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INFLUENCE OF SUBSURFACE DAM ON ENHANCING WATER SUPPLY IN ARID AND SEMIARID REGIONS: A PROMISING RESULTS FROM *KORLONGO,* CHAD

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Abstract

In many arid and semi-arid regions, large amounts of water annually flood the desert during extreme rainfall events without harvesting. Intervention to harvest water through subsurface dam is important to improve water supply during dry season in Chad. This research aims to test effectiveness of the subsurface dam to guarantee and store water during wet season to be used during dry season. A subsurface dam has been built in the Wadi that crosses the village of *Korlongo. Korlongo* located in the *Dangaleat* East canton, *Abtouyour* department in *Guera* province, Republic of Chad. The subsurface dam was built of a trench crossing the wadi. A plastic sheet is placed in the trench and glued to the bottom to stop the subsurfaces lateral flow of water and thus delay the possible drying up of a well placed in upstream. Water levels were monitored using piezometers. The results confirmed that the subsurface dam provides significant volume of water upstream. The water levels at upstream, drops less quickly during the dry season compared with downstream. Despite the daily withdrawal of water from the well, the dam makes water available throughout the year at upstream. A t-test indicates significant difference ($p = .002$) between the water levels upstream and downstream. The findings show the effectiveness of the subsurface dam in providing sustainable water in semi-arid and arid region.

Keywords: Subsurface dam, water supply improvement, Arid, Semi-arid, Chad.

1. INTRODUCTION

The problem of water shortage has always been one of the most principle issues in the world. Fresh water availability for sustainable development is a major challenge facing the global community [1]. The climate change that the planet faces has caused the world's population to be seriously threatened by the lack of water resources in 2050 [2]. Like many developing countries, Chad located in areas where rainfall is seasonal and

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unpredictable [3]. Only 60% of the population in Chad had access to drinking water in 2015 [4]. In Chad, water is surely lacking in huge areas of semi-arid and arid climate where there is no exploitable generalized groundwater.

In many arid and semi-arid regions, large amounts of water annually flood the desert during extreme rainfall events without harvesting. Increase water harvesting activities is the possible solutions to the increasing demand of water in Chad [5]. Augmenting water availability using water-harvesting structures is of importance in arid and semi-arid regions [3]. Due to the seasonality of the surface water drainages in semi-arid and arid regions, it is necessary to use structures of subsurface dams to harvest water [6].

Chad has many streams and most of them are ephemeral flowing for only couple of months in a year. The idea of subsurface dam of this study, comes from the possibility to block and cause the water to be stored in the upper alluvium and the water accumulates in the upper side of the constructed dam. Blocking water losses and storing water of alluvial aquifers, will better provide new sustainable and affordable water resources for dry season.

In recent years, there has been growing recognition of subsurface dam in managing water resources in arid and semi-arid regions. Lack of constructing subsurface dams seems to be a leading cause of ineffective and unsustainable water resources management under arid and semi-arid environment.

The subsurface dam is obstacles/dam placed in alluvial deposits to block flows by storing water from alluvial aquifers, and reduce water loss by evaporation in the dry season to reserve of water available locally during periods of drought [7], [8], [9]. It used to harvest water and to minimize evaporation losses [10]. Subsurface dam is a method for storing water during wet periods for dispersal during dry times [11]. Subsurface dams are widely used worldwide since they are proved to have advantages over surface dams in some cases [12]. Construction of subsurface dams is one of the best methods to conserve water resources in arid and semi-arid regions [13]. Subsurface dam is a promising engineering technology for groundwater resources development [14]. It is a technically feasible and widely used solution to prevent high evaporation in dry and semi dry area [15]. It supports storage of water in the pores of the strata to enable its sustainable use [16]. Increased water security can be realized when water from periods of relative excess can be stored to improve water availability in dry periods [17].

Different techniques for making subsurface dams to store water in sandy alluvium have been developed to increase water resources in basement areas [18]. In Chad, also several types of underground dams have been experimented. To date, however, there has been no conclusive evidence that subsurface dam is scientifically studied in Chad. The objective of this research is to test the effectiveness of the subsurface dam to guarantee and store water to be used during dry season.

