Aqua 4 Sudan Partnership

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Water Conservation for Agriculture

The Case of Mesga-15 in East Sudan

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TABLE OF CONTENTS

INTRODUCTION

Sudan has the largest irrigated area in sub-Saharan Africa and the second largest in Africa, after Egypt. Agriculture is the major water consumption sector in Sudan, utilizing up to 96% of its annual water withdrawal. Internal renewable water resources (IRWR), Nile system resources, and non-Nilotic water resources are rather limited in Sudan. The erratic nature of the rainfall and its concentration in a short season places Sudan in a vulnerable situation. The significance of both natural resource limitations and climate can contribute to extreme water scarcity (FAO, 2015; Falkenmark et. al, 1989).

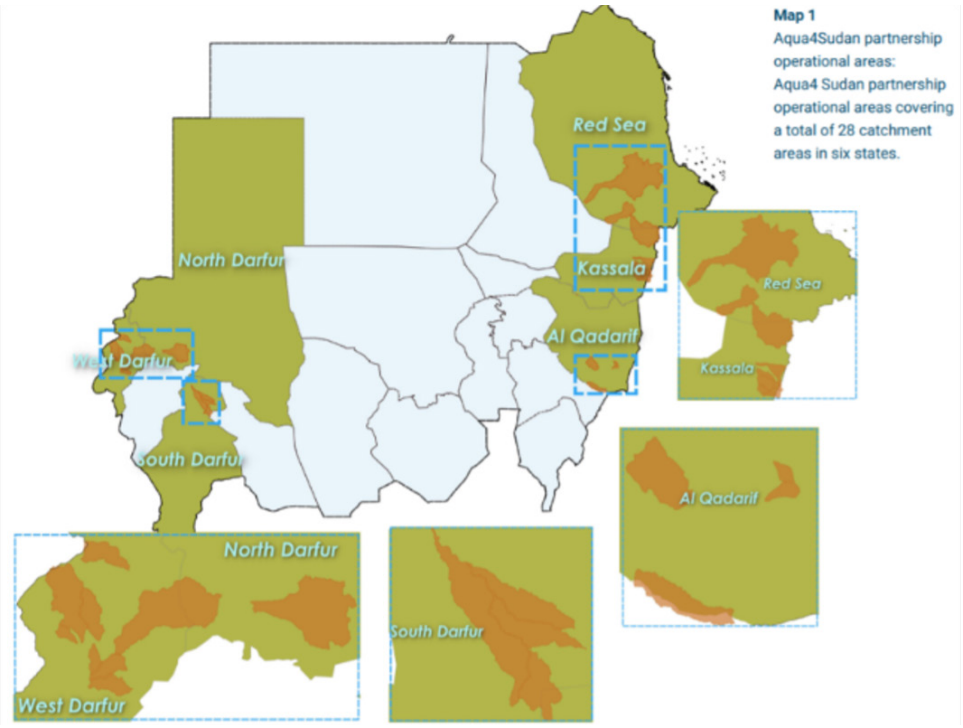
In Sudan, assuming today's poor irrigation infrastructure, the total consumption was predicted to exceed the total annual yield of the Nile basin. Therefore, a key challenge for water resources management in the Nile Basin is balancing the increasing irrigation water demand basin-wide with the available water supply (Multsch et. al, 2017; Hess, et al., 2016).

The existing heavily sectorized policies in Sudan are ineffective or even counterproductive for the long-term, sound use of the resource base. Instead, management and usage of water resources need to reflect the fundamentally interconnected nature of a hydrological unit, such as a catchment area. An Integrated Water Resource Management (IWRM) approach is therefore needed. It balances the different water requirements for domestic, livestock, crop, grazing land and other uses with the total availability of water within the catchment area.

There are many sides to IWRM, which make it a successful approach. It promotes the coordinated development and management of water, land and related resources. IWRM is technically and scientifically informed, while heavily reliant on stakeholder participation. Because of this, communities are empowered and have a shared responsibility for their water use and sustainable resource management in a coordinated and integrated way.

Rural Water for Sudan was a pilot IWRM programme and had the largest geographic representation of IWRM programmes in Sudan in the last three decades. It was implemented by the Aqua4Sudan partnership from 2015 to 2020 with funding from UK aid.[1] The programme aimed to contribute to coordinated sustainable access to water and land in the six states of Red Sea, Kassala and Gedaref, North Darfur, West Darfur and South Darfur.

