Keeping on keeping on

A realist perspective on the scale of sand storage dams in Kenya from 2005-2015.

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i) Abstract

The spatial and temporal distribution of the precipitation in Kenya is highly erratic and decrease water availability in the drought prone rural areas of the Kitui, Machakos and Makueni districts. Rain water harvesting poses a possible solution and sand storage dams are a rain water harvesting technology that is implemented by local NGOs in collaboration with community based organisations. This research aims to describe and explain the scale of the implementation of sand storage dams by examining the conduct of the implementing NGO's over the period of 2005 -20015, applying a realist perspective by detecting causal mechanisms and generative processes. This research also aims to contribute to the development of mechanisms based research approaches.

The local NGO's have increased in scale from 30-50 to 100-140 sand storage dams per year over the last decade. The have largely achieved this scale by a process of replication. At the core of this process of replication is a socio technical interaction concerning the essential site selection process and the way the local NGOs obtain the necessary design parameters from local knowledge. I conclude that the local NGOs have achieved organisational closure and establish a robust sustained relationship by their organisational activity and their desired outcome: an increase in rural water availability through well performing sand storage dams.

Keywords: Rainwater harvesting, Kenya, local knowledge, scaling, causal mechanisms, organisation closure, sand storage dams.

ii) Preface

Every Msc. thesis is probably an experience of epic proportions to the student who wrote it. And usually this reflects in the acknowledgements more often than not filled with emotions of gratitude. I have been mentioned myself in a couple, and I always wondered how it must have felt for my fellow student while they were writing them. Well. I think I get the idea now.

At the time of writing this I pretty much ran out of time, energy and money. I did not run out of friends. So, now it's my turn to thank a lot of people. Because if there is one thing I learned throughout the process over the last years, it is that graduating is a social activity…and off course the person who said that is listed below. Stubborn will only get you so far. Or – as to phrase it much like the authors that provided me with most of my conceptual framework – I view graduating as an emergent outcome of organisational activity. The people that made up much of this organisational activity are too many to list, but I will push my tired brain one more time to give it my best attempt. Here we go:

First of all, I need to mention the interviewees with whom the interviews would almost never be shorter than 1.5 hours. I would like to thank the municipality of Wageningen and Petra Zoer in particular, for providing me with the time and space to recover after illness and the chance to get back in university after absence. Gjin Ceca, of de bikeshop where I worked as a volunteer while slowly picking up speed on academia again, for letting me plot my own course in balancing the two activities. I would like to thank Duncan de Back for all the long walks together in which he slowly guided me back to a healthy state of mind. I also would like to express my gratitude to the KTI group for being so open to me to make my return back into the Leeuwenborch. In particular, I would like to say a very humble "thank you" towards my supervisor Sietze Vellema. Your lectures were challenging and fun, and I consider myself lucky with a supervisor that showed me how complexity in content does not have to be vague in form. Inge Ruisz you as a secretary at KTI saved my butt more than once and you went well above and beyond your official responsibilities whenever asked. I also need to mention Jasmijn Maters who allowed me to be a stowaway in the biotechnion and providing me with a room to work in. And yes, I am still sorry for setting the alarm off every night. Marleen van Maanen-Nooij, thanks so much for believing in me when I came back to the university, and for helping me work through the red tape.

A very warm thanks go out to my band, Skip Pickers, for keeping me sane by encouraging me to be insane on stage. Todd Crane in particular, for being a teacher, a friend, a bandmate and for allowing me to become best friends with Rufus the Superdog with whom I made the many long walks that eventually helped to get my head around this whole thesis thing. My house and the past and present members of the extended Weppa family for their patience and support. Joost and Maria, for letting me use their house as a working space during daytime. Basti, thanks especially to you for arriving exactly at the moment that the wizard intended to. Your timing was impeccable. All of the MAKS students, with whom I embarked on this journey into the wonderful and exciting world of academic theories, which resulted in many a long night of philosophizing and music. My good friends Regina Hasselbach and Wouter Hermsen in particular, with whom I did most assignments and courses together. With my thesis done, I can finally say: "We are done." Marieke Douma needs mentioning here in particular, for pulling me back into

Leeuwenborch when I didn't dare to yet. I wish you were here. Onno Giller, Eva van der Broek, Tim Stevens, Jan-Willem Liebrand, thanks for not only brainstorming with me but also for for structuring that crazy mess that comes out of my brain. Gijs and Linde, thanks for providing a second home, and for making sure I would stop working during dinner by having me over at 18:00 every day for so many months. Little 6 year old Willem and 4 year old Ina, you are really the best for making sure there was at least a couple of hours a day where it was 100% impossible to think about anything study related. Lucie Sovová, to you I can apply the cheesy phrase: "We met at a special time of my life." I happy you did, and happy you stuck around." Thanks for being so patient with me. And while we're at it:"Mom, Dad. I know you despaired. I am sorry. It's almost done now."

Everyone mentioned above has had an important role in the creation of this thesis and in the personal process that is behind. And I am very grateful to all. However, there is two that I really need to give special mentioning here: my very dear and loving and amazing friends Matthijs and Tracey. Or as they recently named themselves: "Team Coen."

With Matthijs I spent 3 months in Kenya, building a sand dam which marked the beginning of this story. My research is of longitudinal design and spans over a decade. I am a very lucky person when I realise that 10 years ago we were working through the night on this topic, and that the last months we are still doing the same. So. This research also marks 10 years of good friendship. Thanks for keeping me focussed, for helping with writing and for having my back when it really counted. Thanks for a decade of friendship.

Tracey. I could spend another page writing my thanks to you. Whether it was making flipcharts, dictating, brainstorming, copy editing, or just taking a walk making sure I wouldn't throw my laptop away…everything. You should have a degree on Coen-management in your CV. Pretty much day by day. You quite literally saw the whole thing through. We will never know if the statement" I couldn't have done it without you" is true or not. But my suspicion is that it isn't that far off. Thanks Trace. You rock.

Lastly, 3 very special people needs mentioning. Joshua Muskusya, Peter Westerveld and Maartje Westerop. I have had the privilege in 2006 and 2007 to work with all three of them both in Kenya and in The Netherlands. All three were pioneers in the field of rain water harvesting and all three retained a sense of idealism and an energy that is usually found in or associated with people a third of their age. To me, they were very inspiring. In fact, my conversations with them are probably the reason you are reading this right now. During this research I found out they are sadly enough not with us anymore. It is my sincerest hope that the tiny contribution that my writings might make to rainwater harvesting in Kenya is in a direction they would view as a positive one.

Asante Sana, to all.

18-11-2015
Coen

Table of Contents

i) Abstract 3

ii) Preface 4

Table of Contents 6

iv) List of Abbreviations 8

v) List of Tables and Figures 9

Chapter 1: Introduction 11

1.1 Background 11

1.2 Problem Statement 12

1.2.1 Topical Problem 13

1.2.2 Methodological Problem 13

1.3 Research Goal 13

1.4 Objective 13

1.5 Conceptual Framework 13

1.6 Methodological Statement 17

1.7 Research Questions 17

1.7.1 Main Research Question 17

1.8 Reader's Guide 18

Chapter 2:Research Design 19

2.1 Longitudinal Design 19

2.2 Methods of Data Collection 19

2.2.1 The Appreciative Interview 19

2.2.2 Selecting Interviewees 19

2.2.3 Participant Observations 20

2.2.4 Document Study 21

2.3 Data Analysis 21

Chapter 3: Technology 23

3.1 Situated Action, Anecdote #1 23

3.2 Technology - T1 28

3.2.1 Implementation of Sand Storage Dams 29

3.2.2 Pre-Building Activities - Site Selection 29

3.2.3 Pre-Building Activities - Digging 33

3.2.4 Pre-Building Activities - Collection of Materials 33
3.2.5 Building a Sand Storage Dam 35
3.2.6 Maturing and Operation 37
3.3 Technology - T2 38
3.4 Summary 39
Chapter 4: Organisation 41
4.1 Situated action, anecdote #2 41
4.2 Organisation - T1 44
4.3 Organisation - T2 47
4.4 Summary 48
Chapter 5: Knowledge 49
5.1 Situated Action, Anecdote #3: 49
5.2 Knowledge - T1 51
5.3 Situated action, Anecdote #4 52
5.4 Knowlegde – T2 56
5.4 Summary 57
Chapter 6: Analysis 59
6.1 Aggregating Information into Plausible Generative Processes 59
6.2 Technology 59
6.3 Organisation 60
6.4 Knowledge 61
6.5 Scale 62
Chapter 7: Conclusion 65
7.1 Scale of Sand Storage Dam Implementation 65
7.2 Methodological Conclusion 66
Bibliography 67
Annex 1: Grey Literature and Websites 69

iv) List of Abbreviations

CBO – Community-Based Organisation

CT – Contour Trench

ED - Excellent Development

KEN - Kenya

NGO – Non-Governmental Organisation

NL - Netherlands

OM - Observable Mechanisms

OI - Observable Outcome Indicators

RWH – Rainwater-Harvesting

SASOL - Sahelian Solutions Foundation

SSD – Sand Storage Dam

TU Delft – Technical University Delft

UDO - Utuooni Development Organisation

UM - Unobservable Mechanisms

WCT - Westerveld Conservation Trust

v) List of Tables and Figures

Figure 1 Rain clouds coming in during an evening in 2006 over a deforested hillside Mavindini town, Machakos District.

Figure 2 Location of Makueni, Machakos and Kitui Districts South East of Nairobi. (Source, Wikipedia, accessed 18-11-2015)

Figure 3Iterative process of hypothesis testing as part of realist investigation, adopted from Pawson and Tilley (2008).

Figure 4 Analytical Framework underlying this research, adapted from Seelos and Mair (2014).

Figure 5 Assumed influence of the technological and knowledge domains on organisational closure and competence, resulting in organisational scale.

Figure 6 A Pick axe in the trench. Not even halfway

Figure 7 Part of the local community digging in the trench

Figure 8 Primary school classes at about close to the damsite

Figure 9 Investigating infiltration rates at the bottom of the trench

Figure 10 Schematic diagram of a sand dam

Figure 11 Flash flood as a result of several hours of rain upstream

Figure 12 The start of the gully that would have a sand dam in it only several hundreds of meters downstream

Figure 13 Water extraction through a scoophole

Figure 14 A teenager carrying a typical 20 litre jerry can with water

Figure 15 Digging with a pick axe

Figure 16 Digging with a hammer and chisel

Figure 17 Transporting of collected stones towards the damsite

Figure 18 Constructing the reinforcements for the concrete

Figure 19 Casing of the dam without wood but by using flat stones

Figure 20 Mixing the mortar

Figure 21 Forming lines during the filling process

Figure 22 A recently finished dam with still surface water

Figure 23 A well matured dam, with saturated sand

Figure 24 A local community has had several attempts at spelling the name right in the upstream plastering of a sand dam. Ngome is Kikamba for “dam”.

Figure 25 Two members of a community with cement bags in front of the storage hut

Figure 26 The result of a participatory mapping exercise where the community was asked to make a representation of their environment

Figure 27 These community members point out during a transect walk where water remains available the longest into the dry season

Figure 28 A package of "Sportsman" cigarettes folded open. The design of a sand dam and its measurements hand written on it

Figure 29 Rain Water Harvesting suitability map

Table 1: Generative Processes in the technological dimension

Table 2: Generative processes in the organisational dimension

Table 3: Generative processes in the knowledge dimension

Chapter 1: Introduction

1.1 Background

Rainfall variability and recurrent droughts are one of the main causes of water scarcity and food insecurity in rural arid and semi-arid regions of sub-Saharan Africa in general, and Kenya in particular (De Hamer *et al.*, 2008).

In Kenya there are roughly two rainy seasons, a short one of about six weeks and a longer one of about ten weeks (Lasage *et al.*, 2008). During these seasons rain arrives in very heavy erratic showers, which can last from just a couple of hours to more than a week. Since the soils often have been dry for months, the infiltration capacity is very often little more than nothing (Ngigi *et al.,* 2005). The total amount of rain that remains in the soil for later use during the longer dry seasons – useable rainwater - becomes in these conditions just a fraction of the total amount of rain. The useable rainfall for drinking water, agricultural activities, and ecosystem services alike is decreasing under the influence of climate change, becoming a more and more scarce resource.

Figure 1 Rain clouds coming in during an evening in 2006 over a deforested hillside Mavindini town, Machakos District.

According to Aerts *et al.* (2007), climate change in Kitui district, Kenya, is predicted to enhance potential evaporation through an increase in average temperature of about 3°C. Even though average precipitation will also increase, approximately 13%, the net water availability is projected to decrease in the future, about 1% and 34% in the seasons November to March and April to October, respectively.

This decreasing availability of useable rainwater has an accelerating effect on a system that is under pressure of a growing population and already prone to being caught in a vicious cycle of decreasing yields, deforestation, soil degradation, desertification, and increased run-off of precious rainwater, all resulting in an even further decline of the overall drought resilience of large areas of south-east Kenya (Hut *et al.,* 2008).

