Review of *Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya* by Lasage, Aerts, Mutiso, and de Vries

General Comments:

I think the authors' analysis of the impacts of sand dams on community health is excellent and the paper should be shortened to focus on this topic alone. I think they currently try to use this analysis as a case study for a general approach to assessing water resources and the point of the paper gets muddled and murky. In essence the paper's attempt to simultaneously be general and specific fails to do either and I would favor a more specific approach. For example, in the abstract the authors claim to have "…developed a method using socio economic vulnerability indicators that can be linked to system hydrology." This sentence provides almost no insightful information and, yet, is the only description given in the abstract about what was done in this study. What is "system hydrology?" What are "socio economic vulnerability indicators?" There's no mention that the analysis was based on interview- or questionnaire-style surveys. Also, the actual work done in this study appears to be linked to the water resources system rather than the hydrology, i.e., the human interactions with the water are a key component. These types of studies that link people with various Earth support systems are important and I hope that venues for publishing this type of work will emerge in the near future; for now, I hope that this special issue will find a place for this work once it has been sufficiently tightened.

A Few Specific Comments and Suggestions:

1) Although this paper is soft on physics and chemistry, there are a few mistakes with respect to physical hydrology that need to be fixed. The most egregious is probably the linking of potential evaporation and evapotranspiration to (air) temperature… temperature is an extremely poor indicator of either process and the papers addressing this are innumerable.
2) I like the link to climate change as shown in Fig. 1. However, typically hydrologists and meteorologists hesitate to use more than 30 yrs of data in a frequency analysis due to temporal biasing (i.e., one end of the data set is statistically different than the other one). Thus, I would like to see this same graph using four 25-yr periods instead of two 50-year periods.
3) In table 1, can the +/- indicators be replaced with quantitative values?
4) Is it feasible to analyze the validity "local lore," which suggests complete drought one-in-four years? Fig. 1 suggests that rain data are available.
5) At the end of section 3.1, the authors mention the comparability of "economic potential" between the two catchments. How is this determined?
6) I have made some additional comments in the attached document.

Review guide:

Do you agree to your identity being revealed to the authors? **NO**

A Is this topic:
1 of broad international interest? **YES**
2 significant? **YES**
3 innovative? **NO**

B Clarity of objectives: **Poor or Barely Sufficient**

C Quality of methods: **Sufficient, but not great**

D Validity of assumptions and analyses: **Sufficient**

E Overall significance of this work: **Sufficient**

F Is this paper
1 properly organized? **Generally ok, but wanders at points, e.g., it is not clear whether this paper is presenting a general approach to assessing water resources or it they are interested in focusing on the Kenyan watersheds specifically.**
2 to the point/concise? **NO**
3 written clearly using correct grammar and syntax? **NO – the text uses awkward English in many places (see attached document)**

G Are the approach, results and conclusions intelligible from the abstract alone? **NO – It is unclear from the abstract, what this specific study did; for example, the abstract suggests a hydrological analysis is included in this study, but the hydrological components were previously published elsewhere.**

H Is the title informative and a reflection of the content? **YES**

I Are the illustrations/tables
1 useful and all necessary? **YES**

2 of good quality? **SUFFICIENT**

J Is the referencing relevant, up to date and accessible? **It is ok, but could be a little more complete. I think Gilbert Levine, for example, did a lot of related work but is not cited and, thus, it is not clear that the approach used here has any benefits beyond the assessment approaches he developed decades ago. Also, Raymond Norman's work in Niger would provide a good backdrop. The authors sort of suggest by omission that assessing African water resources at the community level has never been addressed.**

K Are the keywords appropriate and complete? **NO – I saw no key words**

L Overall quality of the work: **Sufficient, and potentially Good**

M Can you suggest any improvements to this work, or any parts which could be shortened or removed? **– The authors need to decide on what the point of their paper is. It currently reads as a pseudo white paper on sand dams with a nice stand-alone project embedded within.**

N Is this work acceptable in its present form? NO (in my opinion)

O What is your final recommendation?
1 minor revision?