This paper focuses on how one of Aqua4Sudan's water conservation for agricultural activities contributes to the increased efficiency of water use for irrigation. The intervention used for this case study took place in the season 2019/2020. Geographically it was situated in the North Delta Locality in Kassala state, and more specifically in section Mesga-15 of Metateib Block of the spate irrigation system known as the Gash Agricultural Scheme (GAS). The technical design of the intervention was based on research conducted by the Hydraulics Research Center (HRC-Sudan). Since 2015 this research has focused on the question of how the irrigation water distribution can



Map 1
Aqua4Sudan partnership operational areas: Aqua4 Sudan partnership operational areas covering a total of 28 catchment areas in six states.

[1] The Aqua4Sudan partnership in Sudan consists of PLAN Sudan, ZOA, International Aid Services (IAS), Islamic Relief Worldwide (IRW), Practical Action, SOS Sahel and World Relief.

be enhanced at the farm level (HRC, 2020). Of the Aqua4Sudan consortium partners, Plan International in Sudan and the Sudanese Delta Organization were responsible for this project activity, while HRC-Sudan was in charge of its technical design and implementation.

Spate irrigation is “a resource system, whereby flood water is emitted through normally dry wadis and conveyed to irrigable fields” (Mehari et al., 2007). It has been practiced in Sudan for many years and can be found in several areas. The Gash Agricultural Scheme (GAS) in Kassala state provides valuable irrigated fertile farmland for smallholders, but is not being utilized to its full potential. This paper describes an intervention in the GAS which augments efficiency of water use for irrigation and subsequently increases crop yields.

2 FARMING SYSTEMS AND LAND TENURE IN NORTH DELTA

Kassala state in East Sudan has a desert climate with an annual rainfall ranging between 180–280 mm, and an average temperature from 26°C in winter to 42°C in summer (Ghebreamlak et al., 2018b). People in East Sudan have indigenous mechanisms for managing natural resources such as water and grazing land. However, scarcity of water is becoming increasingly problematic.

Farming systems

Water scarcity is a major problem for farmers in Kassala. The farmers in North Delta locality are traditionally agro-pastoralists and many lost their animals because of droughts or floods. A majority of the farmers now have a few animals only for subsistence (milk and meat) and as insurance in the event of crop failure. They own around 2 – 5 farm animals (cows, goats, sheep) which are kept at the home compound. Only a few people have large herds managed through a nomadic system.

All crop cultivation on arable land in North Delta depends on irrigation through floods of the Gash river. Few farmers, but none of the farmers in Mesga-15, own land for rainfed cultivation elsewhere. Crop cultivation is the main source of income for farmers. The main crop grown is sorghum however; vegetables are sometimes grown as a second crop after sorghum is harvested. All production in the Gash irrigation scheme is organic with mainly two sorghum varieties grown in the area: the local variety Aklamoy, and the improved variety Tabat. Aklamoy is grown for home consumption and the surplus is sold on the local market. As it is a tall variety, it produces a lot of green fodder, and the stems are also used for building purposes. Tabat has a higher market value, and is sold in the local market as well as in regional markets. Based on key informants' indicative figures, on average 40% of sorghum yield is for home consumption and 60% is sold on markets.

As to livelihoods, most people are dependent on agriculture and animal husbandry. Some men also have additional paid jobs in the locality. They are shepherds (herding other people's animals), drivers or they move to town to find a job. However, during the cropping season, they return to their farm. All farmers in Mesga-15 are men. There are no female farmers registered or farming in the Mesga-15. The main source of income for women is production of palm leave products. Some women are engaged in the sales of charcoal. Women are responsible for the organization and the functioning of the household needs; household work, craft work and small agricultural activities such as home gardening and caring for small livestock. (HRC, Gender and Equity, 2017). Most of these livelihoods rely on the availability of water.

