

Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya

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Received 1 May 2006

Available online 18 May 2007

Abstract

This paper presents the results of an evaluation of the effects of a local water harvesting project in Kenya concerning the construction of small scale sand dams by communities. Sand dams are small structures built in ephemeral rivers to store excess water to overcome periods of drought. For this evaluation we developed a method using socio-economic vulnerability indicators, which are linked to the state water resources system, enabling the assessment of the impacts of changes in water management. Data for this evaluation was gathered by hydrological research and by interviewing local inhabitants during field research. It appeared that the sand dams have a large impact on the local community. In 10 years time, more than 100,000 people have better access to water through a relative low cost measure. The increased water availability, especially during dry periods, results in higher farm yields. The average income of farmers living near dams rose with 60%. The local water balance is almost not influenced as the sand dams store less than 3% of total yearly runoff. © 2007 Published by Elsevier Ltd.

Keywords: Vulnerability; Water management; Sand dam; Community based; Kenya; Evaluation

1. Introduction

Climate change is expected to increase the severity, duration and frequency of extreme events such as floods and drought (IPCC, 2001), thereby threatening water availability and food security for millions of (poor) people (Dialogue on water and climate, 2003; Aerts and Droogers, 2004). Despite projections about climate change and its impacts are uncertain, most adaptation research tends to focus on reducing *future* vulnerability based on these diverting climate change scenarios. Therefore, we propose that we should first identify and quantify *current* vulnerability to climate extremes (such as droughts and floods) and develop adaptive measures that reduce current vulnerability (e.g. O'Brien et al., 2004). Moreover, this paper

offers examples as to how to reduce current vulnerability through community based adaptation approaches.

Local storage of water is increasingly seen as an important adaptation for ensuring water availability and food security to rural and urban populations, especially in developing countries (Kashyap, 2004). This is particular the case in semi-arid and arid regions outside the reach of perennial rivers and where there is no (or little) groundwater available. The need for increased storage capacity (and thereby an increase in water security) is underpinned by the Millennium Development Goals that specifically address storage needs to adapt to global changes such as sharply growing populations, climate change and catchment degradation (UN, 2000, 2002).

Ensuring water storage capacities is a complex issue. Water storage for urban water schemes may include options such as construction of dams, long distance conveyance of water or desalination. However, for rural water security such solutions are generally too costly and complicated.

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Provisions for rural water supply require low cost systems with easy maintenance that can be constructed and operated with a high degree of community involvement. This perception is supported by the Copenhagen Consensus (Lomborg, 2004), which regards small-scale water technology for livelihoods as likely to be highly cost effective. Examples of such low cost methods are found within water conservation (or water harvesting) methods. They have been applied and used since ancient times in arid and semi-arid regions, such as in the Middle East. Since local communities are traditionally familiar with such methods, development and maintenance need relatively little training and investments. Certainly, when they are compared to larger or medium scale projects. Therefore, they are increasingly seen as robust adaptations to climate variability and change and for the development of adaptation strategies these and other local activities deserve more attention.

This research will provide an example of local ('community based') adaptation to drought in the Kitui District in Kenya. In this area, 500 small scale dams, so-called 'sand dams', have been developed over the last 10 years in order to reduce the vulnerability of the local communities to droughts. The goal of this research is to evaluate the effectiveness of these sand dams. This goal is achieved by

- (1) describing the sand dam methodology as being developed in the Kitui region in Kenya;
- (2) identifying vulnerability indicators for the Kitui District;
- (3) performing a socio-economic assessment of the effects of sand dams, based on the vulnerability indicators and link these to the water resources system.

The data are acquired by performing interviews with local inhabitants and by hydrologic research and modeling.

2. Case study: Kitui Kenya

2.1. Geographical characteristics

The Kitui District is a semi-arid region situated 150 km east of Nairobi. The total land area is approximately 20,000 km² including 6400 km² of the uninhabited Tsavo National Park. The elevation of the district is between 400 and 1800 m. The central part of the district is characterised by hilly ridges, separated by low lying areas between 600 and 900 m above sea level.