In this thesis, sand storage dam as a rain water harvesting (RWH) technique will be examined. A sand storage dam, or in short, sand dam, is a small dam, 10- 25m wide, in a seasonal river constructed with concrete. Sand dams are designed to slow down the current in the bed of a perennial river, and consequently allow the coarse sediment behind the dam to settle and form a layer of sand up to several meters thick. Within this sand, the water is stored between the sand particles, crucially protecting it from evaporation, and the contamination which would typically occur in an open surface-water reservoir (Lasage *et al.,* 2008).

Figure 2 Location of Makueni, Machakos and Kitui Districts South East of Nairobi. (Source, Wikipedia, accessed 18-11-2015)

Sand storage dams (SSDs) are implemented in remote rural areas by local non-governmental organisations (NGOs) such as Sahelian Solutions Foundation (SASOL) in Kitui District, Excellent Development (ED) in Machakos and Makueni Districts, and Utuooni Development Organization (UDO) in Machakos District. These NGOs closely collaborate with local communities, and promote self-help groups, water user groups, or other community-based organisations (CBOs), to be involved in participatory processes regarding maintenance of and, more importantly, the selection of suitable locations for SSDs.

More than 1500 sand dams have been built in Kenya since 1960 (De Trincheria *et al.,* 2015). The SSDs have had a large impact on the local communities. In ten years of SSD building, the increased water availability, especially during dry periods, resulted in higher farm yields, the average income of farmers living near dams rose to 60%, and the distance to the water source decreased after dam construction from 3km to 1km on average, while time spent on collecting water for domestic also decreased (Lasage *et al.,* 2008).

Despite all the studies available which evaluate the effects and outcomes of sand storage dams, and the evident importance of this technology given the socio-economic and environmental challenges in dry regions in Kenya, some knowledge gaps remain. The specific knowledge gap addressed in this thesis is described in the problem statement below.

1.2 Problem Statement

A series of interlocking concepts, and the underlying mechanisms that generate these concepts, are briefly presented as the guidelines along which this thesis is developed towards an answer of the main research question.

1.2.1 Topical Problem

In the development of sand storage dams in Kenya, as described in the background, there has been a drive to upscale the technology of sand storage dams, and a certain scale of operation can be observed.

As described by Seelos and Mair (2014), scale is interesting because often there is a problem of a particular size, and an intervention, technical or otherwise, but that intervention rarely operates at the scale of the problem which prompted it. Sand storage dams are no exception, as described in the background section above. Moreover, there is a lack of understanding in the current literature on sand storage dams about what the existing scale of sand storage dam technology is, and how that is a result of the activities of implementing organisations. Such an understanding is relevant for upscaling, in order to understand how future scaling can be achieved in a timely and efficient manner.

1.2.2 Methodological Problem

When considering interventions such as sand storage dams, the question of whether the intervention can be done “more”, or “bigger”, to solve more of the problem, is frequently posed. Assessing the success factors is an important component of evaluating intervention performance, as a means of assessing how these success factors can be replicated among other interventions, and how a desired scale can be achieved. However, by focusing only on the successful factors behind an upscaling process, the observations are predetermined to concentrate on change, and are more likely to overlook situations of stability which also lead to a certain scale.

This study takes an alternative approach to assessing performance of sand storage dam technology by asking how the scale observed has occurred, and thus identifying situations of stability, as well as change, which may have led to the current scale. This builds on recent work developed by Seelos and Mair (2014), which views scale as an emergent outcome of organisational activity.

1.3 Research Goal

To find and use a systematic way to describe and explain the scale sand dam technology in Kenya observed between 2005-2015.

1.4 Objective

To describe and explain the scale of sand dam technology in Kenya observed between 2005-2015.

1.5 Conceptual Framework

In order to achieve the research goal and objective, we make a choice for a realist evaluation, largely based on the theory presented by Seelos and Mair (2014). In this thesis it is not assumed that a technology, or the organisation which implements it, can *only* be understood from the way they are embedded in their social context. Rather, it is assumed that a technology, and implementing organisation, can exist and have attributes without a discourse on them. For instance SSDs have a size, a weight, and a location which are relevant to their performance without their relation to their social context, or discourse about them.

This approach to describing phenomena entails an iterative process, in which detailed observations of a phenomenon are recorded, and aggregated into generative processes (first iteration). Subsequently, these generative processes serve as hypotheses for causal mechanisms, which are investigated to assess which causal mechanisms can robustly explain the phenomenon (second iteration). These causal mechanisms again serve as hypotheses for the occurrence of the phenomenon under study in a third iteration of investigation. The process within these iterations is described in Fig. 1, adopted from Pawson and Tilley (2008).

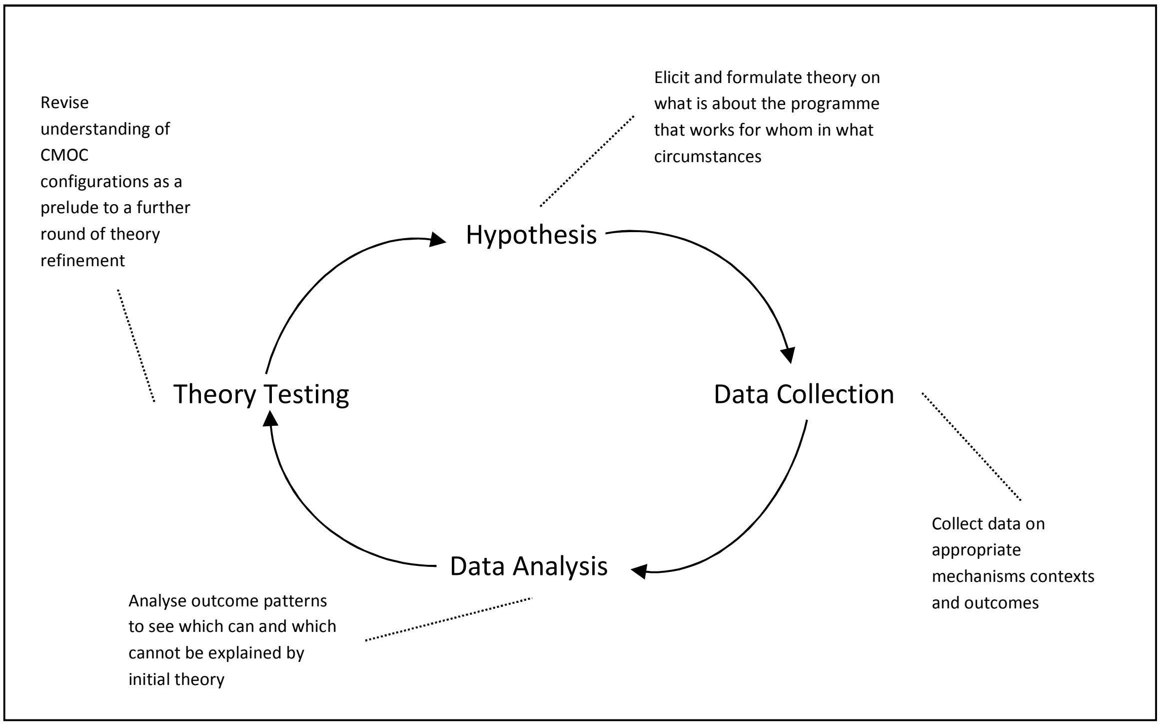
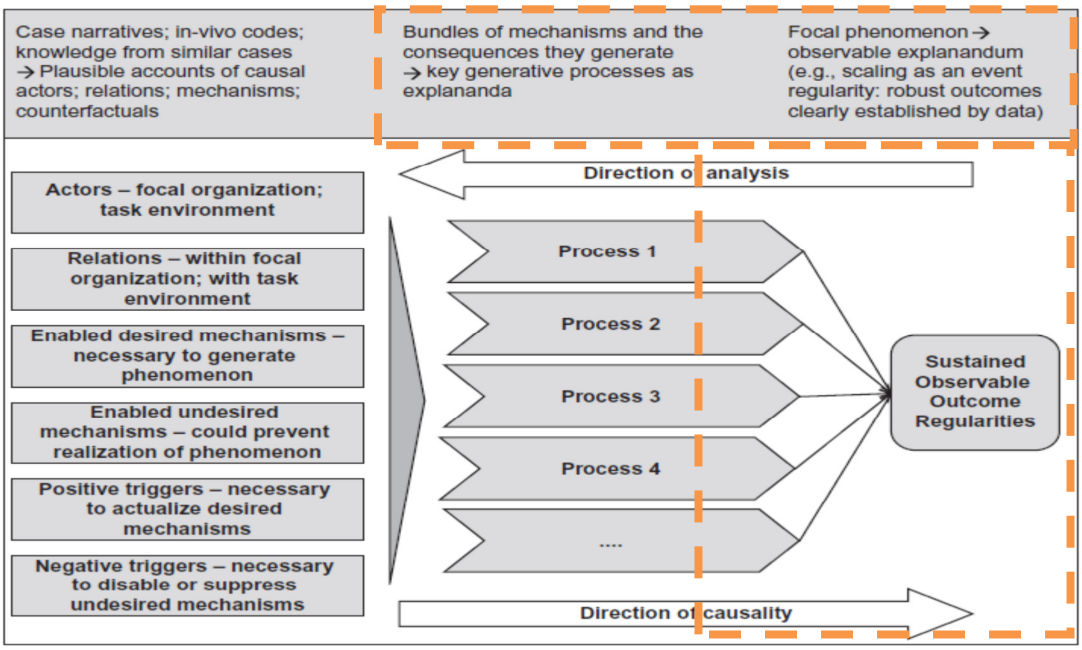


Figure 3Iterative process of hypothesis testing as part of realist investigation, adopted from Pawson and Tilley (2008).

This thesis intends to undertake the first iteration, describing plausible generative processes derived from observations of the phenomenon, but it is beyond the scope of this thesis to go further in the investigation by theorising about plausible causalities. Fig. 2 describes how the process of finding causal mechanisms is undertaken by Seelos and Mair (2014), indicating the steps of this process which are investigated within the scope of this research.



Indicates the extent of the process described by Seelos and Mair (2014) for investigating organisation scale, which is pursued within this thesis. (First iteration, undertaking aggregating data into plausible generative processes, without theorising about causal mechanisms.)

Figure 4 Analytical Framework underlying this research, adapted from Seelos and Mair (2014).

Seelos and Mair view scaling as a result of organisational performance; scaling is about the capacity of an organisation to sustain sets of enabling causal mechanisms, and mitigate sets of counterfactuals, into a pathway of organisational closure. Seelos and Mair's definition of scaling (2014) is adopted in this thesis:

> "Scaling as an increase in *desired organisational outcomes* B that are generated by *organisational activity* A. This equation has a central *explanandum* B – that which explanations are sought for – as the starting point of analysis. The *explanans* – that which explains the explanandum – are sets of *causal mechanisms* and *counterfactuals*, amalgamated into generative processes that have constituted the explanandum."

I have chosen the scale of operation of the NGOs involved in RWH in this area of Kenya as the explanandum, to be used in the same sense as Mayntz (2004), in Seelos and Mair (2014),

"Realist explanations require a clear explanandum – a focal phenomenon of interest – as a starting point for inquiry."

In order to devise this analytical framework to assess scaling, Seelos and Mair investigated the case of the Aravind cataract hospital in India (Seelos and Mair, 2010; 2014). Seelos and Mair gave a role to knowledge in this investigation and specifically paid attention to enabling mechanisms adhered to individual human or organisational activities. However, this thesis expands the explanatory power that lies within their mechanism-based approach, by assuming that explanatory power also lies in the inherent properties of the technology central to this thesis, SSDs. Seelos and Mair do not categorically ignore technology and knowledge in the explanation of eye hospital organisational structure, but if their conceptualisation were strictly applied to this research, these factors would remain under-explained and explanation of scale would be unsatisfactory. Thus the factors of knowledge and technology are also incorporated, as depicted in Fig. 3.

Technology is regarded for this research as described by Jansen and Vellema (2010), that is “the use of skills, tools, knowledge, and techniques, to accomplish certain ends”. The socio-technical interaction involved in technology use is embedded within this definition, lending this conceptualisation of technology a complementary fit with the human-centred framework of Seelos and Mair. It is thus assumed that technologies such as sand storage dams have an influence on the organisational behaviour of the implementing organisations.

The knowledge concerned in the framework described in Fig. 3 goes beyond that involved in the production and use of technology. Knowledge is assumed to be manifested in the physical expression of SSDs and – more specifically – in how local NGOs organise themselves around site selection of dams in seasonal riverbeds.

For this thesis, it is necessary to discern between two different types of knowledge: situated local knowledge and scientific knowledge. Although both types of knowledge are often represented as two parts of a mutually exclusive dichotomy, that is not the intention of this thesis. Different types of knowledge need to be distinguished simply because they hold different places in the causal model, since they have different inherent enabling mechanisms. However, rather than a dichotomy, it is considered that they represent two different zones in a spectrum.