Land tenure

Within the GAS, farmers do not own the land; it is the property of the government. However, they do have user rights. The mesgas are registered in the name of the water user association (WUA). When the WUAs were established in 2003, they divided all irrigated land between farmers according to a local agreement (Assessing WUA's, 2015). This agreement stipulated that every farmer has two fixed plots in two different mesgas (Mesga-15 farmers have a second plot in Mesga-13), which are cultivated in alternating years. Skeikh Algaily Abd Algadier, the head of a local farmers committee in Mesga-15, confirms that this arrangement has been advantageous for the maintenance of the mesga plots, and that farmers are satisfied with this plot allocation system. Additionally, some farmers have a sharecropping arrangement. The details of various sharecropping systems differ depending on the ethnicity and personal preference of the farmer.

Women, however, do not participate in the plot allocation system. Traditional tenure systems

prohibit women from owning land and livestock. Also, inheritance is by production rights and not by absolute ownership, which excludes women. Women are not engaged in agricultural activities outside their homestead. The only women who work on the irrigated fields are labourers who come from elsewhere. Men will not allow their female family members to work on the field. Also female heads of households cannot not perform such work. If a woman with children does not have a husband, she either makes a living through off-farm activities such as sales of palm leaf products and charcoal, or other men in the family will provide for her household or both. Female headed households also receive aid from their community. Women, however, do have vegetable plots around the house. And land preparation, planting and weeding is a joint responsibility for both men and women. Harvesting and selling the surplus of the vegetable crop is done by men.[2]

As to pastoralists around the mesga, they have land allocated to their use on the eastern side of the mesga. This land is meant for fodder cultivation, grazing land and water points for large herds of animals. Animal corridors were demarcated to make sure that animals do not enter the irrigation scheme. Yet maintenance of the demarcation of the animal corridor has been lacking. It became unclear where the boundaries lay. This led to conflicts between the mesga farmers and pastoralists.

[2] Source: Female key informant

3 GASH SPATE IRRIGATION SCHEME

The Gash River is a transboundary river and one of the main water resources in Kassala state. It originates in the highlands of Eritrea and Ethiopia and flows northwest across the flat plains of the Gash River Basin in Kassala. The first 150–200 km of the river, known in Eritrea as the Mareb River is a perennial river (Artan et al., 2006). In Kassala the Gash River is discontinuous, flowing four months per year. The Gash River can be used for irrigation in Kassala because of the flash floods that occur from July to September.

The Gash Spate Irrigation Scheme was established by the British colonial government in 1920 on fertile farmland in the Gash delta. The irrigation scheme is divided into six blocks. A network of seven main canals and 13 sub-canals conveys spate water to the irrigated areas (mesgas), ranging between 1000-2000 feddan (Ghebreamlak et al., 2018a).[3] The total irrigation distribution network is 240,000 feddan.

The Gash Agricultural Scheme (GAS) was originally designed to irrigate 80,000 feddan annually based on a 3-year rotation and a crop water requirement of 5,200 m³ per feddan for cotton. During the IFAD funded Gash Sustainable Livelihoods Regeneration Project (GSLRP) project, which was implemented between 1993 and 2013, this was changed to a 2-year rotation (IFAD, 2014). In accordance with the two-year rotation, half of all mesgas are irrigated each year. All mesgas to be irrigated are divided into two groups: the first irrigation and the second irrigation group. About 70% of the mesgas are irrigated in the first half of the flood season (first irrigation), while the remaining 30% are irrigated during the second half of the flood (second irrigation). The second irrigation is considered less reliable (HRC, 2020).

Maintenance of the GAS

Spate irrigation uses flood water which comes with much sediment in concentrations of up to 10% (Zenebe, 2012). The high load of sediment carried by the Gash River causes major problems for the GAS, such as river bed rising, clogging of irrigation intakes and canals, rising of farm lands and poor water distribution in the irrigation scheme. Costs to realize proper maintenance are high.

Over the course of the years the scheme went into decline, underwent rehabilitation and then went into decline again. In the 1970s the scheme was malfunctioning mainly due to poor maintenance. Starting in 2004, the GSLRP project restored the original design of the main canal system and mesga canals. The project managed to increase the average irrigated area by 25%: between 1993 and 2003 it was 60,871 feddan when in 2004-2013 it was 75,815 feddan (IFAD, 2014). Nevertheless, responsibilities for maintenance of the GAS are not clearly defined, which again results in deterioration and inefficiency of the irrigation scheme.