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2. METHODOLOGY

2.1 Study area: Korlongo

The village of *Korlongo* is located in the *Dangaleat* East canton*, Abtouyour* department in *Guera* province, Republic of Chad. The constructed subsurface dam located between latitude 12.16°N and longitude 18.47°E. The climate is semi-arid with a long dry season and a short rainy season lasting approximately between May and September [5]. The mean annual temperature is about 32^{o}C. The rainy season starts from July up to September. Rainfall mean annual value is about 625 mm, while the mean annual evaporation rate is about 1600 mm. Fig. 1, shows the area where the subsurface dam is being built.

People and animals mainly use natural or managed ponds filled with runoff water and shallow wells. The ponds being in the sun under high evaporation and huge loss by infiltration. High evaporation lowers the pond water level by one meter every two months which makes them dry quickly. During middle of the dry season (December January February), the ponds are mostly dry. The end of the dry season (March April, May and June) is considered the “pastoral” lean period due to the scarcity of surface water. During this period, the breeders are forced to go to lakes and dams to find water

2.2 Subsurface dam

A subsurface dam has been built in the Wadi that crosses the village. The subsurface dam was built using a new technique based on the construction of a trench crossing the Wadi. A plastic sheet (Fig. 2) is placed in the trench and glued to the bottom in a micro trench of 10 cm deep and attached on the sides to the rocks or clays to stop the subsurfaces lateral flow of water and thus delay the possible drying up of a well placed in upstream. A lot of literature demonstrated that, subsurface dams are very usefull instruments to sustainabily increase water storage in an aquifers [19].

2.3 Piezometers

Water levels were monitored using four piezometers (Fig. 3). Two piezometers were placed upstream at a distance of one meter and 30 meters upstream the subsurface dam body and two piezometers were placed at one meter and 30 meters’ distance downstream of the subsurface dam. The monitoring takes place once a week for the full season of 2022.

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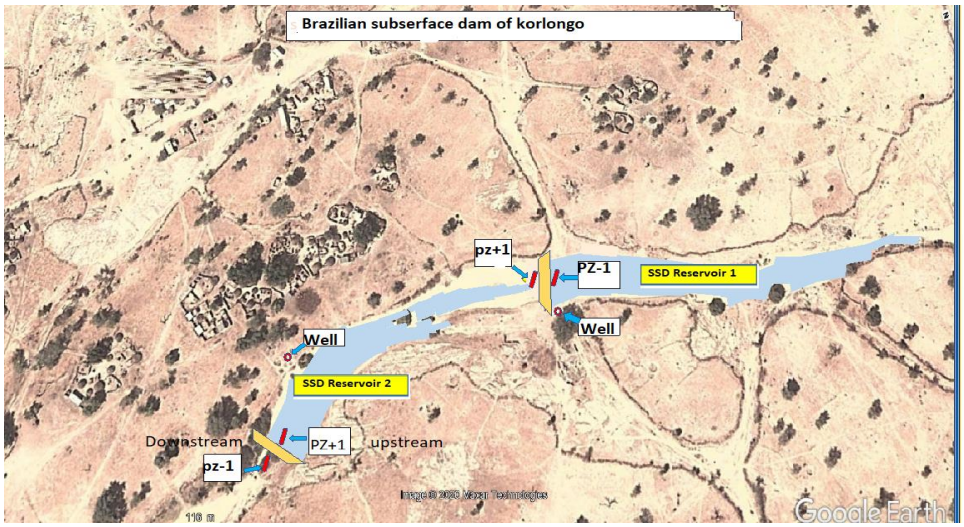