The term situated knowledge refers to knowledge specific to a particular situation. In this thesis it concerns the intricate knowledge of the local communities about their environment. Scientific knowledge here is used to refer to a systematic approach to record information about, and explicate phenomena, often with the use of quantitative analysis, technology, and theory which is radically different and, in the sense of theory, more abstracted from, the situated knowledge through which the same phenomena can be understood.

It goes beyond the scope of this research to review all possible definitions of organisation, but this thesis is specifically interested in the capacity of an organisation to reach closure. Closure here refers to the capacity of the organisation to achieve a robust relationship between their activity and the desired outcome, over a prolonged period of time. This is of specific interest for this thesis because of its centrality to the approach of Seelos and Mair (2014) to explain organisational scale, who assume scale as a result of organisational activity.

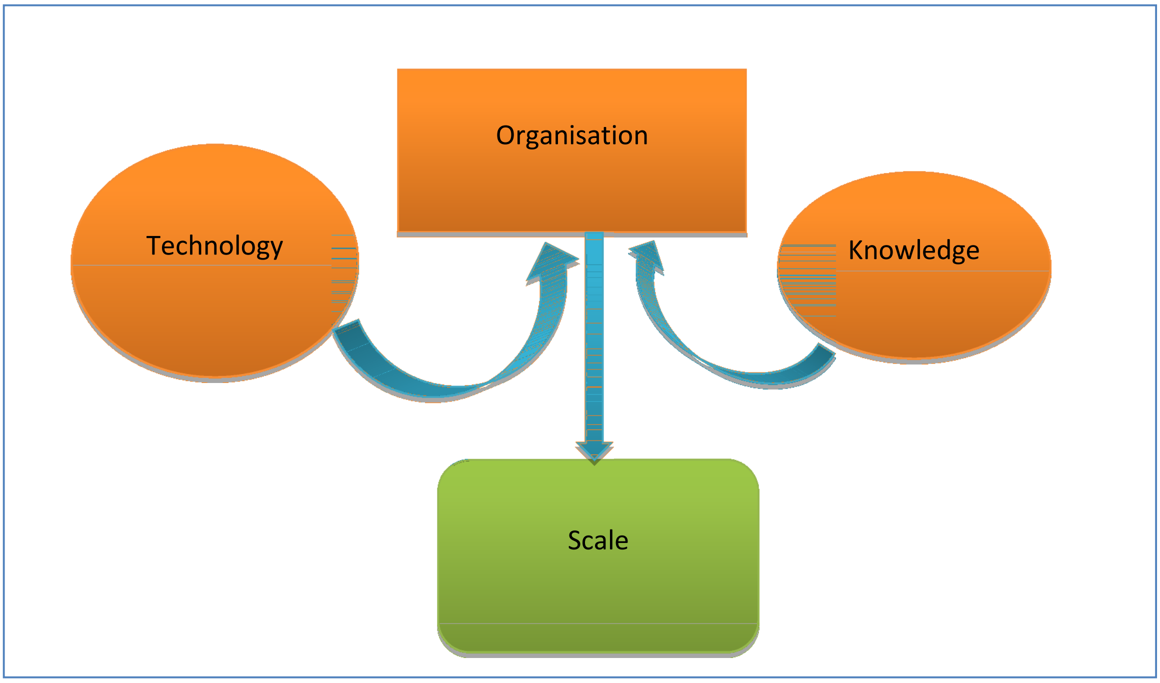


Figure 5 Assumed influence of the technological and knowledge domains on organisational closure and competence, resulting in organisational scale.

In Fig. 3 this framework of Seelos and Mair (2014) is depicted with the domains of Technology and Knowledge influencing the domain of Organisation (organisational activity), as already described above. Scale is defined above as an outcome of organisational activity, and Seelos and Mair (2014) describe four different characterisations of scale. These loose characterisations of scale, A) Increased Size, B) Replication, C) Increased Productivity, D) Knowledge Transfer, will be drawn upon in Ch. 6, in the analysis of empirical material pertaining to the three domains of Fig. 3.

1.6 Methodological Statement

This research has chosen to adopt a realist evaluation methodology largely based on Seelos and Mair (2014), to find and use the scale of rain-water harvesting found, taking an approach based on causal mechanisms.

1.7 Research Questions

1.7.1 Main Research Question

What scale of organisational operation has been achieved between 2005-2015 among rain-water harvesting organisations in Kenya, and how can it be explained?

Sub-Question One

How has sand storage dam technology been implemented in Kenya between 2005-2015?

Sub-Question Two

How have the sand storage dam implementing organisations under study operated in Kenya between 2005-2015?

Sub-Question Three

How have scientific and local knowledge interacted in relation to sand storage dam implementation in Kenya, between 2005-2015?

1.8 Reader's Guide

The activities undertaken to answer the above questions will be described in Ch. 2, Research Design. The data to answer each sub-question are described in Ch. 3, 4, and 5, to address the domains of technology, organisations, and knowledge, respectively. Each of these empirical chapters will be introduced by a reflection on situated action carried out by the researcher during periods of participant observation, described in the form of anecdotes. In the analysis chapter, Ch. 6, the data is aggregated into plausible generative processes, which serve to answer the main research question. Ch. 7 describes the topical and methodological conclusions which can be made on the basis of this research, and provides for reflection and methodological and practical recommendations, in light of the research goals. Appendix I contains information about grey literature obtained from Ex-Change and Westerveld Conservation Trust, a key information source used in this thesis.

Chapter 2:Research Design

2.1 Longitudinal Design

"The purpose of longitudinal designs can vary from the descriptive to the explanatory. As a descriptive tool the value of the longitudinal design resides in the fact that it enables us to examine change or stability. Used in this way a longitudinal study can reveal a great deal about the direction of change at a societal, organizational or individual level (De Vaus 2001:114-115)."

Data collected roughly over a decade is organized along two time points, because the density of data is centered around a first time period, 2005-2006 (T1) and a second time period, 2014-2015 (T2).

The triangulation of interviews, participant observation, and document study is used to give the results more reliability than in the case of using only a single data collection method. In this case, in T1 many participant observations were done but not many interviews or document study. In T2 many interviews and document study were carried out, but not many participant observations.

2.2 Methods of Data Collection

Within a period of 10 years, information about the scale performance and site selection of sand storage dams was collected through appreciative interviews, field visits, participant observations and document study.

2.2.1 The Appreciative Interview

The purpose of qualitative, interview-based research is to describe and clarify people's experiential life "as it is lived, felt, undergone, made sense of and accomplished by human beings (Schwandt, 2001: 84)".

In this regard, "*the appreciative interview takes the interviewees through a journey in which they have an opportunity to reflect on and share their most outstanding personal experiences, ideas about what works well, hopeful aspirations and desired futures (Schultze and Avital 2011)".*

During the interviews, it was important to build up a close understanding of interviewee experiences and understanding of the research topic regarding scale, performance, and site selection of sand storage dams.

Every interviewee tries to build up a story when he is answering the questions. The way the questions were asked, as well as the order in which they were asked, had an effect on how interviewees told their stories. Understanding the interview as a whole gave a contextual overview to the separate questions.

Furthermore for a good understanding of the interviewee's viewpoints, it was necessary to ask follow-up questions. For example, questions such as "What do you mean by that", "Can you explain that further?", "Can you give an example?" were asked.

Finally it was also important to treat every interviewee's statements and interpretations about the research topic as equally important. This equal treatment of perceptions helped to overcome bias.

2.2.2 Selecting Interviewees

12interviewees were selected on the basis of knowledge, and relevance to the topic. These were:

- Sander de Haas (Technical manager Naga Foundation/ volunteer Sam Sam)
- Dennis Karpes (Founder Naga Foundation)

- Lieselotte Tolk (Hydrologist ACACIA)
- Frank Steenbergen (Director Meta Meta)
- Ian Neal (Former employee Excellent Development, currently freelance consultant)
- Fransesco Sambalino (Meta Meta)
- Munguti Muntinda (SASOL director, former community mobiliser)
- Henk Haring (Director Ex-Change)
- Michiel Wolters (Researcher Alterra, Climate modelling)
- Maarten Onneweer (RAIN Foundation)
- Marlies Batterink (3R manager, Aqua for All)
- Joseph de Trincheria(Phd student, Hamburg University)

The interviews were recorded with a voice recorder or via skype (with a build-in voice recorder). The advantage of using the audio tapes from the voice recorder was the ability to work out the interviewee's responses as exact as possible. The disadvantage of using the voice recorder was that interviewees were more aware of being interviewed and may have felt less free to speak. This may have resulted in some bias in the interviews.

2.2.3 Participant Observations

"*Participant observation is a process of learning through exposure to or involvement in the day to-day or routine activities of participants in the research setting*" (Schensul *et al.,* 1999:91).

Thus it is important to build up a trust within the research situation in order to overcome the possibility of people changing their behaviour in the presence of the researcher.

"*It is an unstructured method in the sense that strict controls are not placed on the context, action, or the type of data collected, as well as there not being any a priori research hypotheses to test in the field setting* " (McKernan, 1991:60).

This method of data collection involved two goals: firstly, to take on the role of a participant, and secondly, the role of researcher.

Between 2005 to 2015 participant observation played a major role in several activities:

- During a three-month field study in 2005, the researcher was part of the process of building a sand storage dam, and did a site selection survey for sand storage dams in Kitui district, and worked on changing site selection protocol;
- In 2005-2006, the researcher worked for Ex-Change to recruit BSc. and MSc. students in order for them to do field work for SASOL in topics regarding sand storage dams and other rainwater harvesting systems (RWH);
- In 2006-2007, the researcher executed, together with Westerveld Conservation Trust (WCT), a participatory rural appraisal for four months, that was part of an environment impact assessment for sand storage dams. Field notes were developed in order to understand and contextualize the researcher's understanding of sand storage dam site selection;
- The researcher had personal conversations with MW, PW (both of WCT), and JM (of UDO and ED)
- In 2014 the researcher joined eleven webinars organized by the Water Channel and/or the Rain Foundation, that focused on rainwater harvesting:

- *Kenya's Water Buffer: Recharge, Retention, and Reuse (29 July, 2014)*
- *Rainwater Harvesting and Food Security - IDE cases from Burkina Faso and Honduras (23 September, 2014)*
- *A decade of Water Point Mapping (30 September, 2014)*

- *Building momentum for rainwater harvesting (7 October, 2014)*
- *District monitoring of Rural Water Supplies (14 October, 2014)*
- *Groundwater Recharge (21 October, 2014)*
- *Rainwater Harvesting – experiences from around the world (4 November, 2014)*
- *Water Point Mapping – Failure and the Future (18 November, 2014)*
- *Mapping Groundwater Quality for Decision-Makers (25 November, 2014)*
- *Rainwater Harvesting - the basics (2 December, 2014)*
- *Sustaining Groundwater Supplies (9 December, 2014)*

One limitation of the research is that no participant field observations were done in the last seven years. This makes the interpretation of results biased. Furthermore one problem with participatory observation method is how to interpret the process of events and behaviour as they occur naturally.

2.2.4 Document Study

In different periods of writing the research, peer-reviewed articles and scientific reports about RWH systems and techniques specifically on scale, performance, and site selection of SSDs were collected. This helped the researcher to improve their understanding of the research topic.

Furthermore grey literature such as the "3R Books" from the 3R consortium, Sand Storage Dam conference papers, project reports of Ex-Change, WCT, and Acacia Water, and video material of ED, were used in order to get an understanding of the institutional framework regarding SSDs.

2.3 Data Analysis

By using the coding scheme, it is possible to analyze the data and connect it with the theory.

"Guided by the coding scheme, researchers can explicitly code for sets of relevant actors, enabled mechanisms as properties of these actors or their relations, how mechanisms are triggered, and how they generate their desired effects" (Seelos and Mair, 2014: 159).

In this research, the developments in technical aspects of SSDs, the changes in scale of SSDs, and the role of knowledge in upscaling of SSDs from 2005 to 2015 are described in the next three chapters.

The data described in these chapters are sieved (analyzed) for observable outcome indicators (OI), observable mechanisms (OM), unobservable mechanisms (UM) and counterfactuals in Ch. 6.

