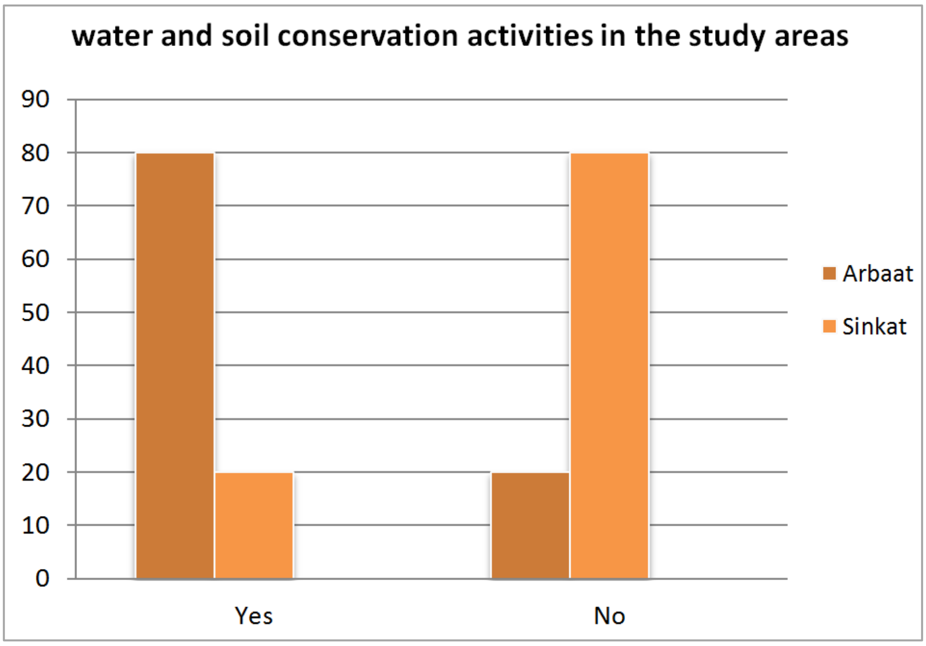


Figure 4*. Water and soil conservation activities in the study areas.*

Table 7*. Commitment of community to water resources management.*

		Areas		Df	p. value
		Arba'at	Sinkat		
yes	Count	10	85		
	% within areas	10.0%	85.0%		
no	Count	90	15	1	000
	% within areas	90.0%	15.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

Table 8. *Institutions activities in the study areas.*

		areas		Df	p. value
		Arba'at	Sinkat		
NGOs	Count	52	20	1	0.00
	% within areas	52.0%	20.0%		
GOs	Count	48	80		
	% within areas	48.0%	80.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

Table 9. *Impact of environmental institutions in the study areas.*

		Areas		df	p. value
		Arba'at	Sinkat		
yes	Count	98	96	1	.407
	% within areas	98.0%	96.0%		
no	Count	2	4		
	% within areas	2.0%	4.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

Table 10. *Effect of traditional laws of natural resources in the two sites.*

		Arba'at	Sinkat	df	p. value
yes	Count	98	94	1	.149
	% within areas	98.0%	94.0%		
no	Count	2	6		
	% within areas	2.0%	6.0%		
Total	Count	100	100		
	% within areas	100.0%	100.0%		

4. Discussion

In the area of study, recurrent droughts with consequent high rates of evaporation could have caused dams' siltation reducing their water storage capacity. Similarly it was shown by [4] that Arba'at area storage capacity has been reduced from 26 m^3 to 10m^3. Also massive soil erosion was shown to degrade the top soil leaving the hillside with a stony surface and no vegetation cover and hence high runoff (Annual Report, 1988). Furthermore, it was shown that Sinkat – Gebeit area suffers from acute water shortage due to geologic, climatic as well as to topographic factors. Moreover, most of the precipitation is lost as surface run off due to the high elevation of the area relative to the surroundings and the high rates of evaporation.

It was pointed out that, other than the seasonality, the natural flow of khor Arba'at used to cause two main problems. The first was the high speed resulting from the steep gradient and short distance to the sea, causing quick loss of water. The second was the variability in the volume of water, so when it is above average it used to burst its tributaries banks and cause damage to the farms and settlements. Resilience building measures started with strengthening of old earth-bunds and the construction of new ones. The bunds have contributed considerably to harness the Khor water and allow for its maximum utilization.

