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Sustainability of subsurface dams: What influences community satisfaction in Korlongo, a village in Chad?

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Subsurface dams are important in improving water supply in arid and semi-arid regions; however, subsurface dams' sustainability depends largely on local community satisfaction. This study examines the factors influencing community satisfaction of the Korlongo village in Guéra, Chad. Data from 40 families representing 5% of the village population using the dam was collected using a questionnaire designed to collect data on the main factors influencing community satisfaction. These are the size of the family (adults), the size of the family (children), water consumption in litres per day, who transports water, community participation in building, operation and maintenance of the Dam and the community satisfaction level. The results show that the size of the family in terms of adults was small (62.5%), family size in terms of children was large (42.5%), water consumption per day is large (40.0%), young people (60.0%) who are transporting water. The community has been largely (95%) involved in the operation (no maintenance of the dam), and 72.5% is significantly involved in the construction of the dam's gravel well. Statistical analysis using linear regression significantly predicted community satisfaction of the dam from the size of family (adults), size of family (children), water consumption in litres per day, who transports water, community participation in building, operation and maintenance of the Dam. The findings are important for the sustainability of the subsurface dam and will contribute to improving water management.

Keywords: Sustainable subsurface dams, community participation and satisfaction, Chad

INTRODUCTION

The Sahelian zone is a strip of land covering 3 million km² that acts as a buffer between the Sahara desert to the north and the Sudan savannah to the south (Johnson, 2013). Less than 5% of water resources are exploited in the Sahel Region. Nearly 30% of the population is deprived of access to water in addition to strong population growth in the Sahel, which will double by 2025. Total annual renewable water resources are estimated at 278,650 million m3 (Wilson et al., 2012).

Traditional techniques and more modern hydraulic infrastructures have so far been unable to guarantee access to water at the end of the dry season in bedrock areas. The subsurface dams, additionally recharged alluvial groundwater with the first few days of precipitation (Ryan and Elsner, 2016). The development and management of groundwater basins is one of the most attractive solutions to water shortages, with relatively low social and environmental impacts, and offers enormous potential for the population of arid and semi-arid zones (Mahfoud, 2011).

A subsurface dam was constructed in 2019/2020 to solve water shortages in the area of Korlongo

situated in a bedrock area in central Chad. Subsurface dam can collect and store huge volumes of rainwater, increasing national income and providing stability for residents in arid regions facing water shortages (Abd-Elhamid et al., 2021). Subsurface dams can help meet water resource requirements in arid regions and support economic development (Shahraki, 2019; Dortaj et al., 2020). Subsurface dams can help manage and relieve water shortages for residents in the dry season (Kharazi and Heshmatpour, 2021).

Subsurface dams can increase water resources by increasing pumping rates and well construction, potentially improving community water services (Oh, 2017). The underground dams facilitate livestock watering in Brazil, where about 500 small subsurface dams were built manually during the 1990s by the efforts of the local population. Subsurface dams store and sustainably benefit communities by not submerging land and avoiding potential breaches due to natural or man made disasters (Ishida et al., 2011). Subsurface dams can aid in sustainable groundwater management, reducing water shortages (Jamali et al., 2013). Therefore, dams are required in desert environments to store excess water, recharge aquifers and provide a sustainable source of freshwater (Attwa , 2021).

In the Guera province, in the centre of Chad, a few (3) subsurface dams were installed in 2019 and 2020, in the village of Korlongo in the Abtouyour departments. The aim was to reinforce wells and reduce water shortages at the end of the dry season, between February and June. After three years of the dam supplying water to local communities, the impact of the dam on the community has not been evaluated. Community satisfaction has not been assessed and the reasons behind their satisfaction are not known. This paper examines the community’s satisfaction with the dam and the reasons behind the satisfaction as this may improve the sustainability of the dam.

METHODOLOGY

Survey site

The village of Korlongo is located in Dangaleat East canton, Abtouyour department, Guera province, Republic of Chad. The coordinates of these dams are latitude 12.16554 and longitude 18.47406, with a height of 437 m above the mean sea level. Three subsurface dams (SSD1, SSD2, and SSD2a) have been installed in the Wadi (river) that runs through the village. The subsurface dams were built using a new technique based on the construction of a trench crossing the Wadies and reaching all along the impermeable zones (layers). A plastic sheet or geomembrane is placed in the trench and bonded at the bottom, and sides to the rocks or clays to stop the underground flow of water. Then the trench is filled with excavated sand and the geomembrane stays entirely burried, thus, delays the eventual drying up of a well-placed upstream.

The climate of the region is Sahelian. The average annual temperature is 28.2°C. The average annual rainfall is 667 mm/year. The rainy season lasts four months (June-October). The Guera province is largely underlain by bedrock, where groundwater is scarce and soil is very thin. Most of the wells that have access to the alluvial water tables along the many temporary watercourses will generally dry up before the end of the dry season.