Chapter 3: Technology

3.1 Situated Action, Anecdote #1

Rock bottom – Somewhere 2005, dry season

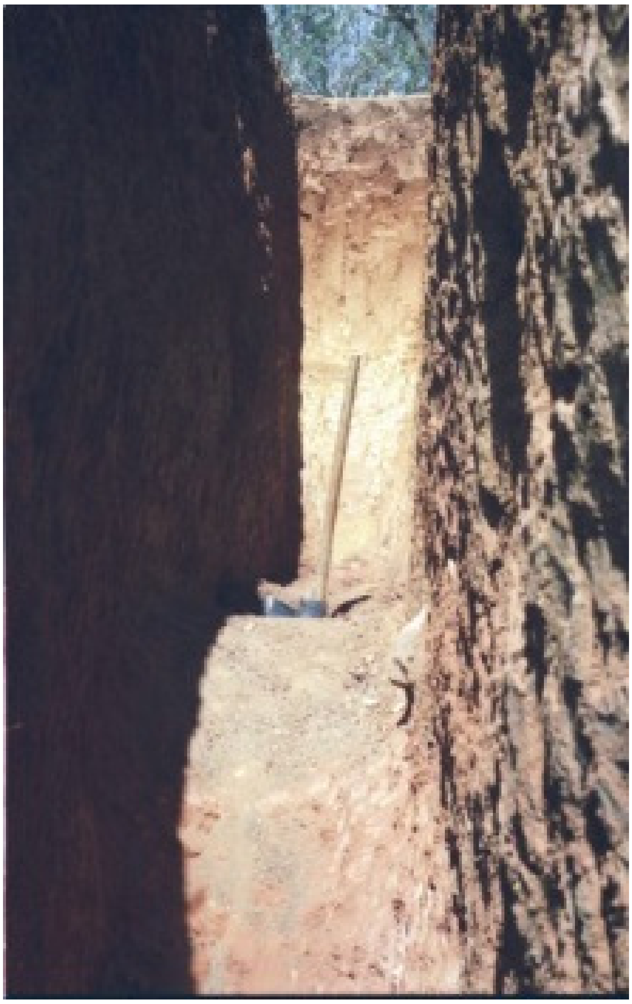


Figure 6 A Pick axe in the trench. Not even halfway

“<tchhuumgK>……….<tchhuunK>
<tjkunmgue>……..”

It’s been at the centre of debate for almost a decade now: the phonetic spelling of the sound of a rather blunt, but moderately heavy pickaxe, at the exact moment it hits the surface of the hard and dried soil, called murram, of a dry riverbed in the South of Kitui District, Kenya. We have had plenty of experience by now: our main occupation over the last seven and a half weeks have been almost exclusively involving the pick axe.

Day in day out, morning ‘til eve we’ve been holding pick axes and we have been using them to dig a trench. A trench across a dry riverbed where eventually a sand storage dam is to going be built. And this process of building a dam was preceded by preparing a trench, and that in turn involved digging with a pick axe. The logic was as simple and clear as the consequent ordeal: We were digging. Digging was our task, and the sound of our pickaxes was our tune. In Kitui South everything had its own particular sound: the lions roared, the hyenas howled, the charcoal trucks hummed, women sang, kids yelled, and our pickaxes thcuunk-ed. Or tjkunmguee-ed. Or tchhuumgK-ed.

Many might have the expectation that when hearing the same sound over a prolonged period of time it will lead to developing a certain deafness to it, just like when people live next to a motorway or railroad over time - they simply become oblivious to the sound of trains and cars. But when this sound becomes informative in its very small changes in pitch, or slight fluctuation in attack, or whatever small amount of brightness that changes, the obliviousness changes into attention, and eventually maybe even to being very attuned. Especially when there is really almost nothing else to focus your attention on, the minor details, no matter how small, start telling really small stories that might hold a really large relevance. And in this case of unending, repetitive, meditative, pounding, tiring, droning sound, hour after hour, day after day, and week after week, it was holding rather large relevance. A change in pitch in the sound of a landing pickaxe could in fact mean all the difference. We were looking for water. Or to be more precise, rocks for water.

The last seven weeks had been hard. Not the type of hard that is commonly used in a complaint when one might say: “It is hard to achieve x y or z”. No, the type of hard that is an attribute to a material and is used in the literal sentence “this rock (or soil in this case) is hard”. In the area where we were working however the word “hard” wasn’t held exclusively to the soil we were digging. It seems everything was hard. The sun burned hard. The bushes and their respective thorns were hard. The roasted chicken – a rare delicacy – was hard. The rocks we were breaking to serve as building material for when the digging was done were definitely hard. Our bunks, or rather the five planks that they consisted of, were hard. The back of a bicycle steered over the rocky roads seemed particularly hard. The usual porridge, named *githeri* - sandy beans, sometimes augmented with some grains of maize – was affectionately renamed into *concrete-on-the spoon* by us. The wooden backseats, and especially the metal frames that held them in place, in the back of the truck that got us here, had been real hard. Our sunburned skins got hard. Our muscles got hard. The blisters on our hands were hard. The wood and steel of our pickaxes were hard. And most important - even compared to all other things hard - one thing in particular was extremely hard: The soil was hard. In fact, it was so hard that sometimes the sparks would fly from the tips of our pickaxes. Or so hard that even the best swung, freshly sharpened axe would land and spark, but then only chipped the surface and remove less than half a centimetre of soil. However hard this soil called murram was, the real problem was a paradox: It wasn't hard enough.

2005, Late June.
Morning in Kitui South. Probably the best moment of the day. Not only was the temperature still quite pleasant and the latrine not smelling deadly yet, there was also every morning a sense of relief: the night had passed again. A good night's sleep was far from guaranteed: the sound of distant hyenas and lions was surely adding to a certain sense of adventure, but the colony of bats that would sleep (and defecate) over our heads wasn't. This, plus the fact we frequently encountered mamba snakes, venomous spiders, and scorpions, would make you think twice about leaving the relative safety of the mosquito net and taking the 20 meter walk to the latrine, armed only with a squeeze-light. Especially when considering we were two to three days travel away from even basic electricity, running water, and tarmac, let alone facilities such as antidote.

"Hmm. Coffee… What do you think? Today is the day?"
"Dunno. Don't really think so." I don't remember whether it was me or Matthijs posing the question or giving answer, and it doesn't really matter. Every morning was the same anyways.
"It's been the same the whole week. Every time the sparks come off the day before, and you think we're almost there. Every time the next morning we try and the bottom just leaks like a sieve."

The mornings were wonderfully serene. We sat sit in front of our little clay house having some chapatti – somewhere between a kind of oily flatbread or pancake - and to flush them some chai, to which we would conveniently add milk to mask the brownishness of the local water. It was all peaceful and business as usual. But the last week something had been brewing.

"Hmm", Matthijs mumbled, "Musembi already left. Seemed to be in a hurry." Matthijs was probably right. I had heard some stumbling from our neighbour, SASOL's appointed artisan mason, to our dam-site that morning, and his door was already locked on the outside.
"Well, it is already quarter to seven. He is usually up early. Besides, we might as well get a move on ourselves soon."

"Dunno", Matthijs looked up from his beloved 'Determining-over-a-100-species-of-acacia-book'. "He kinda got his ears washed last week when his supervisors came. He seems to be rather anxious ever since. Guess SASOL feels we are behind schedule and he is the one to keep it all going."
"Since when are there schedules here?", I grinned. "Although I have to say, I wouldn't mind to see the start of the actual building process and some kind of dam take shape before our plane takes off. I am fed up with digging. Besides...we have only four weeks to go if I count my Lariam pills correctly…"

"Netherlands?", Matthijs laughed, "What *is* that?"

The thought of the Netherlands and showers, roads, cars, rains, grass, all seemed weird, almost unrealistic, alien even. However, some evidence of the existence of our home country was actually there: A calculator, a compass and – most importantly- a copy of a 1988 manual on sand storage dams we got just before we left on our internship. Though old and faded the manual did explain the basics of what we were trying to achieve: provide a source of water by means of harvesting rain with a small dam in a seasonal river bed. The actual construction of a sand dam wasn't very complicated by principle. Not complicated but labour intensive for sure. If you wanted to catch rain and store it as groundwater you had to go into the ground. So although we were supposed to construct and build something *up*, so far we only had been digging, and been going *down*.

Musembi was the mason and overseer stationed by SASOL for the months of our stay within the village. He was an accomplished artisan mason, and he and his apprentice (Fred) were charged with the build quality of the dam as well as keeping the community motivated, and serving as a monitoring man for SASOL. And last week when visiting a neighbouring community together, and dam site at about a mornings worth of walk, we discovered their trench was almost twice as deep. And Musembi wasn't happy with that, especially not after the first visit in weeks from his supervisors.

"I don't think Musembi can do much", Matthijs read my thoughts. "It's not that the people don't work hard. It's just that soil. That incredible soil. It's just superhard. Compared to us these guys got off just super easy. That grey stuff of theirs is like butter – and don't forget they have been able to mobilise about 40 people into their dam committee. We are only 19 now…"

"I'm still surprised that the soil can just completely change within only just a couple of hours of walking." Matthijs looked at his dirty clothes: "Well, at least we got the pretty red – looks better on the pictures too you know." I opened a new package of cigarettes – the Drum I brought from the Netherlands had long run out on the intensive friend making processes around the village – and lit one of my favourite new brand: Sportsman cigarettes. Talk about strong advertising. "Maybe they're just getting tired too", I referred back to Matthijs' remark about our community. "They've been digging on not much else than chai, beans, and maize for fuel for almost two months. Only the women seem to show up on time or at all these days…"

Figure 7 Part of the local community digging in the trench

We didn't mind too much, at least the women were ever cheerful as they would sing instead of just talk and mutter like most of the men did. But it was true, the last weeks the voluntary workforce that was mobilised by SASOL in the form of a sand dam committee was slowly but surely dwindling. The digging was wearing everyone down.

<Sigh>. "Kenya style man. It just goes as fast as it goes. Pole Pole sana", I confirmed – it was really something we learned from the people we dug side by side with. When we started to work we had started digging hard and fast, as in a race. And the small local community of Kakithia had laughed cheerfully at us. To them we had been top-notch entertainment in that sense. Because after half an hour our hands would bleed, our dusty mouths would be gasping for air, and our muscles would be burning. And the women especially – in our minds they had become the toughest creatures on the planet – had actually out-dug us. They were thin, not to say downright skinny, and were usually one-and-half heads shorter than us, but their hands were long and tough, and there upper arms were wiry. In the process of

digging together they had shown us it wasn't so much a matter of strength, it was all about rhythm. To get the right swing, you had to use your whole body, not just your arms. From the legs up, lower back tightened up, and shoulders relaxed, we learned to let the pickaxe do the work and not the arms. And we learned to cheer and sing in the process. And – most importantly - we also learned to listen well to the sound of the axe.

"Come on. Let's go." – "Yeah. Before we have to pay 2 Ksh. of latecomers fine too." Although we sincerely doubted whether the community was really sticking to the rules they had set for themselves during one of the NGO's participatory-site selection days we did get up, and started our daily 15 minute walk towards our dig-site. We put our pickaxes over our shoulder and followed the narrow trails only wide enough for 1 person with a small wheel barrow. I put our sand dam manual away in my bag. I always had the feeling holding books, pens or a calculator would make me look like an engineer and I wasn't comfortable yet with that type of credibility. Especially not now when decision-time seemed imminent.

"Poor folks. Hope we will be able to explain…" I was half thinking out loud, half talking to myself, "wonder if they understand we can't just simply stop digging now…"
"We'll just have to make it a dance. Seems to work for almost everything. Maybe just make another drawing in the sand." Whether Matthijs was just looking at the brightside of things or trying to cheer me I don't know. "And who knows ... maybe today it's different."

I ignored the little school as we passed by. "Howaryouhowaryouhowaryouhowaryou!", it echoed across the schoolyard, from hundreds of enthusiastic throats, mixed with "Musungu musungu musungu!", which is Swahili for white man. They mostly yelled at Matthijs anyways. Ever since we brought them a real leather football we already became some sort of superstars to them, but when Matthijs started doing his mime-inspired theatre when we brought the ball, he really became the local hero. Anywhere within a day's walk from our little house a kid could suddenly pop up out of the bush and start yelling "Sammy Sammy Sammy" at Matthijs, the nickname they had apparently affectionately chosen for him.

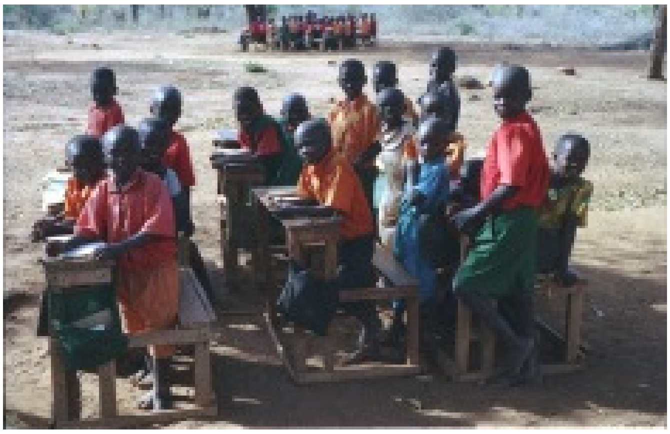


Figure 8 Primary school classes at about close to the damsite

But, however cheerful the thought was that my friend could almost run for president, my mind was with the sand dam manual and the event which had become routine in the morning at the dam-site. And the consequent decision that was to be made. When we had left Holland we had an idea of sand dams, sure. They were built in the dry season, in a dry river bed, to hold the water when the rains come. We also understood they needed to be dug into the bed to make them stable, and last for at least 50 years. But understanding that, in order to do so, you need to dig a trench, is one thing when read in a book. Understanding that the trench needed to be five meters deep, one meter wide, and about 30 meters in total length, is still doable when done from an Excel sheet. But grasping it while using a pickaxe, is something we hadn't prepared for.