2 moderate revision?
3 major revision?
4 rejection?

Thank you for your review!

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

R. Lasage[1) 1], J. Aerts[1)], G-C.M. Mutiso[2)], and A. de Vries[3)]

1) Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, The Netherlands
2) SASOL, Nairobi, Kenya
3) ACACIA Institute, Amsterdam, The Netherlands

0.1. Abstract

This paper is based on a project that aims at finding local level adaptation strategies that, apart from alleviating impacts from climate variability and change, also assure food production, sustain people's livelihoods and contribute to rural and urban poverty alleviation. A local water harvesting project in Kenya concerning the construction of small scale sand dams by communities is evaluated. Sand dams are small structures built in ephemeral rivers to store excess water to overcome periods of drought. We developed a method using socio economic vulnerability indicators that can be linked to system hydrology. The sand dams are evaluated using these vulnerability indicators. It appeared that the sand dams have a large impact on the local community. In 10 years more than 100,000 people have better access to water through this 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 60%. The local water balance is almost not influenced as the sand dams store less than 5% of total yearly runoff.

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 (Aerts and Droogers, 2004; Dialogue on Water, Food and Environment, 2003). It is therefore important for policy makers, planners and managers who are involved in ensuring water availability and food security to take into account the possible impacts of climate variability and change. Consequently, this implies that potential impacts should be outlined and appropriate options for adaptation to the impacts should be tested. Projections about climate change and its impacts, however, are uncertain and adaptation research tends to focus more on reducing current vulnerability rather than using diverting climate change scenarios to evaluate proposed adaptation strategies (e.g. O Brien *et al*., 2004). Therefore we propose that in order to prepare for future climate change we may identify and quantify current vulnerability to climate extremes (such as droughts and floods) and develop adaptive measures that reduce current vulnerability.

Policy makers, planners and water managers play a key role in the development of adequate adaptation strategies, especially at the local level where adaptation measures are implemented (Seckler *et al*, 1999). Local storage of water is increasingly seen as an adaptation for ensuring water availability and food security to rural and urban populations (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).

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. 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 (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, for example

1 Corresponding author.
Email address: ralph.lasage@falw.vu.nl
Fax: +31-20-5989533

(ACSAD, 1998). Since local communities are traditionally familiar with such methods, development and maintenance need relatively little training and investments. Therefore, they are increasingly seen as robust adaptations to climate variability and change. In the development of adaptation strategies these and other local activities should be taken into account.

This research will provide an example, studying the effects of adaptations in water management with a focus on current vulnerabilities to drought and local scale ('community based') adaptation to cope with droughts in the district of Kitui in Kenya. The goal of this research is to evaluate small-scale water storage techniques called 'sand dams' that are currently developed in Kenya, on their effectiveness to reduce vulnerability to droughts. 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 and
(3) performing a socio economic assessment of the effects of sand dams and link these to physical characteristics of the water resources system.

2. Case study: Kitui Kenya

2.1 Geographical characteristics

The Kitui District in the Easter Province is a semi-arid region situated 150 km east of Nairobi. The total land area is approximately 20.000 km² including 6.400 km² of the uninhabited Tsavo National Park. The elevation of the district is between 400 and 1800 metres. The central part of the district is characterised by hilly ridges, separated by low lying areas between 600 and 900 metres above sea level. Approximately 555.000 people inhabit the district and the growth rate is 2.2% a year (Kitui District Development Plan 2002-2008, 2002).

In 1997 the income of 58% of the eastern districts was beneath the poverty line of 2 dollars a day (PRSP, 2001). This is one of the poorest regions of Kenya. The main economic activity is rainfed agriculture (Census,1999). Irrigated agriculture only takes place on small plots on the river banks. 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.

The area is characterised by rainy periods that are highly erratic and unreliable. It usually falls 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, these are the 'short rains'. The names of these periods are based on the length of rainfall events. On average the precipitation in the Kitui District is around 900 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, sometimes rains fail completely. Local lore states that this happens at least one in four years. (Thomas, 1999). The potential evaporation is high, 1500 to 1600 mm a year, caused by high temperatures in the district: the average temperature is 24° C.