Water Users Associations

In 2003, Rural Water for Sudan established Water User Associations (WUAs) to increase participation and responsibility of the farmers. The work of the WUAs, and the fact that farmers now have a specific plot in the mesgas instead of lottery allocated plots every season, resulted in better maintenance and care of the farmland and canals. However, in the GAS the WUAs are only responsible for the maintenance of the mesga canals. The GAS management is responsible for operational work such as river dredging. Consequentially, the irrigation scheme is again deteriorating due to lack of proper maintenance.

[3] 1 feddan = 1.037 acres

Timely land preparation, cleaning and rehabilitation of the canals is not taking place, which negatively impacts water distribution and efficient water use. As the water distribution is insufficient to properly irrigate the mesgas, not all farmers are able to cultivate their allocated plot. During an assessment in 2015, 80% of the farmers stated that they had failed to get irrigation water on their farms at least once in the past five years. Also the two year rotation system is not consistently practiced by all farmers (Bashir, 2020). This can cause conflict in the long run as well.

INTERVENTION IN MESGA-15

In 2017, the Aqua4Sudan partnership established the water resources management committee of North Delta, which consists of representatives of the primary stakeholders in the catchment area. In the year following its establishment it developed a water resources management plan which provided an overview for water availability, supply, demand and existing gaps. The plan also analysed existing issues and proposed a list of prioritised interventions. One of the main issues highlighted in the plan was the ineffective irrigation conveyance system due to annual siltation and poor maintenance. Based on the plan, the committee decided upon the modification of the irrigation structure in one of the mesgas in Gash Agricultural Scheme (GAS). This enhanced water distribution, thereby increasing the efficiency of water use for irrigation.

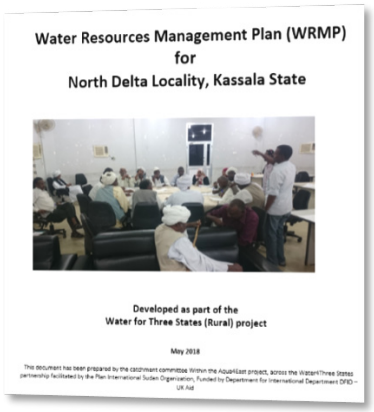


Photo 1 North Delta water resources management plan (WRMP)

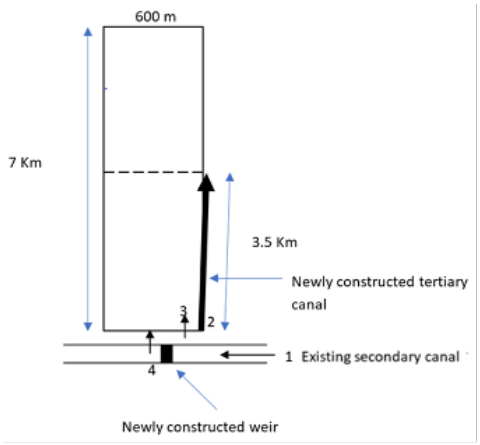


Figure 1 Modification of Mesga-14E in 2017 (HRC)

Research based intervention

The water resources management plan for the GAS heavily relied a research project carried out HRC-Sudan in collaboration with MetaMeta. It was called “On farm water management in GAS”. Phase I of the research started in 2015 with intensive data collection and field measurements (flow and soil moisture measurements) in Kassala Block, Mesga-1. In Phase II different scenarios of irrigation scheduling on the mesga level were examined. WinSRFR simulations were used to predict infiltration rates. Based on the main findings of the research, a set of interventions were proposed.[4] In Phase III (year 2017), the approved scenario was tested on the ground in Kassala Block, Mesga-14E on 1000 feddan.

The intervention consisted of a number of adaptations. First, the mesga was divided equally and horizontally into two parts, each of 500 feddan. Second, to enhance water distribution a new tertiary canal was built along the length of the mesga up to the middle of the mesga. Third, a weir was constructed across the secondary canal to allow water flow into the tertiary canal. The new tertiary canal conveys spate waters directly to the downstream half while the upstream half is supplied from the secondary canal. The researchers carried out flow measurements over the course of 11 days in 4 different sites, as indicated in figure 1. The total incoming flow in Mesga-14E in the 2017 season was 3.00 million m³.

Photo 2 Intake of an irrigation canal in North Delta, GAS, Kassala

[4] WinSRFR 4.1.3 is software developed by USDA (U.S. Department of Agriculture) to analyze surface irrigation.