We arrived under the welcoming sounds of the women and the consequent echoes of the pickaxes coming out of the three meter deep trench.

"Still sounds the same to me...", I muttered. "Still that high screeching pitch every now and then. They are not rocks. Just pebbles."
"Kwa heri! Nzuri…Nzuri sana!", Matthijs didn't listen as greetings went between us, and about everyone around us. From Musembi, only a concerned nod while we approached the trench.

And then, just like every day, silence. The echoes from the trench stopped and sweaty, dusty faces began appearing. A yellow jerry-can of water was opened and thirsty mouths were filled with brown water. At the lowest point of the trench we sat down hoping that the screeches we heard were more than just pebbles. The habit almost became a ritual. Matthijs held the jerry-can, I held a small metal bowl. Only a small amount of water would do. And then the murmuring would stop in anticipation as we would put the sharp point of the chisel down in the lowest point of the trench.

As people gathered around for the most important moment of the day, we would very carefully pour the contents of the little metal bowl on the bottom of the trench. Then, as a point of reference, we would put the tip of the chisel down in the puddle.

And then we would wait.

Figure 9 Investigating infiltration rates at the bottom of the trench

As I was thinking about that 1988 manual burning in my bag I could almost hear what it stated, clear as day: "A sand dam must be built on an impermeable layer of solid rock underneath the riverbed." A donkey would stubbornly make its disagreeing noise, other than that it was silent at the dam site.

And we watched in silence as the water saturated that hard soil...
And – like the week before – the water started slowly but most surely – like almost everything else in Kitui South – slipping away into the bottom of the trench.

It wasn't as much of an announcement anymore, because all present knew by now what it meant. Still it had to be said:

"Today, we dig."

Thcuunk would be the soundtrack of the rest of the day. The sharp TCJJINK of metal hitting hard stone, the sound of hope. Hope that the digging would end, building would start, rain would come and eventually water would be there to stay.

3.2 Technology - T1

In this thesis, the scale of sand storage dams, and the organisations that implemented these, are explained and described. Ch. 1 describes the assumed interactions between technological and organisational spheres, which are likely to hold generative processes and causal mechanisms that have explanatory power. The empirical chapters will thus begin with a detailed description of the technology itself, to gain further insight into this sphere.

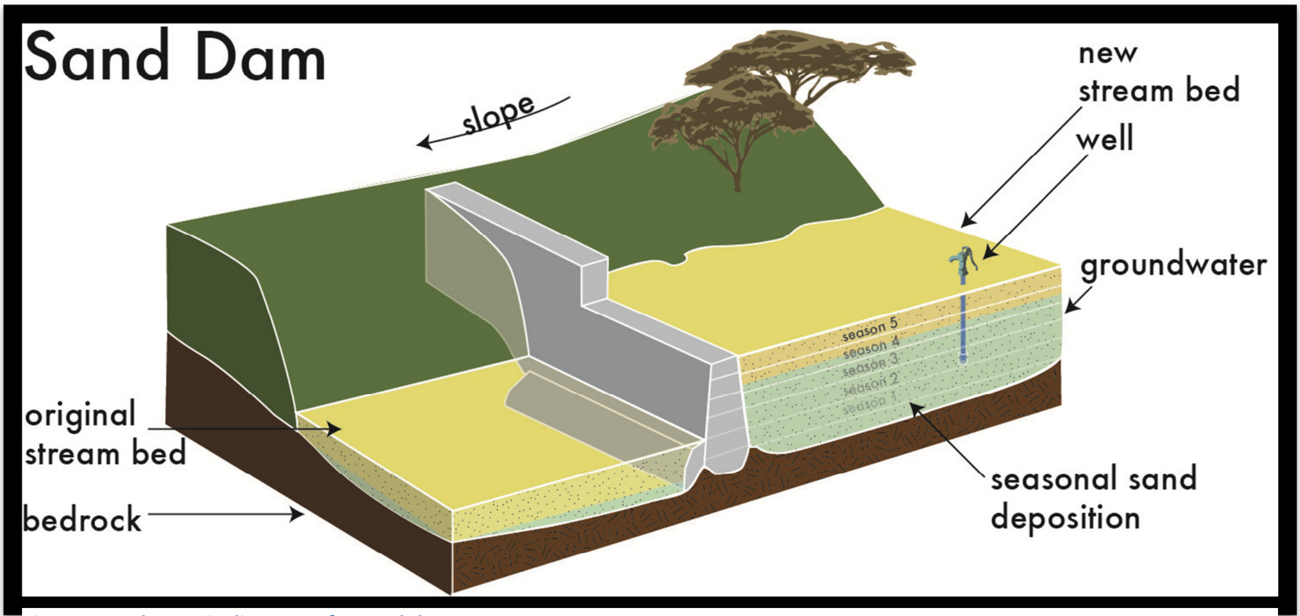


Figure 10 Schematic diagram of a sand dam

In 2005, a period of participatory observation was conducted on the construction of a sand storage dam in Kitui District, south east of Nairobi, in Kenya. For three months the researcher worked together with a local community in Kitui South, about two days walking from the closest mapped settlement, Kanziku. During these months the researcher participated in almost every aspect of sand dam construction. The following section is largely based on these three months, unless stated otherwise.

The function of an SSD is to retain rainwater in a seasonal river in such a way it is available for use after the – typically short but intense - rains have gone, and the riverbed is dry again. The mechanism by which SSDs do so is by slowing down the temporary current that occurs after the rains in such a seasonal river and holding both water – and more importantly – the sand in that water. The obtained water is stored and conserved between the sand particles, sealing it off from evapo-transpiration. If the sand is coarse enough (approximately 1.5 mm-5mm) 1m^3 will hold up to 400L of water, a revenue of 40% (Gijsbertsen, 2007; Nissen-Petersen, 2006). Importantly, by having the sand as storage container for the water (as opposed to creating a pond with open surface water) a mosquito breeding habitat is avoided, and as a consequence, a possible source of malaria. The build-up of sand behind a sand dam is named maturing, and is reported to take between 3 – 7 years (Borst and Haas, 2006).

SSDs vary in size but typically the riverbeds in which they are built are 10- 25 m wide. However, what doesn't vary is the fact they are built deep into the riverbeds. Since the objective of sand dams is to retain groundwater and store it as such, SSDs are built deep into the riverbeds. Depths vary –

depending on riverbed morphology – from just two or three meters up to even eight or ten meters deep (Mandrell and Neal, 2012).

3.2.1 Implementation of Sand Storage Dams

In order to build structures that can retain rainwater in the form of often torrential flash floods, sand dams need to be built out of concrete. From the above numbers it becomes clear that the amount of cement needed is quite substantial. The sand dam around the construction of which participant observation was carried out was relatively small, and consisted of 50m of reinforced concrete. Considering the fact that communities that live close to the dam, and that will be the beneficiaries of the water, live almost without exception in mud houses, this is a quite substantial construction, and explains a commonly used nickname of SSDs, weight dams.

Figure 11 Flash flood as a result of several hours of rain upstream

3.2.2 Pre-Building Activities - Site Selection

It is the site selection process of SSDs that is the key determinant for the performance of SSDs. As stated by Maddrell and Neal (2012) “Building sand dams is not for amateurs. However you do not need to be a qualified engineer or hydrologist to build a sand dam”, and further by Ian Neal in interview, May 2015, “It is possible to make a bad design for a sand dam at a good site, but it is impossible to design a working sand dam at the wrong place”. A lack of maintenance, mainly caused by the fact that many dams are built in areas remote from towns, and more importantly roads, is reported to be one reason for underperforming dams .

Sand storage dams themselves are relatively simple structures with a robust and well-earned reputation for delivering what they promise: a source of drinking water sustained into the dry season, where previously there was none. Commonly mentioned limiting factors to underperforming in this objective are siltation, erosion of the adjacent banks, salinization, and toppling over due to undercutting. All of these occurrences are the direct result of poor site selection.

In order to understand how different types of knowledge influence the performance of SSDs it is important to understand the demands of SSDs on their direct physical surroundings.

The dam mentioned in the introductory anecdote in this chapter was built at an improper site. In this case, it was impossible to design a spillway in the dam that could both handle a peak discharge on one hand, and trap sufficient sand to fulfil its function as a sand dam. The reason for this is twofold. Firstly, the river banks had almost square shoulders in the cross-section. Secondly, and perhaps even more importantly, the river discharge was such that at peak levels the water level would be up to the highest possible point in that river.

In the situation of this happening, the discharge would be larger than what the spillway could handle, thus flowing over the riverbanks, excavating the banks around the wing-walls, and eventually eroding the dam. A possible solution for this is to enlarge the spillway, at the cost of retaining less sand and water. However, when calculating the dimensions of this enlarged spillway, the outcome is the wetted perimeter of the riverbed, thus effectively requiring no spillway at all.

Figure 12 The start of the gully that would have a sand dam in it only several hundreds of meters downstream

This example shows the consequences of inadequate siting. In the example described, the dam might very well have worked for years, and maybe it still does. As long as peak discharges have not occurred, it is very well possible that dozens of households benefitted from the months of work and organisation put in. Zooming out from the micro characteristics of this location, this particular example was situated in a gently sloping, relatively bare shrubland, with steep sides close by at distances between 2-10 km. This is very relevant in explaining the situation. The dam was not built in a dry riverbed, but rather in a very large gully, several kilometres long. A key attribute of gullies is that they expand because they are forced by overland flow to channel more water than what they have capacity for. These physical characteristics created an inherently unstable situation where a sand dam simply was not the appropriate technology, especially as it was a gully in a sloping shrubland with almost no undergrowth, lending itself to more rapid erosion.

Had there been a more V-shaped profile in the cross-section, with banks sloping towards the river, it would have been possible – although not favourable - to build a sand dam. In this case it would have been possible the keep the spillway low, but higher than the original river bed, and then raise the entire dam into the sloped banks.

SSDs depend for their functionality on a couple of factors. As indicated above, the estimated discharge is a crucial determinant for the design of the sand dam, and the spillway in particular. The discharge in a river depends on the cross-sectional profile of a river, the combined roughness co-efficient of that cross-section, and the height of the peak water level. It is in this last characteristic that a frequent problem arises. In Kenya very little reliable data on water levels is available, especially when it comes to the small seasonal streams in rural areas. Therefore local NGOs are required to find another source of information to make that crucial estimate as accurate as possible. The community that is part of the sand dam implementation are providing this information as part of a lager participatory siting process.

This interaction between NGOs and community proves valuable in establishing other key determinants in the siting, and consequently designing, process of sand dams. A sand dam for instance needs to be built deep into the dry river to make it as stable as possible, to withstand the violent currents that occur during torrential flash floods.

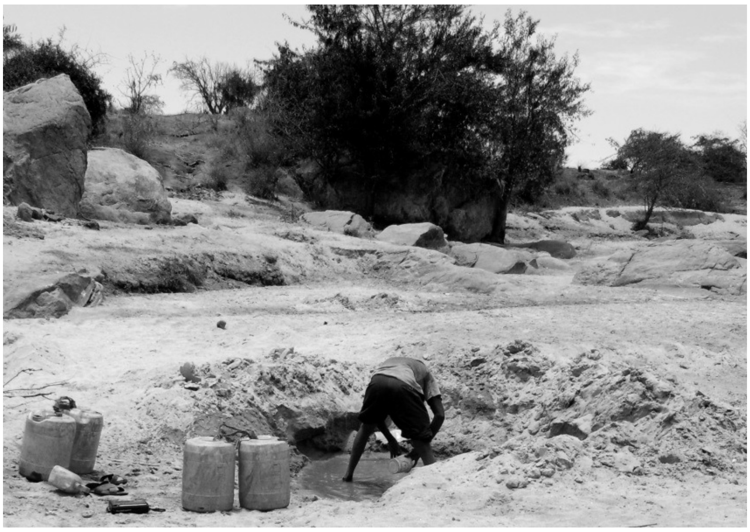


Figure13 Water extraction through a scoophole

Traditionally women use scoop holes to extract water out of sand. A scoop hole is a small hole, dug usually by hand into a river bed. The depth of the water can vary from less than one meter up to several meters deep. This depends partially on the morphology of the impermeable layer underneath the dry riverbed. Where rock formations under the sand are solid, watertight, and stable, the scoopholes lying upstream remain wet after the rains have passed longer than their counterparts lying upstream of less solid and watertight rock. The accounts of several generations of women are combined with other sources of knowledge specific to the situation, such as the presence of water-loving trees such as figs, to build up an idea of the sub-surface rock morphology.

Basic technology for obtaining this essential information about the dam-site environment was available in T1. Local implementing NGOs could probe with long sharp metal rods, for example, in order to determine, to the precision of a few meters, a suitable sand dam location. It is impossible for an NGO to get even close to such a selection of a possible site without taking in the knowledge provided by the community, however, who will eventually help build the dam and own the structure and regulate the newly obtained water.