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 has access to potable water (Kitui District Development Plan 2002-2008, 2002). Water is the most essential development commodity in this area, the major sources are the ephemeral rivers. During the dry period between the rainy seasons woman and children have to walk up to 4 kilometres to get to water. During periods of prolonged drought this distance rises up to 10 to 15 kilometres.

Historical analysis of metrological data shows that climate (change) is already an issue in the Kitui district. For example, figure 1 shows the relative frequency of yearly precipitation of one meteorological station for the period 1904-1954 together with the relative frequency of yearly precipitation of 7 meteorological stations for the period 1954 to 2004. The frequency of years with low annual precipitation has increased in the period 1954-2004 compared to 1904-1954. Mean yearly precipitation for the first period is 1000 mm and decreased to 875 mm a year for the second period. The district has become drier in the last 50 years. These historical time series of precipitation were provided by the meteorological department of Kenya.

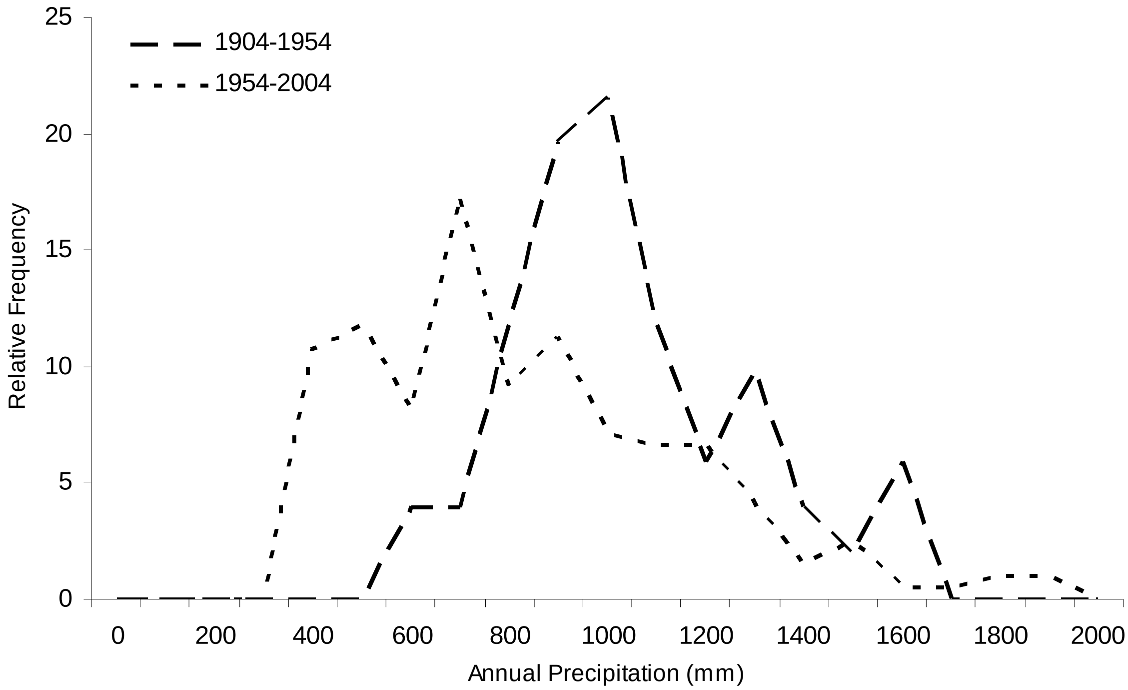

Figure 1: Occurrence of annual precipitation in Kitui for two periods. The figure shows that in the second half of the past century, the annual precipitation decreased as compared to the first half (from: Meteorological department of Kenya).

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 to 4 degrees Celsius this century and precipitation will rise 10% in the second half of the century, but the first 50 years it remains nearly constant. It is expected that despite the expectation that precipitation might increase, the increase in evapotranspiration caused by temperature increase will cause a net negative trend in water availability (IPCC, 2000).