Fig 1: Subsurface Dam at *Korlongo*, The Study Area

Fig 2: Plastic Sheet To Block Water Losses

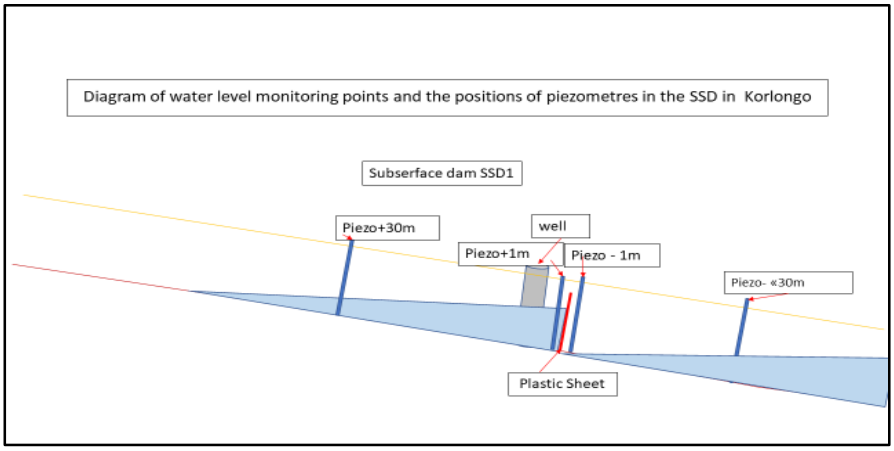

Fig 3: The Piezometers

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3. RESULTS AND DISCUSSION

The weekly measurement by the electric probe of the piezometers set up upstream and downstream of the dam, allowed precise hydrological monitoring to show the effectiveness of the subsurface dam to block possible water losses. Fig. 4, represents the variations of water levels of the two piezometers placed upstream and the other two placed downstream of the dam. Specifically, water levels indicated by piezometers installed upstream and downstream of the dam at 1 meter and 30-meter distance. The water level in the piezometers located 1m upstream, shows higher reading compared to the piezometer placed 30 meter. Water level at the well located upstream the subsurface dam rose up to 5.7m, 3.50m and 3.25m during rainy, winter and summer times respectively. Results indicate that the water level in the upstream of the body of the subsurface dam, drops less quickly during the dry season. This makes the water available all year round. This result is in line with Yibeltal et al. [20] who found that subsurface dam was effective in controlling subsurface water level.

Seasonally, rainy time showed better water levels in the piezometers including of the well. December, January, February and March, showed better water levels. The upstream piezometers indicate good water levels during summertime (April, May and June) compared with water level during try period before the subsurface dam. Figure 4 shows that the dam was providing considerable water during the winter and summer times. The water provided by the dam was used to fill in the gab of water during summer time. Weekly measurements of the quantity of water withdrawn by the agro-pastoralists and herders, have showed that water is always available at a distance of 30 meters upstream the body of the reservoir. Obviously, this quantity of water decreases in the dry season. Observations showed that despite the daily withdrawal of water, the water is available throughout the year. This improvement of water, is compatible with the main objective of the construction of the dam that, to alleviate the lack of water during dry season. It is also noted that there was water downstream of the dam but it decreased gradually from the body of the reservoir.

Fig. 4, shows that, the water level at the well rises up to 5.7 meters because of the dam. The results are in agreement with Raju et al. [6] who found that there was an average rise of 1.44 m in post-monsoon and 1.80 m in the pre-monsoon period after the subsurface dams were constructed while Sahlin and Tyfur [21], found that an underground dam rose the water levels by an average of 9.5 m

Chad is like any other semi-arid and arid regions of Africa, has a series of periods of droughts and suffering from serious water stress [22]. Long periods of droughts have caused the population and animals in Chad to be seriously threatened by the lack of water resources [23]. Thus, one of the ways in which surface water storage has been considered in the form of construction of subsurface dams in the direction of the bedding of alluvial rivers or Wades. During the rainy season, the alluvium that constitutes the reservoir upstream of the dam fills up much earlier and remains full of water. The water flows rapidly downstream of the dam and begins to run out at the beginning of January as the case of the majority of the Wades in the area. An analysis of hydrographs of

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piezometers of subsurface dams, reveals that there is significant rise of water levels after the subsurface dam was constructed.