Finding an impermeable layer underneath the dry riverbed depends for a large part on the accounts of the local community, while at the same time it is crucial to the success of a sand dam. If a dam is not well anchored onto an impermeable layer it will hold less water in the sand, and might get undercut by seepage and eventually topple over. A very deep impermeable layer also requires a lot more preparation in terms of digging, and an equal amount of extra material that needs to be collected, bought, and transported.

Local communities also hold accounts on the quality of water. Unfavourable scoopholes often hold salty water or water containing biological contaminants, for example. For a local NGO whose core business is rural water supply this is of course vital data, since scoopholes that are considered bad by the communities are often connected to aquifers that have naturally-occurring contamination.

Determining the peak discharge has proven to be key in determining a good site for a sand dam, and it also determines the dimensions of the spillway. A spillway in a sand dam is designed to let the river water pass through in a controlled manor, without eroding the river banks and ultimately encouraging the river to change course, or damage the dam. A spillway is therefore a vital part of the design process. However, in 2005 there was considerable debate among practitioners on how to design the spillway based on the estimated peak discharge (Nissen-Petersen; Mukusya (SASOL)).

Roughly three views on spillway design exist. Some claim a spillway should be rectangular, and as wide and high as possible. This should allow the maximum volume of water and sand to be captured.

As the peak discharge is estimated, the wetted perimeter for the spillway can also be estimated. The amount of water passing through a riverbed should pass through a spillway without causing damage to banks or without allowing the banks to overflow. However, within those guiding principles there is room to choose the width and the height. By making the spillway as high and wide as possible, a safe maximum of water is slowed down and captured. The risk here is that the current is slowed down to the extent that not only sand is trapped, but also the smaller particles in the water, resulting in what negatively has been nicknamed a silt-dam (Nissen-Petersen, 2011).

Another common design for spillway is the staged V-shape. Depending on the width of the dam, two or three V-shaped spillways are built on top of each other. The advantage of this design is that if the occurring discharge is only a fraction of the peak discharge, the water is still slowed down to quite an extent, but not so much that the siltation problem described above might occur. With a much wider spillway overarching the smaller one, the dam is still prepared to handle peak discharges without the danger of eroding banks and wing-walls.

Both designs require a compromise. On one hand, the dams cannot have a spillway that is too high since they might slow down the current too much and become silt dams holding little to no water. On the other hand, a lowered spillway might be a well-chosen design in the sense that it causes only the rough sand to be trapped, but by being low, only leads to a moderately thick layer of sand, thus holding less water.

In the light of communities in which the women walk several hours daily to collect water, it is apparent that the choices described above have to be subject to careful consideration. A third way of designing spillways, which avoids this compromise by both optimizing the current for maximum sand load, and avoiding siltation is to build the spillway in stages. Within this approach, after one to two rain seasons, the dam should be inspected for the sedimentation. If properly sited, the dam should trap about 20-30cm of coarse sand. This means a sand dam's spillway could be raised after only one or two years. In 2005, several sand dam manuals were available, all based on Erik Nissen-Petersen's work, and without exception they prescribed this last way of building dams, with an adaptive spillway. However, this approach to spillway design has not been observed by the researcher either in grey literature or in reality. This could be due to the heavier organisation and maintenance burden which it places on the usually limited capacity of local NGOs.

Figure14 A teenager carrying a typical 20 litre jerry can with water

Discharge and peak discharge do not only depend on the recorded or locally remembered water levels. They also depend on many other factors, that can influence the level of the water through the principle of adding "friction" to a riverbed. Friction describes here objects or characteristics that obstruct water, or slow it down, so that water levels are higher upstream than would otherwise be the case. Vegetation or irregular banks can cause this friction, or general roughness of the entire riverbed.

To summarize, site selection on local scale depends on many factors. A key determinant is water levels, and these are in turn influenced by a myriad of factors, such as the slope, bends in a riverbed, roughness, and general irregularity of the banks.

Peak water levels and discharge are not the only factors determining site selection (2013 SSD conference, Annex I). Other factors include the availability of building materials, the thickness of sand deposits, the stability of the banks, the shape and height of the banks, general accounts on water quality in nearby scoopholes, and the existence of nearby scoopholes.

3.2.3 Pre-Building Activities - Digging

The purpose of sand dams is to retain shallow ground water, not surface water, and in order to do so the sand dam needs to be set deep into the riverbed. In fact, sand dams need to be connected to an impermeable layer of solid rocks under the sediment in the dry riverbed. It is often not clear how deep this layer is, since prospecting is only done at a few spots in the middle of the riverbed, but for instance not in the riverbanks.

Figure 15 Digging with a pick axe

Figure 16 Digging with a hammer and chisel

To reach this layer the most labour-intensive activity in the entire implementation is undertaken: digging. Digging can take place for several weeks, up to two months, and is done by hand using pick-axes, chisels, and sledge hammers. Digging takes place in shifts of small groups of people, men and women alike, of about half an hour duration.

A second activity takes place simultaneously as part of the digging process. While the people with the pickaxes are loosening the soil centimetre by centimetre, another group empties the trench. This is done with shovels, buckets, and wheelbarrows. As the trench becomes deeper and deeper, this task becomes more and more challenging, as with the digging. Ropes and buckets are used when the trench becomes deeper than the reach of the people shovelling out the loosened soil, with another group hauling the soil from the deep trench. This is also a dangerous activity, since then a trench can be ten meters deep, especially in the places where the wing-walls of the dam are built. A further reason for the work slowing down as the trench becomes deep seems trivial, but is in practice a factor of concern. As the trench becomes deep, the dust remains in the air in the narrow trench, causing the turns between each group of diggers to become shorter and shorter, since vision and breathing are progressively hampered.

3.2.4 Pre-Building Activities - Collection of Materials

During the process of digging out the trench the process of collecting materials is often already underway. The materials for building a sand dam that need to be collected are sand, steel rods, stones, cement and most importantly water. Cement is the only non-local material used in the construction of a sand dam.

Accumulating the materials required for mixing is far more labour intensive. The cement in 2005 came from Nairobi, and could be transported by truck and wheelbarrow. However, the sand has to consist of coarse and sharp grains, which aren't always available on site. In my own experience, suitable sand was dug several hundreds of meters away from the site and transported by buckets or wheelbarrow towards the mixing spot. It requires a sharp eye and a steady shovel not to excavate loam or fine sand with the coarse sand.

Sand dams are not constructed from pre-shaped blocks like bricks, but rather from locally quarried rocks. This means finding a close rock outcrop and breaking pieces off by chisel and sledge hammer, collecting them, bringing them to the dam-site often several hundred meters away, and then piling them up again, to be sorted by size, at the dam-site. The larger slab like stones are kept apart to act as casing during construction.

Figure 1730 Transporting of collected stones towards the damsite

Figure 18 Constructing the reinforcements for the concrete

Reinforcement is done with barbed wire and steel rods, which come from regional hardware stores.

The most striking element in the process of getting the building materials ready isn't the rocks, the wood, the sand, or the cement. Paradoxically, it is the water. Since sand dams are very often built in rural, dry areas during the dry season, water availability is already problematic for drinking. The construction of a sand storage dam requires a lot of water, even more than a brick house would, since most masons want the mortar to be very thin so that it fills the spaces between the rocks.

Depending on the water-point, collecting water can easily take up a full working day. One example was that some women left the village at three in the morning, which due to wildlife, can be dangerous. They walked with three to four donkeys for several hours to a scoophole, each carrying four 20L jerry-cans, comprising a total of 240-320L of water-carrying capacity. They would leave early in the morning in order to have to water ready for the men, the building party, to be able to start mixing at around 9am. Having delivered the water the women would go for a second walk, taking up to another six hours. It is important to note that waiting for several days for it to be your turn to scoop water at scoopholes is not uncommon in the dry season. If this were the case, the entire building process could be halted.

In order to cope which such a contingency, a water tank can be constructed close to the dam-site. This water tank is built with the same technique of masonry as the dam, serving as an object of practice for apprentice masons, and a possibility to demonstrate their skills not only to the head mason, but towards the community as well.

Not all materials collected actually go into the dam. Where some NGOs prefer to build dams without casing, some NGOs use wooden casing. The latter method is a lot faster and is generally used for larger dams. Wood is available in these remote areas, but the quality of sawing machines is limited, resulting in planks that are rarely straight. This has some effects on at least the aesthetics of the dams and – since reputation appears to be a resource of value – it is one reason why other NGOs prefer to build without wooden casing.

Figure 19 Casing of the dam without wood but by using flat stones

In the latter instance, the large flat stones are separated from the irregular shaped ones, and used to construct the casing. These different types of stone have different places in the construction process, with large flat stones placed on the outside and irregular shaped ones on the inside.

3.2.5 Building a Sand Storage Dam

One reason for the size of the dams is the lack of accurate mixing tools for the cement. Although tumbling drums are available in Kenya, they are hard to transport and therefore hardly found in the remote, rural areas of Kenya where sand dams are built. Mixing of sand, cement, and water happens therefore by hand, in a puddle as close to the dam-site as possible, on a clean, clear, and crucially, level spot. The bags of cement are opened and the coarse sand is mixed. For different parts of the dam, different ratios of cement to coarse sand are used, varying from a 1:3 to a 1:4 ratio (Cement : Sand). The cement-rich mortar (1:3) is used for the parts of the dam that are in contact with the water to be obtained, such as the upstream wall or the spillway. The filling, the interior parts of the dam, are built with the 1:4 ratio

Figure 20 Mixing the mortar

mortar, to save on funds.

Since mixing of these ratios occurs on a sandy, or even loamy, soil on the riverbanks, it is never exactly possible during construction to estimate the exact strength of the resulting concrete, which in in turn influences the size of the dams. The width at the base, for instance, is often, but not always, correlated to the height by a ratio of at least 0.75 times the height of the spillway (Nissen-Petersen, 2006).

Sand dams are constructed by the community who are going to reap the benefits of the dam, and utilise and govern the newly acquired source of water. Men and women are part of construction and share tasks under the supervision of a mason appointed for several months to the dam site and the community.

Figure 2131 Forming lines during the filling process

After the digging process is complete and the bedrock underneath the river is reached, a layer of mortar is formed on the bottom of the trench. The mason, a necessary expert, and usually an NGO employee from within the same district, but not of the community, has to estimate the amount of mortar that can be processed on that day. This depends on the amount of available water, sand, rocks, and local labour.

Filling is a group activity in which two to three lines of people are formed, passing stones and containers of mortar from person to person until it reaches the trench. The mason stands over the trench while dropping the stones perpendicular to the stream of the seasonal river, into the trench. This requires careful precision and experience to ensure that the dam will be water-tight and strong.

Reinforcement occurs during the filling process. The steel rods for reinforcement are bent by hand to form squares as part of pillars, where they are connected by barbed wire knots. In order to be able to make knots of the barbed wire the wire is heated, so that the barbs can be removed by hand and the steel is slightly weakened.

Casing is the frame within which the dam is built. There are two dominant approaches to casing. Excellent Development carries out wooden casing, which is faster, but SASOL uses stone casing. When asked why this very difficult way of casing was not replaced with the wooden casing, the answer of the masons consistently was “Ours look better”, indicating a sense of pride from the masons in their highly specialised craft. The stone casing remains an integral part of the dam, while the wooden casing is removed post-construction.

For stone casing, large flat stones are placed on top of each other vertically with the perimeters touching. By balancing them out with sticks, the mortar that is holding them together gets enough time to dry. However aesthetically pleasing this might look, it does mean that the filling of the dam can only go in stages since the outside needs to dry first every time. The big advantage off course is that much less of the relatively expensive, and harder to obtain, wood is required, and that experienced masons have an opportunity to put their skill on display.

In the last stage of the building process, the upstream side of the dam is plastered to improve water-tightness with the 4:1 ratio mortar.

3.2.6 Maturing and Operation

In order for sand dams to function as intended a layer of sand needs to accumulate behind the dam. The common timeframe given for this is three to seven years. However, this depends entirely on whether the rain seasons follow a more, or less, regular pattern and – as demonstrated above – on the proper site selection. A dam is considered to be mature when the sand levels have reached the height of the spillway crest.

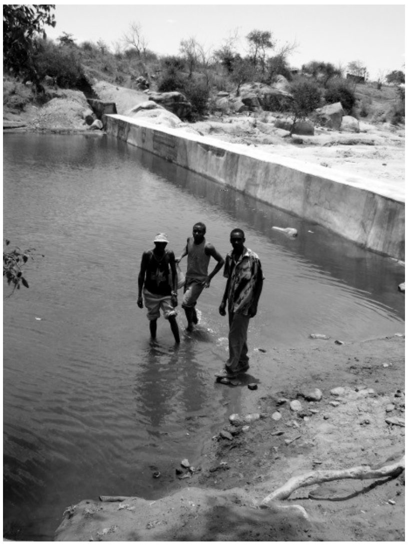


Figure22 A recently finished dam with still surface water

Figure 23 A well matured dam, with saturated sand

If a dam has not been properly designed according to the physical characteristics of its location, as described above, silt lenses might occur. Silt lenses are very thin layers of sediment, consisting of clay or loam, that are deposited when discharges are too low for the chosen spillway height to generate deposits of only sand. The effect of these lenses is a decline in water retention because the silt itself cannot hold much water, and because the lenses act as blockades in the deposited sediments, decreasing the flux of water towards a low pressure point in the sand, such as a scoop hole.