2.2 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. This technique improves the availability of water. SASOL's strategy is to reduce the distance to water sources to less then 2 kilometres and make water available for irrigation. Over the past ten 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.

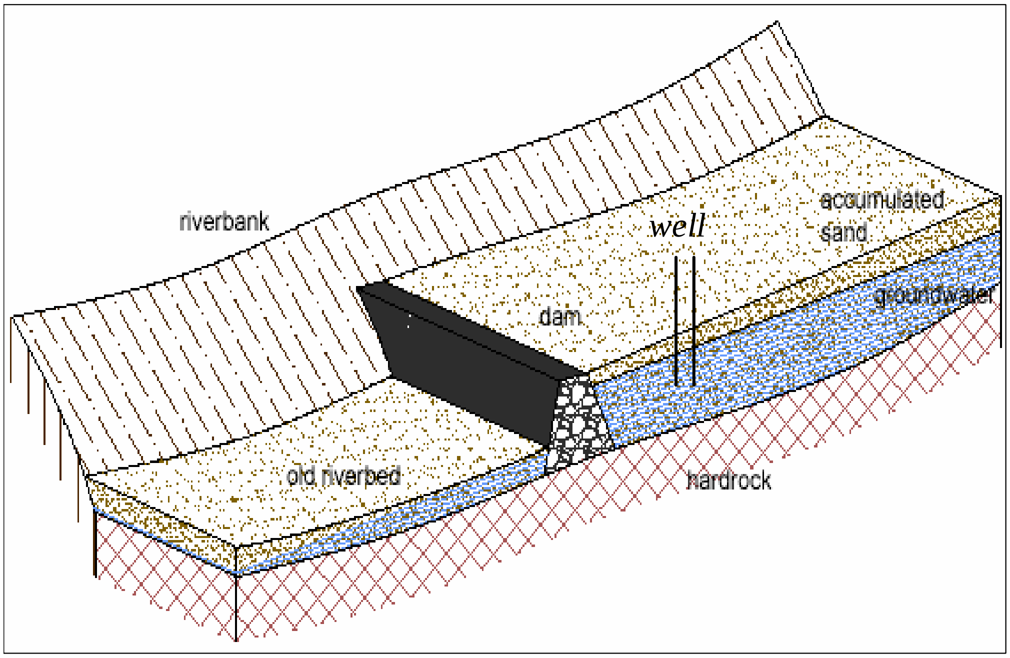

Figure 2: Technique behind the sand dams.

Sand dams are impermeable 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 behind against the dam and forming an aquifer (Figure 2). Coarse gravel and sand can store and retain up to 35% of its 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 *et al.*, 2003, Guiraud, 1989). As water flows through the sand it is also filtered and biological threats, like bacteria, are reduced (Huisman, 1974). Another advantage is that fewer mosquitos are present in the area, because of lack of surface water. The dams store up to 5% of the yearly runoff produced from the catchment area between two dams (Borst & de Haas, 2006), supplying an extra 8,000 m^3 of water a year. 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 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 choosing the location 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 to 4 metres above the surface, depending on the local circumstances. The work is done by a group of circa 15 persons originating from the community, the people working on the construction changes over time. The construction normally takes approximately 3 months and the material costs lay around U$ 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 are 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 group of people making use of the dam, this might be under guidance of the site committee. Usually the users are committed, as they have built the dams themselves. (Beimers *et al*. 2001, Mutiso, 2003, Aerts & Lasage, 2005, Borst & 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 water storage (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).

Figure 3 shows the link between vulnerability indicators and the physical state of the water resources system. The water resources system may vary in size from a small catchment of a few km^2 to an entire river basin. The main characteristics of the water resources system are captured in state indicators, like 'amount of water in the system' and 'variation in dicharge over time'. Stakeholders have objectives they want to realise in this system and vulnerabilities can be defined as to whether or not people can reach those objectives, measured through quantifiable vulnerability indicators. By developing adaptation strategies, like constructing sand dams, the water resources system will change, affecting the vulnerability indicators. Hence, the indicators allow for trading off different adaptation strategies and their effect to reduce vulnerability. The indicator values can be determined with models or from expert judgement.