The area is characterised by rainy periods that are highly erratic and unreliable. The rains usually fall in a few intensive storms (Nissen-Petersen, 1982). There are two rainy seasons, one from March to May, these are the so-called 'long rains' and one from October to December (the 'short rains'). The names of these periods refer to the length of the individual rainfall events. On average the precipitation in the Kitui District is around 1000 mm a year, but there are large local differences in amount due to topography and other influences. There is also a large fluctuation in precipitation over the years and sometimes rains fail completely. Local lore states that this happens at least one in four years (Thomas, 1999), which is supported by the precipitation data, which shows a drought every 4–5 years (MDK, 2005). The potential evaporation is high, 1500–1600 mm a year, exceeding the precipitation caused by high temperatures in the district and the location near the equator. Runoff is high because of low infiltration and soil moisture deficits are limiting crop production (Ngigi et al., 2005).

Historical analysis of metrological data shows that climate (change) is already an issue in the Kitui District. For example, Fig. 1 shows the deviation of yearly precipitation to the average precipitation for the period 1904–1990. The average precipitation over this period is 995 mm per year. The bars in Fig. 1 show the yearly data

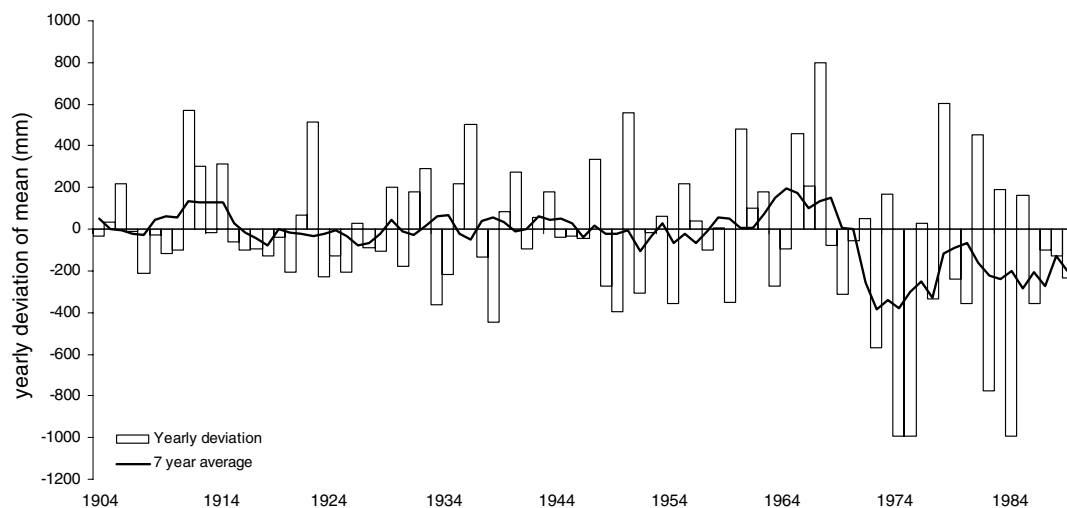


Fig. 1. Deviation of annual precipitation and running mean for 7 years compared to the long term mean in Kitui for the period 1904–1990 (data from Meteorological Department of Kenya).

and the line is the 7 year running mean value. This figure shows the district has become drier and that years with extreme precipitation increase from the 1970s until 1990 (MDK, 2005).

Climate change and climate variability are expected to affect water resources further in the Kitui District through changes in precipitation and evaporation. According to the Hadley model – HadCm3 – for SRES scenarios A2 and B2 temperature will roughly rise 2–4 °C this century and precipitation will rise 10% in the second half of the century, but the first 50 years it remains nearly constant (IPCC, 2000).

2.2. Socio-economic characteristics

Approximately 555,000 people inhabit the Kitui District and the growth rate is 2.2% a year (District Commissioner Kitui, 2002). In 1997 the income of 58% of the eastern districts was beneath the poverty line of 2 dollars a day (PRSP, 2001), and hence is one of the poorest regions of Kenya. The main economic activity is rainfed agriculture (Central Bureau of Statistics, 2001). Irrigated agriculture only takes place on small plots on the river banks and water availability is often the limiting factor for sustainable agriculture development. During prolonged dry periods the farmers are dependent on relief food from donors. In 2004 and spring 2005, for example, up to 50% of the inhabitants of Kitui received food aid (FEWS-NET). Besides farming the main economic activities are charcoal burning, brick making and basket breading.

Only 45% of Kenyans have access to clean water for domestic use and even fewer have access to water that is potable. In the Kitui District these numbers are even lower; only 6% of the inhabitants have access to potable water (District Commissioner Kitui, 2002). Water is the most essential development commodity in this area. However, the major sources are ephemeral rivers, which fall dry dur-

ing the dry period. In the dry season, woman and children have to walk up to 4 km to get to water. During periods of prolonged drought this distance rises up to 10–15 km.