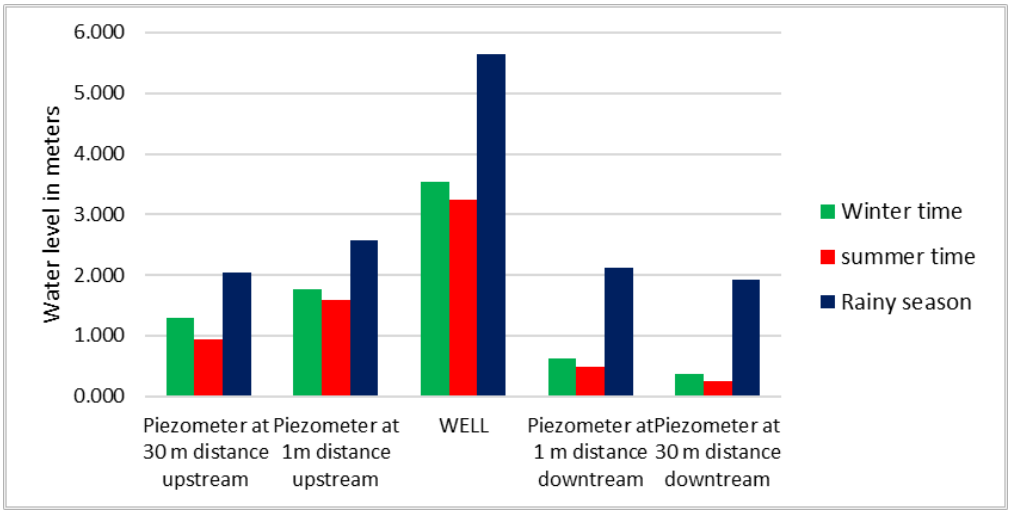

Fig 4: Water provided by the subsurface dam indicated by water levels in meters

Fig. 5 shows, the stored water at the well during August. The stored water is used during dry season for human and animal drinks. Zwarts, & van der Kamp, [24], confirmed that, the majority of resources in Chad, dry up as soon as the dry season reaches the months of January and February. The figure shows continuity of presence of water throughout the year. The water provided by the dam reduces the migration of pastoralists and agro-pastoralists in drought period fetching for water. People travelled up to ten kilometres per day fetching water during dry season. The analysis shows that the subsurface dam is efficient to provides water upstream the dam to be used to satisfy human and animals needs across the year particularly during summer time where dryness is everywhere in Chad. These results have important implications for developing water resources and add to a growing body of evidence that suggests adoption of subsurface dams in arid and semi-arid regions of Chad.

Fig. 6 shows, water extraction from the well set upstream from the dam. The water abstracted from the well, has been used to meet humans and animal's needs. Water abstraction begins just after rainy season on November. Maximum extraction of water occurred during January and February. During January, the average abstracted water reaches more than 12,800 litres per day and more than 12,500 litres per day during February. Before the dam, people and animals mainly use natural or managed ponds filled with runoff and shallow wells however, ponds and shallow waters losse rapidly. During the middle of the dry season (January February), the ponds are mostly dry and the watering of animals is based on sumps. Beginning of June - just before rainy time - the daily water abstraction reached about 10,300 litres per day. Then the water abstraction reduced to the minimum level during the period after rainy time of August, September and October. During September, no water abstraction was registered as water is available everywhere. Despite the daily withdrawal of water from the well, the dam makes water available throughout the year at upstream. This result is in line with Telmer

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and Best [11], who proved that subsurface dam is a method for storing water during wet periods for use during dry times.