Extraction of the water occurs in several ways. The most common ones are simple, but effective, scoop holes. Scoop holes are holes in the sand, usually dug by hand, in which the water accumulates over a short period of time. Scoop holes are typically only a meter deep, however, at favourable locations some more permanent scoopholes exists which can be over five meters deep, taking the shape of a shallow well. Other means of extraction are rope pumps and treadle pumps installed on top of a shallow well, or even a tap on the downstream side of the dam. Shallow wells are dug by hand just like scoop holes but have a big advantage in that they provide better filtered water. Since a concrete lining is installed after the well is finished the water has to travel a much large distance through sand, and is thus cleaned and filtered much better.

3.3 Technology - T2

From interviews and content analysis during T2, very few significant changes become apparent. A limitation here of coarse is that the resources to conduct further field observation in Kenya were not available, but secondary sources suggest that substantial changes in construction or design have not occurred. A possible example of a substantial change in construction or design would be something which had an effect on scale, one of the main objects of interest in this thesis. For instance, if the sand dams had not been constructed out of stone-masonry, but rather out of metal dam-walls (as can be observed in the Netherlands) , which can be placed by construction machinery in a matter of hours, there could be an increased capacity for rapid construction. But this would not only have affected the speed with which they could have been built, and thus the scaling process, it also would have had a very large effect on how the communities organise themselves to manage water, since it is imaginable that the sense of ownership would be different after a three-month construction period, than after three hours.

Ex-Change, a student internship organisation whose goal it is to assist the local NGOs by coordinating student exchanges, has an extensive catalogue of student reports on sand dam technology. When looking at the reports from 2005-2015 (Appendix I) it can be observed that the issues that regularly come up over this decade in relation to building sand dams are very consistent. Key issues which persist include damage to the masonry, washed out stilling basins, and washed out wing-walls. These reports mainly refer to the actual construction process. The ones that deal with site selection consistently give the same recommendation on site selection processes, namely that it should be more systematized, more transparent, and better documented. Two or three reports that particularly deal with the build quality of the sand dams report that relatively large amounts are damaged, or have some sort of structural issues, but that of the dams with issues, most seem to be functional in the sense that they do hold sand, and that the sand does hold water. Interviews with SASOL director Munguti Muntinda and Josep de Trincheria, a PhD student of sand dam and rain water harvesting guru Erik Nissen-Petersen confirm this picture.

In 2013 there was a small sand dam conference held in Machakos Hotel, Machakos. Two of the NGOs under study, UDO and SASOL, presented their current state of affairs. The proceedings of the conference also indicate that there have been no substantial changes in sand dam technology from period 2005-2013. SASOL presented their site selection process, including the technical sheet of sand dam site selection which they use. This technical sheet was an exact replica of the one used during the field research period of 2005. This strengthens the observation made in this chapter that the technology of sand dams has not changed much over the last decade.

Some small, incremental changes can be observed, as well as indications for opportunities to change. In 2005, spillway height was unrelated to water levels or the height of the dam. The common practice was to build it 70cm from the river bed, regardless of the estimated water levels in the seasonal river, and independent of dam height. When dam height exceeded the 70cm spillway height, the issue that the dam was no longer able to efficiently hold water and sand became evident. At the time of field research, approaches to tackling this issue were under debate. Over the decade, this issue has been resolved and it is now common practice to relate spillway height to the maximum expected water levels. This consensus can be observed in the reports of SASOL and ED, especially the Sand Dam Manual produced by the latter in 2012. In 2005, cement had to be obtained from Nairobi, a labour-intensive process. By 2015, there was a cement production plant in the town of Kitui, reducing the labour demands of this aspect of SSD technology.

Another aspect of the technology which was raising issues in 2005 was the process of building spillways. As described in T1, it is widely recognised that any fixed height of a spillway is a compromise between having the right particle size of sand and maximising the amount of trapped water and sediment. As can be observed from interviews and email conversations with Josep de Trincheria, Muntinda Munguti, Ian Neal (formerly board member of ED), and Erik Nissen-Petersen, this compromise is still acknowledged, and how to deal with it is still under debate. All now agree on the possibility of building sand dams in stages, in order to solve this inherent problem. However, they do not agree on the importance of solving it. The implementing NGOs acknowledge that building a spillway in stages would further improve the performance of the sand dams, however they do not believe that the increase in efficiency would be significant enough to justify the added investment of time, money, and labour to implement it. From the interview with Josep, and email conversations with Erik and Josep, it is clear that they now have the firm belief that the sand dam technology cannot be justified if the spillway height is not increased in stages. This debate indicates an opportunity for change to occur.

This debate connects to a broader debate about the relevance of sand dams for RWH more generally. The implementing NGOs are keen to defend the contributions of sand dams to RWH, and take the position that sub-optimal performance is better than no RWH at all. Erik Nissen-Petersen and his PhD student, Josep de Trincheria, argue that sub-surface dams far outperform sand dams when the conditions for optimal sand dam construction and maintenance are not met. While this debate has been ongoing from 2005 until now, there has been an increase in the intensity with which it is debated, and the fierceness with which both sides defend their positions. This is most evident from email exchanges and interviews with Erik and Josep. Erik has referred to the implementing NGOs as the “sand dam Mafia”, for example, in a description of the current state of affairs in relation to SSD effectiveness. ED, meanwhile, has posted a response to public criticism from Eric about the poor economic performance of SSDs, in a YouTube video entitled “In Defence of Sand Dams”, in which they defend the cost-effectiveness of the currently existing SSDs.

3.4 Summary

In summary, although the debate on SSD technology hasn’t fully reached closure yet, in terms of implementation, no significant changes have occurred over the last ten years. Furthermore, there have been no changes in the design and construction of sand dams which are influential on the scale of implementation. These findings are derived from field research, including participant observation, at the start of the period under study (2005), as well as review of grey literature from the period 2005-2015, and interviews and email exchanges with representatives of implementing NGOs and RWH experts. The significance of these findings will be addressed further in Ch. 6 (Analysis) and Ch. 7 (Conclusion).

Chapter 4: Organisation

4.1 Situated action, anecdote #2

Some time in 2006, Emali Town on Mombasa Highway

Figure 24 A local community has had several attempts at spelling the name right in the upstream plastering of a sand dam. Ngome is Kikamba for "dam".

A rather desolate place which had probably been built to cater for the needs of long distance truck drivers in this otherwise empty stretch of land. Crouching on the side of the road, so as not to get scorched by the hot tarmac, I was waiting to meet JM. JM was the well-known and locally influential head of the NGO "Excellent Development". To me, his reputation had preceded him in the form of his name, which had been inscribed into the wet concrete of several sand dams. Whenever I would mention that I worked for him to local people, things I needed and wanted suddenly became very easy. However, I had so far not met this local celebrity. With me was his employee Mumina, who seemed to be getting increasingly nervous over the arrival of his boss. At that point I could not make out the reason for his anxiety...

A little while later, Mr. JM and me were driving along Mombasa Highway in his '85 Mitsubishi Pajero. The luxury of riding in a private vehicle on a relatively even and paved piece of road did little to overcome the nervousness that I felt. Sitting next to this stern, distant, and authoritarian character certainly was intimidating. Conversation was sparse, so I settled on observing the landscape through the window, which was gradually changing from flat and yellow plains, to hills with red soil and intermittent specs of green vegetation – a beautiful and refreshing change indeed! I was disrupted from my musings when in front of us appeared a large worn-down truck, slowly and painstakingly making its way up the hill on the lane to the right.

"These are the guys who are drying up our country!", said JM in a matter-of-fact way.

I quickly realized that this must be one of the infamous "sand-smuggler" trucks. On several occasions when I had been staying close to sand-dam sites, I had been woken up in the dead of night by the noise of heavy diesel engines. They would die off and come back to life about a half hour later – the next day large portions of the precious water-laden sand would be gone. To understand this phenomenon, one must consider the massive building boom which was going on at the time in Nairobi. With a soaring demand for concrete, came a rise in the monetary value of its raw material – sand.

While unable to stop these wrongdoings, at least we were able to overtake the truck on the fast lane, and continue on our way towards our intended destination, the town of Machakos. The next surprise came when after a short mumbling of "Let's check these guys", Mr JM took a sharp right turn – full speed - onto a sand-track. The sides of this narrow passage were lined with thorny shrubs and bushes. At that point I understood why he preferred the slim-bodied Pajero over the more common vehicle of choice, the bulkier Toyota Landcruiser. He wanted to be able to reach every one of these remote places by car – as opposed to the usual foot- or motorbike travel. Thorns clawing at the sides of our car, Mr JM went on to explain that we were going to visit a community which had been busy with the construction of their dam, but was possibly not making the expected progress.

After what had felt like hours, we arrived to a dry stream which to my eyes looked like a model site for dam construction. It had the right shape, a good width of about 50m, and suitable sediment. However, the trench that had been dug was barely half a meter deep. We walked across the river bed, the merciless sun of the dry season beating down on us. On the other side appeared a small congregation of the clay-wall, straw-roof huts which were typical for this area. A group of children seemed scared, and scrambled, probably not because of me, but due to the stern and determined looking man striding next to me. We finally met up with a group of locals consisting of five women and ten men. Even without understanding any of the words spoken, it was clear to me that JM was not amused. He went on in an angry tone for a while, then headed towards one of the huts, motioning me to follow him. Inside were about 25 cement bags of 50Kg each. Without further words, my superior heaved one of the bags onto his head and started towards our car. Needless to say, the villagers and I were supposed to follow suit. They did not seem happy about this development, but were apparently not going to get into any kind of argument against him. We drove back along the same narrow path, the car now close to dying under the extra weight in the trunk.

Figure 2532 Two members of a community with cement bags in front of the storage hut

I sat in the car – unable to speak with the thoughts driving in circles in my mind. Something had been going on which I did not understand. Were we not supposed to help these people to improve their livelihoods, by helping them to build means of water harvesting? Why did we now take the concrete from them? How are they to finish their dam?

In the back of my head I knew about the laborious and time-consuming process that this community must have gone through in order to be entitled to start such a project. It typically started with recognizing the advantages that a sand dam brings, by seeing it employed in another community. The villagers would then form a committee, which is “encouraged” to consist of 50% women, in accordance with the equality policy of development agencies. Filing an official request can be seen as a major hurdle for people who are usually busy with subsistence farming to ensure their survival. And then there had already been a substantial building effort in this trench, with all the sweat and blood that I knew it must have included. I finally mustered the courage to ask:

“Mr. JM, what has just happened?”

“Let me tell you something: I get at least ten requests per week from communities who would like to have their own dam. Each and every one of them is struggling to get their daily drinking water, carrying the yellow jerry-cans that you know already for hours on end – be it with the help of their donkeys, or on their bare forehead. The concrete that I can give them to build a dam is not enough for the demand I have. If a community does not work fast enough in to finish their dam before the rainy season, it is their problem. There are others which are ready to use the concrete.”

I was baffled. To him, this was clearly an issue of pragmatically allocating his scarce resources in the face of a huge demand. To me, my naive idea of how we would save the poor people in rural Kenya had been seriously challenged. However, I was starting to understand why people would look up to and admire, but also fear, JM.

4.2 Organisation - T1

In 2005 there were three implementing NGOs in Kenya relevant for this research, Sahelian Solutions Foundation (SASOL), Excellent Development (ED), and Utuooni Development Organisation (UDO). All four organisations have a grassroots history and operate in a similar fashion. The internal organisation of SASOL in 2005 will be described in detail, as well as their approach to developing sand dams with the participation of the local community. This will serve also as an example for how ED and UDO operated at that point in time.

The NGOs themselves confirmed in 2005 that they operated in a very similar fashion. Muguti Muntinda, one of the mobilising community members of SASOL, described at that time that SASOL wanted to be different but that that was difficult to achieve, as UDO and ED operated in the same way, doing the same thing, except in different areas. What they share is their vision that the sustainable development of these rural areas should focus on sub-surface water recharge through the participatory construction of sand dams. SASOL operated in Kitui district, ED in Machakos and Makueni, UDO in Machakos.

SASOL was registered as a local NGO in 1994. Although they didn't start off with a focus on water but also focussed on agricultural practices and schooling, their approach always involved rural participatory processes. At the point when they shifted their attention to providing water for local communities, they chose the sand dam technology as their main tool. This is not surprising given that this technology lends itself easily to the bottom-up approach that they already favoured. SASOL has, since this time, trained their own artisan masons through a master apprentice system, where the apprentice is recruited from a local community where a sand-dam is being constructed. A mason is assigned for the construction of a sand dam to a local community, where they stay and work with the local community, over a period of 3-4 months. If, during this process, young people (generally men) from that community show their talent and interest in the craft, there is a chance that they will be proposed by the experienced mason to the SASOL management for an internship where the apprentice will accompany the mason when assigned to the next sand dam and respective local community.