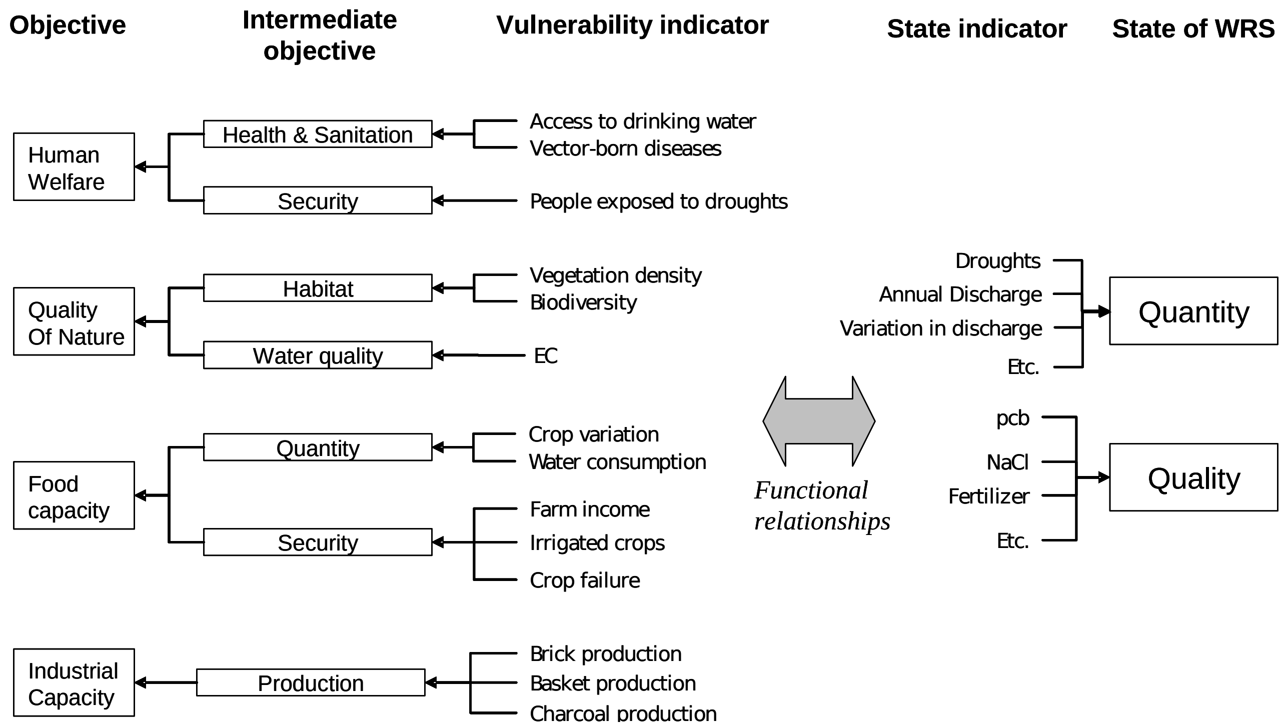

Figure 3: Decision tree with objectives and vulnerability indicators on the left and state indicators on the right (Aerts, 2005)

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 km^2) contains three 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 economic potential of the catchments is comparable, so we assume that the differences in socio economic developments are mostly the result of sand dam construction.

3.2 Socio economic assessment

The research starts with collecting data through interviewing farmers with a questionnaire in the Kiindu and the Koma catchments. The aim is first to get insight in the socio economic developments in the two catchments. For the Kiindu catchment the period for development is 1995 (before dam construction) to 2005 (after dam construction). This is compared to the developments in the Koma catchment, where no dams are built. Furthermore, the interviews provide information on differences between the communities in time spend on collecting water and economic activities (basket breading, brick making, etc.). The interviews also provide numbers for the vulnerability indicators as listed in Figure 3, such as ‘household income’. In the Kiindu catchment 20 out of 60 households using sand dams were interviewed and in the Koma Catchment 19 households were inteviewed.