Other problems were related lack of maintenance. This had affected provision of water for drinking and irrigation. Also uncontrolled water during flood time caused crop failure in spite of establishment of earth banks by farmers at Arba'at where the catchment areas were used for growing crops and fodder. In Sinkat, the catchment areas due to dam construction did not satisfy community needs for either drinking water or irrigation due to the huge human migrations from nearby areas. Several agricultural schemes targeted small-scale farmers including water harvesting techniques, soil conservation and seed plantations were undertaken. Predictions of water supply and demands for the years 2007 to 2027 showed a great deficit in all sectors.

The unreliability of rainfall substantially raises the value of and dependence on Khor Arba'at by the local community for both drinking and irrigation purposes. Khor Arba'at supply has been for decades sustained as an all-year supply, except under very extreme and long drought conditions. This has been realized through measures of control: the damming of the Khor at its entrance to Arba'at on the foot of the hills, creating an artificial reservoir and controlling distribution through a piped network.

The farmers traditionally build up terraces to harvest water for crop production purposes in a limited scale. However, these terraces are improperly designed and thus either washed away or proved to be inefficient in harvesting adequate water to be retained for sufficient time duration to sustain plant growth for successful cropping season. The irrigated and cultivated area is rather small in order of less than 0.5 ha. Therefore, flood water obstruction; retention and conservation are crucial for successful cropping and runoff farming.

There have been many efforts in promoting community based rainwater harvesting projects by government institutions and development organizations in order to increase resilience to recurring droughts enhancing food security for pastoralists and agro-pastoralists communities in rural areas of Sudan. Earth-moving machinery was brought to the area and some earth embankments were constructed to harvest the Khor waters to the maximum. The community from its side formed a committee for the distribution of the Khors water among the nine sub-villages. The area did not benefit from the government commitment to support the rural areas to produce their stable food such as millet and sorghum because Arba'at production was viewed as commercial crop production [4].

There were several water harvesting techniques such as mountain catchment as expressed by most respondents in Sinkat (81%), concrete and earth dams (54%) as well as earth dams (Kirrab) (46%) were practiced techniques, at Arba'at, while very few thought of subsurface water (magolab) as effective water harvesting technique in Sinkat area. For all the above aspects no significant (P =.048) associations were obtained for the respondents' opinion between the two area. As the community used to practice different water harvesting techniques, their different opinions might be an outcome of their own experience of the best techniques that provided the satisfied quantities for different water uses.

Local communities at both localities were aware of the positive impacts of water harvesting techniques programs but they also thought that they were not enough. Most of the respondents at both areas felt the impact of environmental institution on conservation of natural resource. This could be related to some of the successful programs carried out such as UK SOS Sahel in collaboration with the government in rehabilitation of Khor Arba'a training of farmers in management of soil erosion, construction of dams for big catchment areas [4].

5. Conclusion and Recommendations

Due to lack of dams' maintenance and siltation, water capacities of dams was reduced as a result farmers suffered from crop failure. Many respondents in both areas were aware of the positive impacts of water harvesting techniques programs implemented. It is therefore recommended to improve in situ conservation of water, construction of small and low-cost water harvesting structures, complementary action-research designs for making effective links between on-farm problems and solutions to ensure the success of watershed development programmes. GIS in combination with hydrological modeling and indigenous knowledge can be applied to make maps of rainwater harvesting suitability and identify several possible sites. Furthermore, a holistic approach should be provided to combine small and low-cost water harvesting structures throughout the top sequence to benefit all farmers, as against the large storage structures at the lower end of the watershed that benefit only a few, and thus address equity issues for water use. In-spite of the several research carried out on the potential benefits of rainwater harvesting systems for rural communities, little attention was directed to communities' perception regarding the rainwater harvesting projects. The significance of the perceptions of the recipients (community participants) has been ignored mainly by excluding them from the designing, implementation and assessment stages for enhancing food security and the influence it plays.

Conflicts of Interest

The authors declare no conflicts of interest.

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