2.3. Sand dams as local adaptation

A local NGO in Kitui (Sahelian Solution Foundation, SASOL) assists local communities in building small-scale sand dams to store water in sandy aquifers in ephemeral rivers. The strategy is to reduce the distance to water sources to less than 2 km and make water available for irrigation and other economic activities. Over the past 10 years they succeeded to reach these goals in a large part of the district. Some 100,000 people have better access to water and are less vulnerable to droughts.

Sand dams are impermeable concrete structures constructed across ephemeral rivers with the purpose to harvest water. The sand dams differ from traditional dams by not only storing water in upstream reservoirs, but storing this water within the sand and gravel particles (up to 600 µm) accumulating against the dam and forming an aquifer (Fig. 2). Coarse gravel and sand can store and retain up to 35% of their total volume as water. The sub surface reservoir is recharged through flash floods following on rainstorms. When the reservoir is filled, surplus water passes the dam without infiltration. The stored water is captured for use through digging a scooping hole, or constructing an ordinary well or tube well. By storing the water in the sand, it is protected against high evaporation losses and contamination (Tuinhof and Heederik, 2003; Guiraud, 1989). As water flows through the sand it is also filtered and biological threats, like bacteria, are reduced (Huisman and Wood, 1974). Another advantage is that fewer mosquitoes are present in the area, because of lack of surface water. From hydrological research, it appears the dams store only up to 3% of the yearly runoff produced from the catchment area between two dams (Borst and de Haas, 2006),

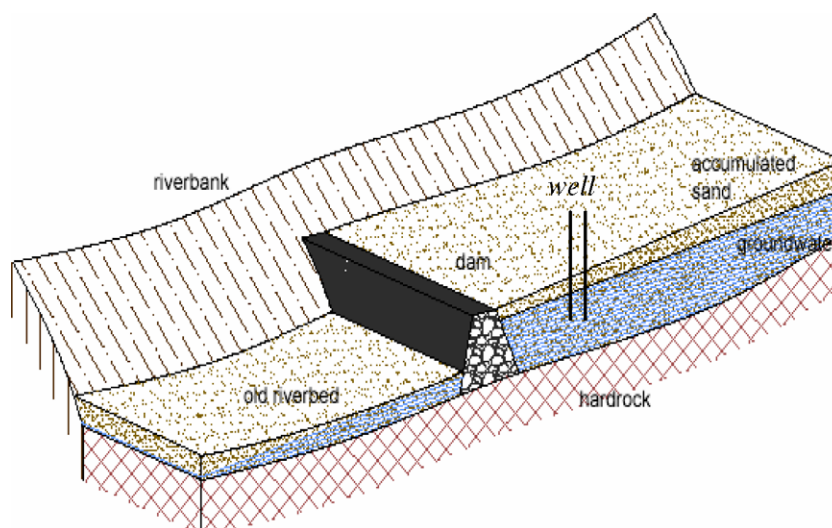


Fig. 2. Technique behind the sand dams.

supplying an extra amount of water of 8000 m³ a year to the on average 150 people that use the dam. This water is used to bridge the dry periods during the year.

The construction of a dam is largely dependent on the inputs and commitment of the local community. When the community and SASOL agree to construct a dam, a site committee (or dam committee) is started to coordinate community involvement in the building process. The members of this committee are selected by the community. On average some 20 families are involved in dam construction. The site committee can follow on existing structures, or can be created for this purpose. Within this committee agreement on site selection, rules and inputs of work are made. SASOL facilitates the site selection and the engineering of construction works as they have technical expertise and over 10 year experience with dam construction. During the process of dam construction an artisan of SASOL is present to support the community with technical knowledge. After the community chooses a dam location, which meets the technical requirements, construction starts with digging a ditch in the river bed to reach the bedrock. This ditch is filled with mortar and rocks and the construction will rise 1–4 m above the surface, depending on the local circumstances. The work is done by a group of circa 15 persons originating from the community. The construction normally takes approximately 3 months and the material costs lay around US\$ 5000. The number of dams constructed by a community depends on the length of the river, the number of suitable locations and the availability of funding. A number of dams were built in cascade, increasing the effect of the dams by slowing the water down and increasing base flow during the dry periods. Maintenance of the dams is the responsibility of the farmers that use of the water from the dam. Usually the users are committed in the maintenance of the dams, as they have built the dams themselves (Beimers et al., 2001; Mutiso, 2003; Aerts and Lasage, 2005; Borst and de Haas, 2006).