4. Results

Table 1 shows the results of the socio economic assessment. The table presents several vulnerability classes and vulnerability indicators and shows how the values of the indictors 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, the values represent exogenous developments.

In general, the analyses of the data collected during the interviews shows that after dam construction in the Kiindu catchment, farmers rapidly shifted to grow water demanding crops such as tomatoes, unions, fruit trees and Kale (figure 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..

Table 1: State and vulnerability indicators for Kiindu and Koma catchment.

Indicators[1]	Kiindu 1995	Kiindu 2005[2]	Koma 1995	Koma 2005
State indicators				
Annual discharge	0	-	0	0
Variation in discharge	0	+	0	0
Vulnerability indicators				
Human welfare				
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-born diseases	0	+	0	0
People exposed to droughts	420	0	600	600
Quality of nature				
Vegetation density	0	+	0	-
Biodiversity	0	+	0	0
Food capacity				
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	15000 KSh[3]	24000[4] KSh	15000 KSh[3]	15000 KSh
Industrial capacity				
Brick production	500 KSh	1850 KSh	0 KSh	0 KSh
Basket production	1050 KSh	2600 KSh	0 KSh	0 KSh

[1] data per household

[2] after sand dam construction

[3] IDS Roskilde 1992

[4] includes income out of industrial activities

+ = positive effect on this indicator (*quantitative effect can be an increase or a decrease*)

- = negative effect on the indicator

0 = no effect on this indicator

1000 KSh. = 14 USD

The state indicators only change for Kiindu after dam construction, the annual discharge decreases slightly 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 on the indicator variation in discharge.

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% sell their harvest, earning between 1,000 and 13,000 Kenyan Shilling (Ksh.) per year (USD 13 to 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 season the people in the Kiindu catchment are able to produce more bricks. These bricks are sold, generating an income of 1,850 KSh. per household, an increase of 1,350 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 region. In the Koma catchment there is no commercial brick production. Another income generating activity is basket weaving, because less time is spend on fetching water, people in the Kiindu catchment can spend more time on this activity. The income generated with it increases 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 minutes on average per day and after construction it takes 90 minutes per day after (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 minutes a day.

Time saved on fetching water is spent on other activities. 33% of the households spends 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 generate an extra income from agricultural and non agricultural activities of 9,000 KSh. The household incomerose from 15,000 KSh. to 24,000 KSh in the Kiindu catchment over a period of 10 years. As a result vulnerability of the households to shocks is reduced. The economic base of the household is more diverse and income goes 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 kind of numbers, the number of radios increased with 107% and 26% for Kiindu and Koma catchment respectively (de Bruijn and Rhebergen, 2006).