The experiment proved that the existence of more than one intake leads to better and faster distribution of irrigation water and an improved yield of sorghum (HRC, 2017). The total number of irrigation days decreased from 15 days (current practice in GAS for mesgas of 1000 feddan) to 11 days (the experiment case). This means that 27% of irrigation water (of 4 days) was saved. The applied water depth in 2017 was 715 mm compared to 700 mm in 2015, which was achieved in fewer days. In 2017 sorghum production figures show that the yield of Tabat variety remained the same, but that of Aklamoy more than doubled from 0.9 MT/ha to 2.0 MT/ha in Mesga-14E compared to mesgas without interventions. The Gash stakeholders, including farmers, recommended replicating this experiment in order to prove its results (ZOA, 2018). ZOA did so in 2019 by improving the irrigation system in Mesga-15.

Mesga-15

The improvement in the irrigation system in 2019 was implemented in Mesga-15. This mesga has a total acreage of 1500 feddan and is located in Metateib Block at the downstream end of the GAS; a total of 500 farmers are allocated a plot of 3 feddan each. Mesga-15 was selected based on the regular shape and the good condition of the offtake structures. Other reasons for selecting this mesga were that it is levelled well, it can easily be accessed during the wet season, it has a limited spread of Mesquite trees and a recommendation by the block inspector. Finally, the commitments of beneficiaries to remove the Mesquite trees from the targeted area, and to participate in the construction of the canal and its maintenance in the future was a precondition for selecting the mesga.

Metateib Block consists of 36 mesgas, with a total irrigated area of 42,300 feddan (IFAD, 2014). From time to time farmers in this block experience irrigation failures. In the downstream part of Metateib only a few farmers could cultivate their lands because of the incomplete or lacking canal and poor water conveyance. Hence, several fields were left abandoned, as the water did not reach them (Bashir, 2020).

Farmers in Mesga-15 have been allocated a second plot in Mesga-13. They cultivate their plots in these two mesgas in alternating years. During 2019, when the intervention took place, Mesga-15 was in the first irrigation group. In 2020, Mesga-15 was left fallow while Mesga-13 was in the second irrigation group.

Technical improvement of the irrigation structure

Mesga-15 is 7000 m long and 1000 m wide. Spate water enters the mesga through two offtakes, located in the south-east corner and in the south-west corner. The core idea of the intervention was to divide the area of the mesga into two parts to have better distribution of spate irrigation water through an additional canal. The 1500 feddan mesga was divided horizontally in two parts of 700 and 800 feddan. An embankment of 900 m long and 1 m high was constructed to divide the total mesga area horizontally into two parts. A new mesga canal was constructed to serve the northern part of the mesga (700 feddan). The existing canal starts from the corner of the east part of the mesga along the mesga up to 750 m. The new canal was constructed 2.95 km along the mesga, and supplied the upper part of 700 feddan with irrigation water (2 m³/s) for 17 days with an application efficiency (AE) of 75%.

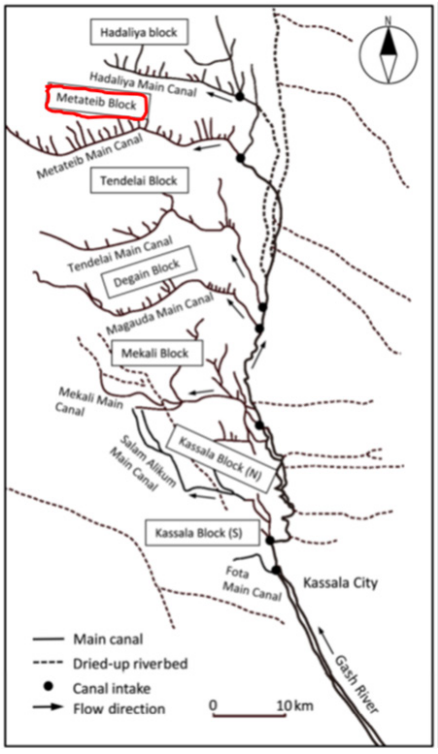


Figure 2 Gash Delta Spate Irrigation System (Ghebreamlak et al., 2018b).