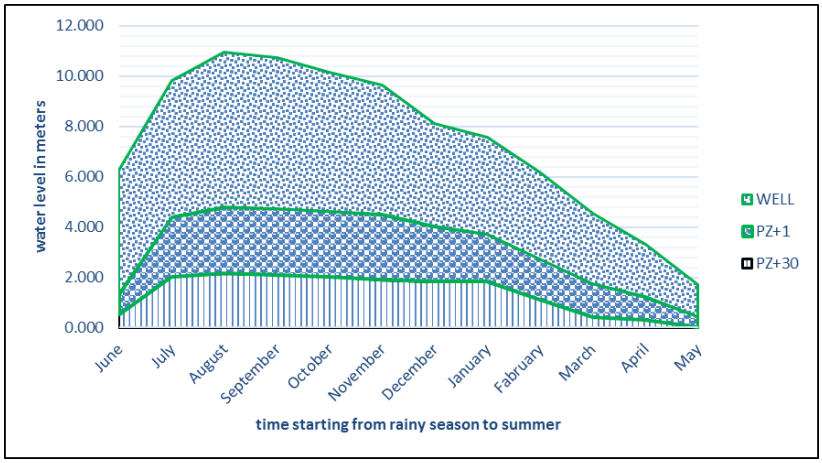

Fig 5: Water level monitoring curves in piezometers upstream the subsurface dam

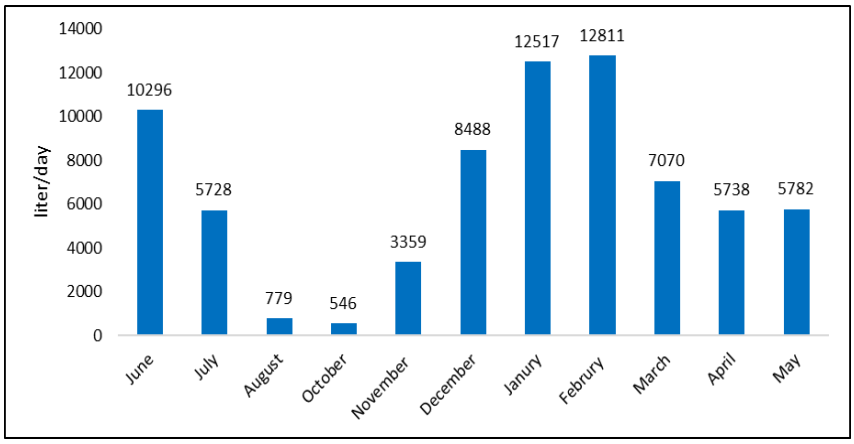

Fig 6: Average water extraction (litre per day)

A t-test is used to determine if there is a significant difference between the means of the monthly values of water levels at 1 meter upstream and 1m downstream from one hand and the difference between monthly mean values of water levels at 30 meters upstream and 30 meters downstream. the dam (Table 1). The t-value of I meter upstream (t=7.96) and 1 meter downstream (t=3.98), indicates the big difference between the means of the two groups. The positive value of the difference, illustrates that the upstream water levels has a higher mean than the water levels downstream. The results show the difference between the means is statistically significant (p = 0.002). The t-value of 30 meters upstream (t = 5.72) and 30 meters downstream (t = 4.22), indicates the big difference between the means of the two groups. The positive value of the difference, illustrates that the upstream water levels has a higher mean than the water levels downstream. The results show the difference between the means is statistically significant (p = 0.001).

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These results show significant impact of the dam in securing significant volume of water upstream the subsurface dam.

Table 1: T-test statistical analysis

	PZ at 1 meter upstream	PZ at 1 meter downstream	PZ at 30 meters upstream	PZ at 30 meters downstream
t	7.966	3.98	5.719	4.22
df	11	11	11	11
Sig. (2-tailed)	.000	0.002	.000	0.001
Mean Difference	1.83875	0.97944	1.35372	1.18295

4. CONCLUSION

In Chad, water is inadequate in huge areas of semi-arid or arid climate where humans and animals are suffering water shortage particularly during dry season. The introduced technique of subsurface dam to block groundwater losses and storing water from alluvial aquifers, allows better water and provides sustainable water resources for livestock and populations across seasons. Measurements' of water levels upstream the subsurface dam showed significant volume of water stored because of the developed subsurface dam. The study suggests subsurface dam to solve water shortage during dry season under arid and semi-arid climate. Improvement of water supply in arid and semi-arid areas through subsurface dams proved to be possible.

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