3. Research approach

3.1. Method

In order to determine whether the sand dams reduce current vulnerability of the local population to water related stresses, the relation between vulnerability and the availability of water resources (the sand dams) needs to be established. This is done through the use of vulnerability indicators. The relation between vulnerability to droughts and sand dams is quite straight forward; the created aquifers store an amount of water which is used during the dry period. The extra water, compared to the situation before sand dam construction, is accessible for the local population and can be used for many activities (OECD, 2003; Aerts, 2005).

Fig. 3 shows the link between vulnerability indicators and the physical state of the water resources system. The indicators are partly based on Aerts and Droogers (2004) in cooperation with SASOL. The main physical characteristics of the water resources system are captured in state indicators, like ‘amount of water in the system’ and ‘variation in discharge over time’. Stakeholders have objectives they want to achieve given the physical boundaries of the water resources system and hence vulnerabilities can be defined as to whether or not people can reach those objectives, measured through quantifiable vulnerability indicators. These indicators are, for example, ‘crop production’, ‘income’ or ‘access to safe drinking water’. By developing adaptation strategies, like constructing sand dams, the water resources system will change and hence will change the values of the vulnerability indicators. Hence, the indicators allow comparing different adaptation strategies and their effect on vulnerability. The indicator values can be determined with models, from expert judgement or from data from interviews and field research.

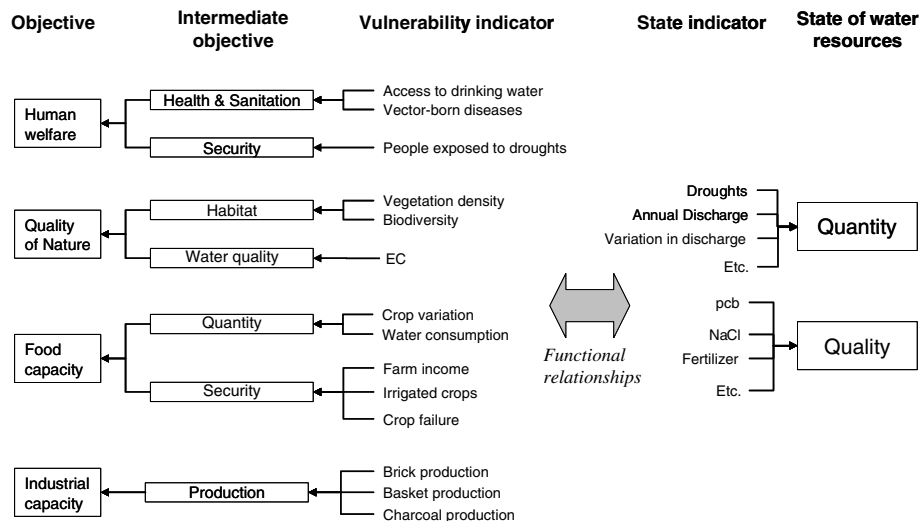


Fig. 3. Decision tree with objectives and vulnerability indicators on the left and state indicators on the right (Aerts and Droogers, 2004).

The above described method requires data to quantify indicator values. During a field survey in the fall of 2005, data on hydrological and socio-economic parameters were acquired. Two comparable catchments in the Kitui region were selected. The Kiindu catchment (length of 16 km, area of 37 km²) contains three sequential sand dams constructed during the 1990s. The other catchment ('Koma') has no sand dams because the layers of hard rock are too deep below the surface and thus not accessible for dam construction. Also the sediments in the river are too fine, making them unfit for aquifer forming. Apart from the suitability for dam construction, the socio-economic conditions in these catchments are influenced by the same external drivers like access to markets, population density and natural resources. Hence, the socio-economic potential over the last decade of the catchments is comparable, so we assume that the differences in socio-economic developments are mostly the result of sand dam construction. The used method builds on the experiences of earlier research to the effectiveness of changes in irrigation or land cultivation (e.g. Norman, 1997; Mutunga and Critchley, 2001) and goes further in combining hydrologic measurements, comparable with Ngigi et al. (2005) with data on agricultural harvest and other socio-economic information.