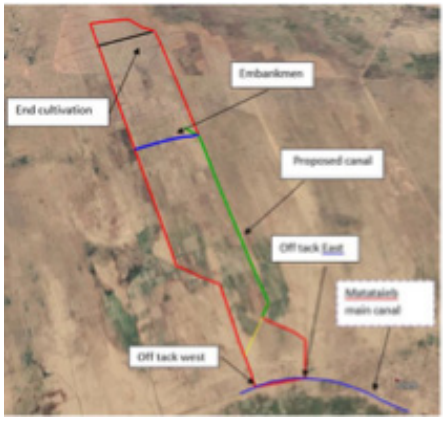


Figure 3 Location of Mesga 15

To quantify flood water entering Mesga-15, intensive measurements of water levels were carried out on a two-hour basis at the water offtake structures. A determination of flow velocities was carried out in the offtakes as well as in the Metateib canal. The total flood flows entering the pilot farm were determined from the continuous flow measurements that have taken place over 17 days. The total incoming flow to Mesga-15 was found to be around 4.5 million m³. Consequently, the applied irrigation depth is calculated by dividing the irrigation water volume (4.5 m³) by the farm area (1500 feddan). This results in 710 mm applied irrigation depth.

The ability of a soil to store water in the root zone determines its ability to support plant growth and crop production. The soil of Mesga-15 in Metateib Block is silty clay which has a high water holding capacity. Soil moisture was determined prior to the flood season, immediately after flooding, during the growing season with certain intervals, and after harvesting. Each sampling point has been sampled at three depths: 0-30cm, 30-60cm and 60-90cm. The figures were compared with samples taken during the earlier trial in Mesga-1 Kassala block in 2015.

Rainfall and flooding in 2019

Highly variable and unreliable water supply is the main source of risk in the Gash spate irrigation system. This risk manifests itself in low and high floods, late and early floods, short and long floods. In 2019 water supply in the Gash spate irrigation scheme was good: the total rainfall in 2019 was 162.5 mm (Kassala station). Nevertheless, a break in the main canal caused overflooding before the water reached Mesga-15. This resulted in loss of water, and opening the inlet for more calendar days in order to irrigate the mesga for 17 days.

Support to farmers

During the project, Plan International, one of the Aqua4Sudan consortium partners, supported local farmers with technical trainings and access to inputs to ensure optimum utilization of the irrigated area.

Farmers received training on land preparation, planting, weeding, pest management (including biological pest control), harvesting techniques and post-harvest handling. As cultivation in the GAS is entirely organic, all agriculture training was based on organic practices. The curriculum of the training was provided by the Ministry of Agriculture. There were 50 training of trainer sessions held in which Field Officers trained farmers. The project also provided training for women on vegetable production. Five groups of 17 women were trained and provided with vegetable seeds and a drip irrigation system for a home garden of 100 m2. In addition, the project provided improved seeds which are available through local input suppliers.

Achievements

The interventions in both Mesga-15 and Mesga-14E prove that productivity of the irrigation scheme can be increased substantially. The cropped area has been increased with the same amount of water, while the crop productivity improved. Also the irrigated area of Mesga-15 increased. In 2017 only 374 feddan of land was irrigated, while 1500 feddan was irrigated in 2019. This also means that many plots in the mesga were not or only partly irrigated before the intervention – 40 to 45 farmers did not receive irrigation water on their plots at all in previous years. In addition, the total time needed to irrigate the mesga decreased. Before the intervention it took 21 days (in GAS for 1500 feddan), whereas after the intervention it took 17 days.

In 2019, during Focus Group Discussions, farmers in Mesga-15 stated that their sorghum yields increased due to the provision of water in sufficient quantities. Their yields of Aklamoy sorghum variety increased from an average of 0.5 MT/ha to 1.5 MT/ha, while Tabat yields increased from 1.3 MT/ha to 2.8 MT/ha (HRC, 2020). Sheikh Algaily A. Algadier confirmed that farmers are very satisfied with the achievements, especially the farmers whose lands were irrigated after a period without irrigation.

Cost-benefit

The total cost of intervention was 800,000 SDG. The average increase yield mounted to 1.25 MT/ha. For the total of 1500 feddan, which equals 630 ha, the total increased yield as a result of this intervention is approximately 700 MT of sorghum. The average sorghum price in Kassala in November 2019 was 23 SDG/kg (WFP Market Monitor, 2019). This resulted in a 18 million SDG profit, made by an investment of 0.8 million (intervention costs). Although the cost-benefit ratio is high, it must be taken into account that the high inflation also contributed to this outcome.