The Abtouyour department of the Guera province is a very densely populated area, with an estimated population in 2020 of 197 745 inhabitants in a surface area of 9 448 km² and a density of 20.9 (inhab./km²)(PDL, 2020). The number of farmers and agro-pastoralists of the Dangaleat, Kenga, Arab and Djonkor ethnic groups, who mainly grow sorghum, peanuts, millet and transplanted sorghum. Transhumant herders, mainly Arabs, cross every year along a north-south axis.

Data collection and sampling

To ensure a representative sample of the village's population, we used random sampling. Out of the 67 concessions (groups of family houses) identified in a satellite image, 40 were randomly selected using a random number generator. This method was chosen to minimize selection bias and ensure that the sample accurately reflected the diverse socioeconomic conditions and water usage patterns present in Korlongo. The randomization process ensured that each concession had an equal chance of being selected, thereby enhancing the generalizability of the study findings.

Within each of the 40 selected concessions, the interviewers were instructed to randomly choose one family home for the survey. This intra-concession selection was conducted using a random walk method, where the interviewer would start at a designated point within the concession and select a household based on a predefined interval (e.g., every third house). This method helped maintain the integrity of the random sampling process by ensuring that every household within a concession had an equal probability of being selected. By adopting this Approach, we aimed to capture a broad spectrum of household experiences and perspectives, reducing intra-concession variability and enhancing the representativeness of the sample.

The survey took place from March to April 2022. Trained interviewers, proficient in the local language and well acquainted with the community accompanied by a person designated by the village chief, conducted face-to-face interviews to administer the questionnaires. This approach was chosen to ensure clear communication and facilitate accurate responses from the participants. The timing of the survey was carefully selected to avoid seasonal fluctuations that could influence water usage patterns, thus ensuring that the data collected accurately reflected typical conditions.

The survey questionnaire was designed to gather detailed and relevant data on various aspects of water usage and community satisfaction with the underground dam. The questionnaire included a mix of quantitative and qualitative questions, such as level of satisfaction and reasons, quantities of water used daily, family size, community participation, knowledge of underground dam experiences and difficulties and suggestions. Some of the data were categorized into qualitative groups to ease analysis and understanding as shown in table 1. The data gathered from the 40 questionnaires were entered and processed using SPSS, to ensure accurate recording and organization of the survey responses, facilitating subsequent analysis and interpretation of the findings.

RESULTS AND DISCUSSION

The population of the Korlongo village and those surrounding it are the direct beneficiaries of this water. Water extractions start at 6 am and stop at 6 pm in the rainy and cold seasons. In the dry season, water is extracted day and night. Children and girls carry water in 10- to 15-liter cans and buckets; older children carry 20- to 25-liter cans. Women use to carry one bucket and 15-liter cans on their shoulders, linked by ropes. Donkeys carry two 25-liter drums and carts may carry one 200-liter water jugs or more (Figure 2).

In arid and semi-arid zones such as the Sahel, the relationship between people, animals and the environment is complex. This is because the level of available resources is highly variable from one year to another since it depends not only on the total volume of rainfall but also on its distribution in time and space. Therefore, the subsurface dam technique, consists of recharging the water table and storing it by stopping the sub surface transfers, is effective in arid environments. The dam stored water may recharge the water table with a single Wadi flow, enabling the population and herds to drink easily until all stored water is extracted.

The survey results showed that, the vast majority of households were satisfied with the improved access to water provided by the subsurface dams. The not entirely satisfied households (30% considered average satisfaction) were living too far from the existing subsurface dams and were requesting a similar investment (installation) in their neighborhood (vicinity). In addition, the reasons for dissatisfaction have always been requests for additional new subsurface dams to make

these improvements accessible to all village districts and, if possible, to all their inhabitants. The risks of a return to past situations of cruel water shortages at the end of the dry season were often raised.

At the time of the survey, at the end of March, the start of the final period of the dry season, more than half the families were drawing water from wells located upstream of one of the three underground dams (Figure 2). This suggests that water in these wells dries up more slowly, or not at all.

It has been observed that local water users appreciated the quality of the dam water for drinking and cooking more than that of human-driven pumps. In fact, human-driven pumps use boreholes to extract groundwater stored in faulted and/or weathered rocky areas, which are generally higher in salt content.

Most surveyed families of the community have participated in the work carried out during construction, and 90% of them said that at least one member of their family had taken part in the work. Ananga et al., (2020) confirmed that community participation in dam construction, including labour, meeting attendance, financial contributions, and timely payments, positively impacts beneficiary satisfaction and overall effectiveness. Similarly, all the surveyed families have confirmed their readiness to support new subsurface dams. This is why local stakeholders' concerns are key incentives and influencing their involvement in participatory monitoring (Verbrugge et al., 2017). The majority of respondents were aware of the subsurface dam and participated in the discussion when the dam was initiated. Community awareness and participation contribute to the success of community self-help projects, such as the Kumbo water supply scheme in Cameroon (Njoh, 2006). Local communities strongly participate in the manual work of digging the trench, even if this has to be done at the end of the dry season when temperatures were high. Community participation, through contributions, cooperation, consultations, and utilization, plays an indispensable role in the realisation of public works projects in less developed countries (Njoh, 2003).