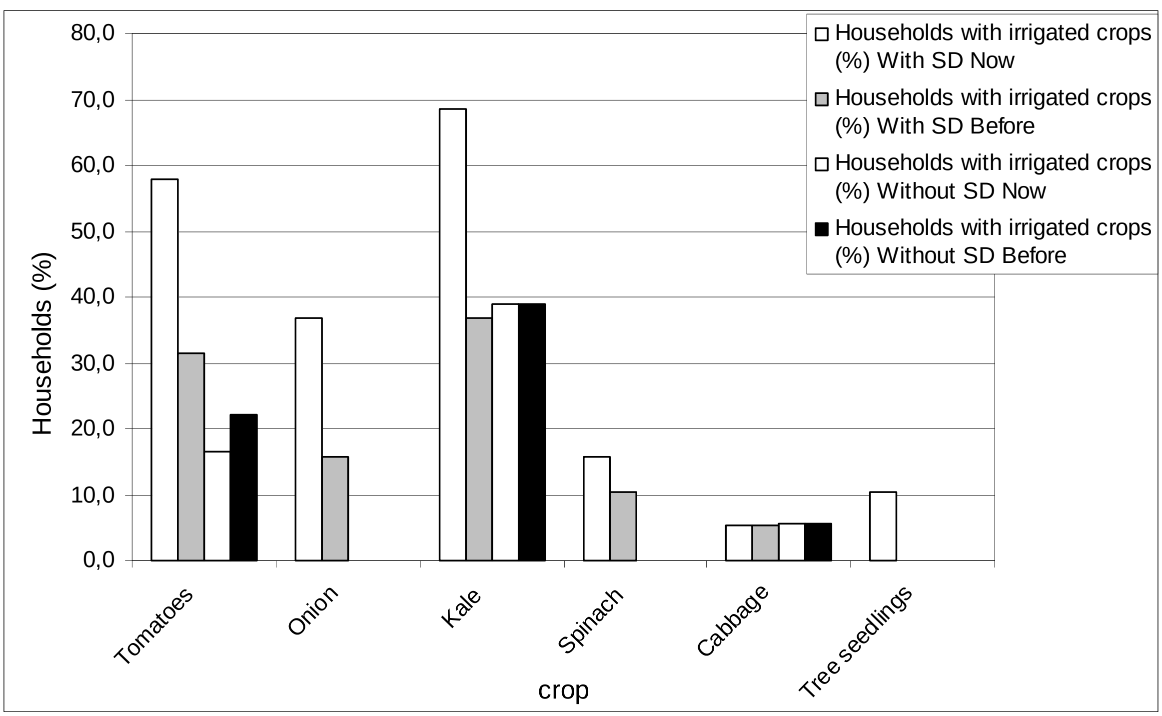

Figure 4: Number of household growing irrigated crops. *Before* are values from before sand dams (SD) construction in both catchments. *Now* is after dam construction in Kiindu catchment only. The Koma catchment still does not have dams.

5. Discussion and conclusion

This research shows the sand dams are a successful socio economic adaptation to cope with drought. Through identifying measurable vulnerability indicators, it has been illustrated that the sand dams have reduced vulnerability in the region and the increased water availability results in higher farm yields, as well for irrigated and non irrigated crops. The average income of farmers living near dams rose with 9.000 KSh. (USD 120), while less than 5% 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 system 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 introduced in 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, the 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.

References

Aerts, J.C.J.H. (2005). *Adaptation for river basins: connecting policy goals to the water resources system.* Water Science & Technology, Vol 51 No 5, 121–131.

Aerts, J.C.J.H. and Droogers P. (eds) (2003). *Climate Change in Contrasting River Basins*. Cabi Publishers, pp. 264.

Aerts, J.C.J.H. and Lasage, R. (2005). *Mission report Kenya*. Institute for Environmental studies, Amsterdam, pp. 14

Beimers, P. B., Eick, van, A. J., Lam, K. S., Roos, B. (2001). *Building sand-storage dams, SASOL Foundation Kitui District, Kenya, Practical work report*, Delft University of Technology, pp. 100

Borst, L. and Haas, de, S.A. (2006) *Hydrology of Sand Storage Dams: A case study in the Kiindu catchment, Kitui District, Kenya*. Vrije Universiteit, Amsterdam, pp. 146.

Bossenbroek J. and Timmermans, T., (2003). *Setting up a measuring program at Kisayani, to measure the effected area by sand storage dams*, Traineeship Report, Delft University of Technology, pp. 87.

Bruijn, de, E. and Rhebergen, W. (2006) *Socio-economic Impacts of Sand Dams, Case Study in Kitui District, Kenya.* Faculty of Earth and Life Sciences, Vrije Universiteit, Amsterdam. pp.40

Dialogue on Water, Food and Environment, (2003). http://www.iwmi.cgiar.org/Dialogue/index.asp.

District Commissioner Kitui, (2002). *Kitui District Development Plan 2002-2008*. Kenya, pp. 72.

FEWS-NET, Faminine early warning system network, http://www.fews.net/centers/?f=ke

FAO 2003. *World Agriculture: towards 2015/2030. An FAO perspective*. Jelle Bruinsma (Ed), Rome, Italy.

Global Water Partnership, (2003). *Effective Water Governance: Learning from the Dialogues*. Available through the GWP website, www.gwpforum.org.