Sustainability

The efficiency of the irrigation system in Mesga-15 increased substantially in terms of total irrigated area and cultivated area. Therefore, keeping the scheme well-functioning is in the interest of the farmers and the Water Users Association (WUA). The farmers have a fixed plot in the mesga for which they are responsible, and which they cultivate every second year. Farmers are also responsible for maintenance of the new canal constructed by the project, according to the agreement that was made with them when it was constructed. The canal needs to be cleaned and cleared seasonally. Farmers received training in maintenance and water distribution in the mesga. Before the project intervention, some farmers over-irrigated their plot, creating water shortages elsewhere in the system. Afterwards, this hardly happened. Cooperation between farmers in order to make the system work for all users improved. If a bund or canal is damaged, the mesga farmers repair it together.

The upkeep of the intervention was also well thought-through. The WUA collects a water fee from the farmers to cover regular operation and maintenance expenses. This is general practice throughout the GAS. In 2019 the water fee was 110 pounds per feddan. Farmers only pay for the plots that are actually irrigated in a particular season. The WUA of Mesga-15 also initiated an additional fund at the community level for future maintenance of the mesga canals and inlet structures. However, the maintenance of the main irrigation canals and the river dredging, which fall under responsibility of Al-Gash Scheme Management, remain a challenge mainly because of the increasing costs.

Nevertheless, there is potential for upscaling. The increased efficiency of water use which reduced the total irrigation days of the mesga from 21 to 17 days, has the potential beneficial effect of water availability downstream of the mesga. The actual effect has not been measured, but the decreasing water flow on one mesga will naturally have a positive effect on the efficiency of the irrigation scheme. For one mesga this effect will be limited, but if upscaling of the intervention in other mesgas would take place, the benefit for downstream mesgas would increase.

5 CONCLUSIONS AND RECOMMENDATIONS

The Gash irrigation scheme has not used its full capacity, because it has not been well maintained over the years. The capacity of the canals is not sufficient anymore to irrigate a full mesga through one or two intakes directly from the secondary mesga canal. Therefore the Aqua4Sudan partnership invested in community committees, which decided to carry out an intervention in the GAS irrigation scheme. A number of main conclusions can be drawn from this intervention:

- Splitting a mesga into two equal portions resulted in a larger total irrigated acreage within the mesga, and enhanced the efficiency of water usage for irrigation.
- The improved field water management increased crop productivity, thus contributing to enhanced food security and increased income.
- Farmers were satisfied with the achievement, and show commitment to maintain the improved irrigation system.
- The total amount of water used for irrigation did not increase, thus the intervention does not negatively affect the irrigation scheme as a whole.

Scaling up the technical improvement of the irrigation scheme to other mesgas is recommended, although there are preconditions for the intervention to be effective:

- Mesga-15 has been selected for this pilot, based on its favorable conditions (e.g. in-field irrigation structures, proximity to the main canal, commitment of the farmers). Other mesgas should also meet these requirements in order to reach similar results.
- Mesga-15 has a well-functioning Water Users Association (WUA). An effective and trustworthy WUA is a prerequisite for investing in an intervention.
- The intervention can only be sustainable if farmers are committed to clean and maintain the mesga canals and inlets, to control the spread of Mesquite trees and to ensure timely field preparation.
- Farmers do not control the entire water supply throughout the irrigation scheme. Many stakeholders have responsibilities regarding the operation and efficiency of the irrigation structures, as well as the timely river dredging. For policy makers and donors it is therefore essential to involve all responsible parties, including the Ministry of Agriculture, Ministry of Irrigation and Water Resources, the Gash Authority, and the Gash Farmers' Union when scaling up interventions to increase efficiency in the mesgas.
- An extensive hydrological analysis for the entire irrigation system is mandatory to understand the different effects of integrating wires. Before upscaling the approach to the entire scheme it should be known how the intervention will affect the overall water balance under different climatic scenarios. This is particularly important to avoid magnifying drought risks during low flood years.

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INTERVIEWS

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Almadani Alhassan	PLAN
Awadiya Osman Abakar	Female project beneficiary (Mesga-15)
Hussam Aldeen Hayder	PLAN DPM & FSL Project Coordinator
Mona Suliman	Female project beneficiary (home gardening)
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