Community participation in water projects correlates with increased satisfaction with the work of the water management committees (Ananga et al., 2020). Later (2023) the community have undertaken the construction of a new cemented well in the centre of the alluvium, expecting the installation of new underground dams immediately downstream. Community participation in decision-making significantly influences the sustainability of community water projects, with increasing participation strength positively correlating with project sustainability (Muniu and Rambo, 2017). Community participation in rural water supply in India leads to better water quality, improved health habits, and higher satisfaction compared to projects without community involvement (Manikutty, 1997).

Each family collects and brings home an average of 176 liters of water every day. This represents an average of 32.4 liters/person/day. The main uses of water are, drinking, cooking, laundry, bathing and watering animals. Families don't bring water home to make bricks, but 12.5% of families surveyed mentioned taking water to make bricks, but directly from the alluvium Wadi in Sumps.

Young girls carrying two buckets of water mainly transport water from the well to the houses on foot. Next come donkeys carrying two drums and, to a lesser extent, horse-drawn carts carrying large metal drums (Figure 2). Each family fetches water an average of 4.7 times a day, keeping young family members busy for an average of over an hour (75 min) every day.

Frequency analysis

A survey was conducted among two categories of agro-pastoralist families to assess the early satisfaction levels of beneficiaries with the water provided by the Korlongo underground dams,

three years post-construction. Out of the 40 sampled families, those comprising children, including both the youngest and eldest, constituted 42.5%, whereas families with only children represented 22.5%, with an average proportion of 35% (Table 3). Regarding adult families, the youngest members were significantly more inclined to draw water from the dams, accounting for 62.5%, compared to 25% among the eldest members, resulting in an average of 12.5%. Analysis of water consumption patterns revealed that adults consumed a larger proportion of water, with 40% sourced from the subsurface dams, compared to 35% among children. This suggests a division of labor where children are primarily involved in water transportation while adults are not responsible for consumption. Notably, small children (mainly young girls), often seen carrying two buckets, transported 60% of the water from the dams to the concessions, while donkey and horse-drawn carts, equipped with large metal drums, transported the remaining 35%. Additionally, all surveyed families reported having observed the construction works, with 90% indicating participation from at least one family member. Moreover, regardless of their current usage of subsurface dams, all families expressed a desire for more dams and were willing to support new constructions, even if located up to 5 km away. The majority of respondents demonstrated awareness of ongoing discussions regarding the establishment of three new subsurface dams at the local level. Two key indicators of the technique's acceptance were evident. Firstly, the active involvement of the population in manual labor, including trench digging, even during periods of high temperatures at the end of the dry season, and secondly, communities initiating the construction of new wells in the center of the alluvium, anticipating the subsequent installation of underground dams downstream.

Regression analysis

Regression analysis showed R 0.966, R2 = 0.933 which indicates a good level of prediction. The regression model is a good fit for the data (Table 4). The model predicted community satisfaction from family size (adults, children), volume of water consumed, responsibility of transporting water, and community satisfaction of the dam. These variables statistically significantly predicted community satisfaction, F (5,295) = 66.1, p less 0.005, R2 = 0.933. Two variables of community participation in the well gravel of the dam, and community participation in initiation of the dam added statistically significantly to the prediction. Community participation indicating dam ownership and hence will lead to the sustainability of the dam. Responsibility of water transportation and water consumption insignificantly influenced the community satisfaction because the dam makes water abundant and near to homes and therefore, community feels water availability is not a challenging issue after the dam. The family size in terms of adults and children, insignificantly influenced community satisfaction because the family size influence the consumption of water by the families which is small compared with water used by animals and agriculture (Izady et al., 2021).

The equation

Satisfaction =0.143*family size children -0.176*family size audults+0.091*who transport water-0.043*water consumption per day+1.790*community participation in cleaning the dam area+0.479*community participation in well gravel+ 0.200*total water consumption

The figures below depict the correlation between the independent variable, representing water extracted daily by agro-pastoralists and livestock breeders, and the dependent variable. A thorough analysis of the results underscores a robust relationship between these variables, affirming the significant contribution of subsurface dams in enhancing water accessibility within the study area.

CONCLUSION

The subsurface dams, constructed utilizing an innovative and cost-effective artisanal technique, have demonstrated remarkable effectiveness, eliciting widespread satisfaction among the local population. Notably, these dams have substantially augmented water availability, particularly

during the latter stages of the dry season, benefiting over half of the village residents. The overwhelming support for expanding such initiatives among families underscores their recognition of the scheme's benefits. However, given their specific requirements, including adequate upstream sand volumes and suitable impermeable land characteristics, the feasibility of widespread replication remains limited to areas of identical hydrogeological situation, especially in meeting the demand for proximity to individual households. Nevertheless, scaling up this technique in favorable areas with abundant sand rivers holds promise for significantly enhancing living standards and livestock watering conditions for numerous communities. The survey findings revealed consistent water provision throughout the year, mitigating the pronounced water deficit during the dry season. In light of global changes, population growth, and increased mobility, reinforcing existing infrastructure by constructing additional subsurface dams in adjacent Wadis emerges as a pressing necessity to address escalating demand effectively.

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