Government of Keya, 2002. *Water Act No. 8*

Guiraud, R., (1989). *Les Barrages d'Inféroflux Leur Intérêt pour l'Afrique Saharienne et Sahélienne* [Interflux Dams : Their Advantage for Saharan and Sahelian Africa], Proceedings of the Sahel Forum, The State-of-the-Art of Hydrology and Hydrogeology in the Arid and Semi-Arid Areas of Africa, Ouagadougou, Burkina Faso, 18-23 February 1989, International Water Resources Association, Urbana, Illinois, 320 – 329.

Hellwig, D.H.R., (1973). *Evaporation of water from sand, 4: The influence of the depth of the water-table and theparticle size distribution of the sand*, Journal of Hydrology, 18, 317 – 327.

Huisman, L., Wood, W.E., 1974, *Slow Sand Filtration*, World Health Organization, pp. 122.

IDS Roskilde (1992). *Towards integrated development in Kitui; A socio economic situational analysis of selected sublocations in Kitui District, Kenya*. International Development Studies Roskilde

IPCC, (200). Emission scenarios: A special report of working group III of the international Panel on Climate Change. Nakićenović, N. and Swart, R. (eds) Cambridge University Press, Cambridge.

IPCC. (2002). IPCC *Special Report on The Regional Impacts of Climate Change: An Assessment of Vulnerability*. Intergovernmental Panel on Climate Change.

Kabat, P and van Schaik, H. (eds.) (2003) *Climate changes the water rules: How water managers can cope with today's climate variability and tomorrow's climate change*.

Kashyap, A. (2004). *Water governance: learning by developing adaptive capacity to incorporate climate variability and change*. Water, Science and technology, Vol 29 No7, 141-146

Mutiso, S.M. (2003). *Community groundwater management based on integrated sand dam development*. Sasol Foundation, Nairobi, pp. 9.

Nissen-Petersen, E. (1982). *Rain catchments and water supply in rural Africa: a manual*. United Kingdom: Hodder and Stoughton.

O'Brien, K., Sygna, L. and Haugen, J.E. (2004). *Vulnerable or resilient? A multi-scale assessment of climate impacts and vulnerability in Norway*. Climatic Change 64: 193–225.

PRSP (2001). *Poverty Reduction Strategy Paper for the Period 2001–2004, Volume 1*. Ministry of Finance and Planning, Kenya.

Rempel, H, C.H., Nyaga, H.K., Manzi, P. and Gaff (2005). *Water in the Sand: An Evaluation of SASOL's Kitui Sand Dams Project.*

Seckler David, Upali Amarasinghe, David Molden, Rhadika de Silva, and Randolph Barker, (1999). World *Water Demand and Supply, 1990 to 2025:Scenarios and Issues Research Report No. 52*. Colombo, IWMI

Sperling, Frank (eds) (2003). *Poverty and Climate Change: Reducing the Vulnerability of the Poor through Adaptation.* Interagency paper. http://www.oecd.org/dataoecd/60/27/2502872.pdf

Thomas, D.B. (1999). *Where there is no water – a story of community water development and sand dams in KituiDistrict, Kenya.* SASOL and Maji na Ufanisi, pp. 55.

Tuinhof, A., Heederik, J.P., (2003). *Management of Aquifer Recharge and Subsurface Storage – Making Better Use of Our Largest Reservoir*, NNC-IAH publication No. 4, Netherlands National Committee – International of Our Largest Reservoir, NNC-IAH publication No. 4, Netherlands National Committee – International

United Nations (2002). *Report on World Summit on Sustainable Development*, on 4 September 2002, Johannesburg.

United Nations (2000). *United Nations Millennium Declaration*, United Nations Resolution, A/RES/55/2, pp. 9.

Zaal, F. and Oostendorp, R.H. (2002). *Explaining a Miracle: Intensification and Transition Towards Sustainable Small-scale Agriculture in Dryland Machakos and Kitui Districts, Kenya*. World Development vol. 30, 1271-1288.