3.2. Socio-economic assessment

The research started with collecting data through interviewing farmers in the Kiindu and the Koma catchments. The aim was to get insight in the socio-economic developments in the two catchments over the last 10 years. For the Kiindu catchment the period for development is 1995 (before dam construction) to 2005 (after dam construction). Next, these results will be compared to the developments in the Koma catchment (where no dams are built) over the same period. The interviews provided information on differences between the communities in time spent on collecting water and on other economic activities (basket weaving, brick making, etc.). When people reduce the time they need for collecting water they can use this time on other income generating activities. The interviews also provided numbers for the vulnerability indicators as listed in Fig. 3. In the Kiindu catchment 20 households using sand dams were interviewed and in the Koma Catchment 19 households were interviewed.

4. Results

Table 1 shows the results of the socio-economic assessment. The table presents several vulnerability classes and

Table 1
State and vulnerability indicators for Kiindu and Koma catchments

Indicators ^a	Kiindu		Koma	
	1995	2005 ^b	1995	2005
State indicators				
Annual discharge	0	–	0	0
Variation in discharge	0	+	0	0
Vulnerability indicators				
<i>Human welfare</i>				
Access to drinking water, wet season	1 km	1 km	1 km	1 km
Access to drinking water, dry season	3 km	1 km	4 km	4 km
Domestic water use	61 L/day	91 L/day	136 L/day	117 L/day
Vector-borne diseases	0	+	0	0
People exposed to droughts	420	0	600	600
<i>Quality of nature</i>				
Vegetation density	0	+	0	–
Biodiversity	0	+	0	0
<i>Food capacity</i>				
Households with irrigated crops	37%	68%	38%	38%
Crop failure (rainfed)	n.a.	24%	n.a.	28%
Crop variation	7.8	8.5	4.3	4.5
Agricultural water consumption	220 L/day	440	160 L/day	110 L/day
Household income	15,000 KSh. ^c	24,000 KSh. ^d	15,000 KSh. ^c	15,000 KSh.
<i>Industrial capacity</i>				
Brick production	500 KSh.	1850 KSh.	0 KSh.	0 KSh.
Basket production	1050 KSh.	2600 KSh.	0 KSh.	0 KSh.

+, positive effect on this indicator (quantitative effect can be an increase or a decrease); –, negative effect on the indicator; 0, no effect on the indicator; 1000 Ksh. = 14 USD.

^a Data per household.

^b After sand dam construction.

^c IDS Roskilde (1992).

^d Includes income out of industrial activities.

vulnerability indicators and shows how the values of the indicators have changed through the construction of the dams. The two series for the Kiindu catchment describe the situation before sand dam construction, listed in the column ‘1995’ and after sand dam construction, listed in the column ‘2005’. In the Koma catchment no sand dams were constructed and hence changes in indicator values mostly represent influences of exogenous developments such as economic growth or decline.

In general, the analyses of the data collected during the interviews show that after dam construction in the Kiindu catchment, farmers rapidly shifted to grow water demanding crops such as tomatoes, unions, fruit trees and Kale (Fig. 4). There is less crop failure compared to the Koma catchment over the same period. Farmers in the Koma catchment remained growing rain dependent crops and some irrigated crops.

The state indicators for Kiindu show a small decrease after dam construction and this is valued as a negative effect. The variation in discharge, however, decreases, the peak flows are slightly lower than before dam construction, but more importantly, base flow increases due dam construction (Borst and de Haas, 2006). This is valued as a positive effect.

Access to water improved in the Kiindu catchment, leading to an increase in domestic water use of about 50% and a doubling of agricultural water use. These results are in line with trends in the study of Rempel et al. (2005), who found an increase in water use of nearly 50% in communities where sand dams were constructed. In the Koma catchment water use decreased over time and most vulnerability indicators remain the same. In the Kiindu catchment the percentage of households growing irrigated crops rose from 37% before dam construction to 68% after dam construction. From these households 50% sold their harvest, earning between 1000 and 13,000 Kenyan Shilling (Ksh.) per year (USD 13–175) (de Bruijn and Rhebergen, 2006). In the Koma

catchment, there has not been any notable change over the last 5 years in terms of both crops and income change.

Due to the extra availability of water during the dry seasons, the people in the Kiindu catchment are able to produce more bricks. These bricks are sold, generating an income of 1850 KSh. per household per year, an increase of 1350 KSh. compared to the situation before dam construction. The bricks are also used for construction of houses in the community, improving living standards. In the Koma catchment there is no commercial brick production. Another income generating activity is basket weaving, because less time is spent on fetching water, people in the Kiindu catchment can spend more time on this activity. The income generated with it increased with 150%.

The distance to the water source decreased after dam construction from 3 to 1 km on average, while time spent on collecting water for domestic also decreased. Before dam construction it took a family 140 min on average per day and after construction it took 90 min per day (de Bruijn and Rhebergen, 2006). The decrease is due to the fact that water is available throughout the year, whereas scoop holes in the river go dry between the rainy seasons before dam construction. The women used to go to other catchments further away during the dry period. This is no longer necessary. Also the number of water points increased after dam construction, decreasing the queues and thus waiting time. In Koma the time spent on collecting water for domestic use stayed the same over the past five years. A household spends on average 180 min a day.

Time saved on fetching water is spent on other activities. 33% of the households spent more time on farming (terracing, irrigate, prepare the land before the rains), 29% further developed domestic tasks (increase hygiene, cook meals) and in 43% of the responses it appeared the households shifted to other income generating activities (de Bruijn and Rhebergen, 2006). On average households generated an extra income from agricultural and non-agricultural activities of 9000 KSh. In the Kiindu catchment the household income rose from 15,000 KSh. to 24,000 KSh. over a period of 10 years.

In general, the economic base of the household is more diverse and income have increased up, helping them to bridge difficult periods like droughts. The improvement in the economic situation of the households in the Kiindu catchment reflects in the increase in assets they own. For example the number of bicycles has risen with 240% since sand dam construction, where this number is only 10% in the Koma catchment. Also items for leisure show this trend, the number of radios increased with 107% in the Kiindu catchment compared to a rise of 26% in the Koma catchment (de Bruijn and Rhebergen, 2006).

5. Discussion and conclusion

The socio-economic indicators and hydrologic data show that the sand dams are a successful adaptation to cope with drought. Through developing measurable

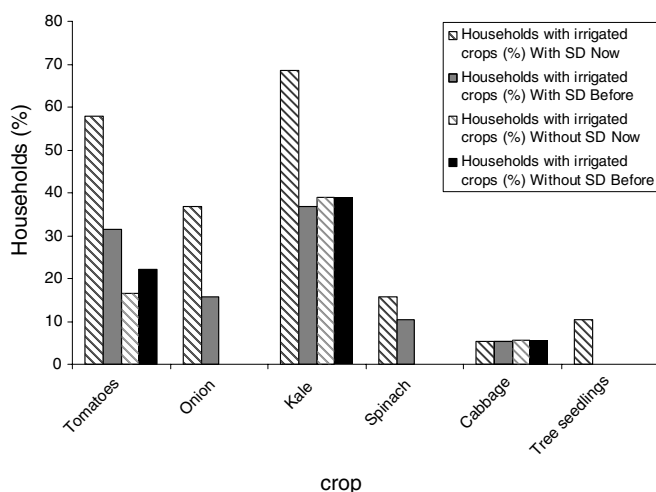


Fig. 4. Number of household growing irrigated crops. Before are values from before sand dams (SD) construction in both catchments. Now is after dam construction in Kiindu catchment only. The Koma catchment still does not have dams.

vulnerability indicators, it has been illustrated that the sand dams have reduced vulnerability in the region. The increased water availability results in higher farm yields, as well for irrigated and non-irrigated crops. The average income of farmers using sand dams rose with 9000 KSh. (USD 120), while less than 3% of total runoff is used. It is estimated that in 10 years time, more than 100,000 people have better access to water through low cost measure at an investment of about 35 USD per capita. As the sand dam technique reduces vulnerability of communities to current climate variability it is assumed that sand dams are a potential good measure to cope with droughts under future climate change.

The method of linking hydrology to socio-economic vulnerability is appropriate in assessing the effects of measures in water management. The method can be easily applied to other case studies, in which the indicators might need some adjustments. However, more research needs to be done before sand dams can be up-scaled to other areas as adaptation to droughts. Besides the relative simplicity of the technique the commitment and organisation of the community is a very important factor for the success. This must be taken into account when the feasibility of implementing the technique in other regions is explored.

Further research may aim at gathering more data on the hydrology of sand dams and increase the number of households that are interviewed, to enlarge the representativeness. Furthermore, additional data may provide more in depth information on the degree in which households are influenced by the positive effects of the sand dams and how this spatially varies through the district of Kitui. A hydrological model might be developed for the whole district linked to the socio-economic indicators as provided in Table 1. In this way, water managers and policy makers can be better supported in developing strategies to cope with additional future climate changes.

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