In 2005, SASOL employed five community mobilisers. These community mobilisers reached out to communities in remote areas more often than not using motorbikes, in order to make it through the narrow bush trails. The process of community sand dam development starts when a community files a request to the organisation for assistance with their water provisioning. SASOL operates on a demand-driven basis, so the initial request is critical. The community mobilisers seek out this community with one or more casual visits, in which contact is made and community leaders are identified. The mobiliser informs the community that the organisation is planning to assist the community, and the community should begin by forming a water user group. After a period of weeks to months the community mobiliser returns to guide the finalisation of a water user group, with a democratically elected board where gender equality is mandatory, and officially registers the community board as a self-help group with the local government. While SASOL is planning for the allocation of resources, such as making the labour available, a participation week is planned with this water user group.

During such a week, there is attention to health and sanitation issues in relation to water also, and building fences around water points such as shallow wells to prevent livestock from defecating in the water. However, the main focus of this participation week is to identify the possible locations suitable for a sand dam. Different techniques in this participatory process are used, such as transect walks, scenario analysis, participatory mapping. During this week, candidate locations are identified, as a result of both

Figure 2633 The result of a participatory mapping exercise where the community was asked to make a representation of their environment

community wishes and hydrological properties recognised by the community mobiliser. The community mobiliser can recognise these properties because of information provided by the community about their experience of the behaviour of their water extraction points into the dry season. For example, the women (often the older women), can indicate which scoopholes or shallow wells have the best water quality into the dry season and remain hydrated the longest after the rains have passed. Another example of how local knowledge is used in predetermining a selection of possible sites are community accounts on which trees and vegetation remain green the longest into the dry season. This knowledge is particularly relevant because the recharge rate of the scoopholes might indicate the vicinity of impermeable bedrock closer to the sandy service of the seasonal riverbed. Since sand dams need to be situated upon this impermeable bedrock, this knowledge is important to reduce the time and effort required to dig the trench in which the dam will be placed.

After this process, four to five possible sites may be identified.

Several weeks later the community mobiliser returns to the community this time accompanied by

Figure 27 These community members point out during a transect walk where water remains available the longest into the dry season

the technical engineer. In 2005, SASOL had one technical engineer, while ED did not make a strong distinction between community mobilisers and technical engineers. The board of the self-help group, the community mobiliser, and the technical engineer made the final decisions on the location of the sand dam. In this process, the environmental parameters such as the dimensions of the river bed, the estimated and expected water height, and shape of the river banks are measured, and a preliminary design is made. On the basis of this preliminary design, the community is advised to start digging the trench, and are provided with tools, such as chisels, sledge hammers and pick-axes. The final design of the sand dam is made at the SASOL office in Kitui, with a sketch of this design as a result. This design is handed to the masons, and the mason is allocated to the community until the sand dam is completed.

The self-help groups can be very successful in organising themselves, and managing the sand dam building process. UDO is an excellent example of this, as it was borne from Meka self-help group, in the village of Kola, Machakos district. This particular self-help group was among the first to try sand dam technology, as a member of the board of Meka self-help group, JM, had observed the technology elsewhere and attempted to apply it in his own village. Neighbouring communities observed the success of this experiment, and asked for assistance in replicating this sand dam technology, causing Meka self-help group to start functioning as a local NGO. Several years later the decision was made to form this local NGO, named Utuooni Development Organisation, with JM as director.

The field research period involved time in the financial management of Westerveld Conservation Trust (WCT), and Stichting Ex-Change, which has been a partner of SASOL since 2004. Records of funding requests to Ex-Change and WCT from the implementing NGOs were made on the basis of each individual dam. Ex-Change and WCT acted as an intermediary connection between the implementing NGOs and funding facilitation organisations such as Aqua For All, which serves as a lobbying and advocating organisation in order to facilitate funding, including from public bodies. An example of how this process goes, which is heavily dependent on philanthropic activity, is a personal experience with managing the funding request for a dam in Mavaindini community. The request was brought from UDO, and processed by organising a collaboration between WTC, Aqua for ALL, and Meppel Rotary Club. An event was organised with a school in Meppel (NL), by these collaborating organisations, to raise funds from the community of Meppel. The Dutch Ministry of Foreign Affairs met the funds raised by Meppel community, to double the amount raised. This money funded one entire dam in Mavaindini. The amount of requests from local communities to the local NGOs, far outstrips the capacity of the local NGOs to find funding for all of them, as can be seen from the introductory anecdote.

At this time point evidence for a drive to upscale sand dam technology can be observed among the implementing organisations. Again SASOL serves as a good example for this. In 2004, SASOL entered into collaboration with Acacia Institute, a Dutch private research institute focussed on groundwater hydrology, and developing projects for Dutch government institutions. TU Delft also joined this collaboration, via connections with Acacia. The collaboration identified sand dam technology as a viable solution to water scarcity in rural, arid areas, and committed to building 500 sand dams in Kitui district as a pilot of upscaling sand dam technology. ED and UDO, working in collaboration with WCT, had a more integrated approach to scale, with a heavier emphasis on combining multiple RWH technologies such as contour trenching, terracing, and tree nurseries with sand storage dams. They replicated this integrated approach in which sand storage dams played one part, albeit a crucial part, of this whole package.

4.3 Organisation - T2

Some aspects of the organisation of sand dam construction and management have changed over the past decade, but by and large things have remained the same. Consortiums and collaborations, such as those which were observed in 2004-2005, have become more frequent and more integral to organisational structure. However, the participatory approach of the local implementing NGOs, through a community-based site selection process, is still at the core of the organisational behaviour of the local NGOs.

The 3R consortium is an example of a collaboration between Kenyan and Dutch NGOs involved in RWH, which has developed on the last decade. It consists of SASOL (KEN), Acacia (NL), Meta Meta (NL), RAIN Foundation (NL) and Aqua for All (NL). It is centred around the concept of 3R, which is centred around the concepts of Recharge, Reuse, and Retention. This consortium is not a closed group, as other organisations can, and have expressed an interest in, becoming involved, such as NAGA Foundation (NL), the successor of WCT. This interest from other organisations is also an indication of how relevant collaboration between NGOs has become for the sector. All the organisations in this specific consortium subscribe to the 3R principles, and aim to apply them in their development of RWH technology. The main characteristic of the 3R approach is that it has systematized knowledge over a very wide spectrum of RWH harvesting technologies, and specifically organised the suitability of these technologies across the bio-physical properties of the potential landscapes into which they will be introduced.

There have also been new players to the scene, such as African Sand Dam Foundation, and NAGA Foundation, although the latter is based on the work of WCT, while the former is run by a direct descendant of UDO's founding member.

Although the practice of implementing sand dams still is essentially the same as it was in 2005, a future change in organisational behaviour might be expected. In an interview with former ED technical manager, Ian Neal, it became apparent that ED aspires to become much more a consultancy on sand storage dams. Rather than having their primary focus on implementation they are trying to become advisors to governmental organisations and local NGOs. The shift in organisational focus from being an implementing to a knowledge-based organisation can be further observed in African Sand Dam Foundation and ED's organisation of trainings for local-scale NGOs and local-scale governmental organisations from around the African continent, including those based in communities in Zimbabwe, Uganda, Ethiopia, and Somalia.

SASOL meanwhile wants to have a more business-like profile, as expressed in interview with their director, Munguti Muntinda, stating "We at SASOL should consider our experience in sand dams as a resource". SASOL has already given this ambition shape, by collaborating with the 3R consortium and setting up a Sand Dam Knowledge Centre in Tanzania in 2014. Organisations which collaborated with the implementing NGOs in 2005 encourage this shift within the NGOs towards becoming more business-oriented and knowledge-based. Ex-Change director Henk Haring expressed his view, in interview, that since the Dutch policy on international development is now much more focused on exporting the Dutch water management knowledge as a commercial product, donor/funding structures have also changed. For him, this means that the funds through international development are viewed as commercial investments in local organisations that have to become financially self-sustainable, with the aid of Dutch knowledge and water management expertise.

Marlies Batterink, 3R programme manager of Aqua for All, also expressed in interview her ambition to see SASOL become a more knowledge-based consultancy, that can commercially sustain itself. She also indicated her frustration in this process when explaining SASOL had undertaken a consultancy project, commissioned by a local government group in Somaliland, in which they were not designing and implementing sand dams, but training government and extension officers to undertake community mobilisation and site selection processes, as well as the technical designs of the sand dams. Her frustration arose due to the failure of SASOL to pursue the prospect of further consultancy assignments in the area, despite sharing tribal identity and culture (Kikamba) with the local community.

4.4 Summary

It can be observed from all organisations involved in sand storage dam technologies that there is an interest in upscaling and collaboration, which was present in 2005, but has intensified since. There are strong indications that this trajectory will continue, as observed through the attempts which have been made since 2005, and aspirations expressed by interviewees. Nevertheless, the organisational behaviour is still very much oriented towards the implementation of individual sand dams. In organising the implementation processes, the collaboration between the local NGOs and the community-based organisations, through the participatory site selection processes, is essentially at the core of their activities, and has remained similar over the past decade.

Chapter 5: Knowledge

From the previous two empirical chapters, the essential role in sand dam implementation of local knowledge has already been established. In this chapter, the contribution of local knowledge and scientific knowledge to upscaling will be examined more closely.

5.1 Situated Action, Anecdote #3:

Nov 2006, PW's Landcruiser – the "non-speaking car"

I was in the car with former artist, now acting developmental engineer, PW, and a film team with full professional equipment. When I first entered the car, PW introduced his vehicle as "the non-speaking car, except for me". Apparently he did not appreciate discussions with students very much!

I had previously heard of him, and was fascinated by his life story. Having grown up as son of an agronomic consultant in Tanzania, he had seen the destructive capacity that large scale changes to ecosystems could have**.** He became an artist working in Amsterdam, using African soils as raw materials for his paintings. Later in his life, he became an ecological activist in Africa, focussing on the design and implementation of revolutionary techniques of rainwater harvesting and geo-engineering. His expertise was mainly in trenches to capture rainwater. Selective planting of trees would increase canopy cover, which would in turn cool down air in such a way that you could increase rainfall. He had gained substantial publicity with bold statements on TV: "Give me enough bulldozers and I will bring back the snow-caps on the Kilimanjaro". He had said such things in a time when boreholes and bigger pumps were considered the answer to combat droughts, and when there was no public debate on climate change whatsoever. He was also said to have refused donor money on several occasions, because there were conditions attached to it. To me he was a visionary and a rebel in his field, certainly a person I was looking up to. I wanted to learn from him and had so many questions... But, since I was in the non-speaking car, I sat in the back, silently trying to hide my excitement.

How did I end up in this situation?

MW, PW's ex-wife and Netherlands-based coordinator of Westerveld Conservation Trust, had arranged for me to meet him and the film crew. They were supposed to shoot a documentary on sand dam construction in Voi region, at the foot of the Taita hills. Since I had spent enough time in the area dealing with this topic I was considered the local expert, and was supposed to show them the sites to film. After hours of silence in the car, I finally thought of a relatively unproblematic question, and asked if he was excited about the airplay and publicity that this documentary would bring with it. "MW knows that we will do what she wants us to do anyway", was his brief answer. Apparently he considered it a waste of time and distraction from his actual tasks at hand. Nevertheless we journeyed on – in silence.

Our travel was abruptly stopped when we came upon a military checkpoint, a rather intimidating sight, with sand bag fortification and grim, machine-gun-carrying soldiers. One has to know that this was a time of extreme political imbalance in Kenya, with presidential elections coming up, and violence between supporters of the opposing factions breaking out on an almost daily basis. The situation had gone so far, that at some stage the entirety of Uhuru slums had been cut off from contact with the rest of the country by military roadblocks.

The car came to a halt and a young soldier stepped up to the car, demanding from PW, with all the authority that the situation issued him:

“Passport!”

PW answered in Swahili. The one word which I could make out was “Hapana!”, the most explicit way of saying “No!”

Seemingly unmoved and calm, he wound the window back up, put the car in reverse and slowly backed off for about 100 meters. He then drove back to the same officer and uttered in a very controlled manner:

“You may try again.”

“May I please see your passport, Sir?”

After the checking of documents and a short conversation on the destination of our journey, we were allowed to drive on. At that point I thought to myself: Why did he do this? Was it really necessary to demand respect when the situation is as menacing as this? I realized that this was a man who is used to working completely independent, who had devoted his life, marriage, and health to the goals he was striving for. A lone ranger who had no patience for anything that was not beneficial to his cause. And most certainly he was the uncontested captain of the non-speaking car…

5.2 Knowledge - T1

Sand storage dam design and implementation has not always attracted scientific attention. During the field research period, little to no peer-reviewed literature was available. When undertaking site selection processes for requested sand dams, the available literature consisted of a handful of MSc. Theses and Erik Nissen-Petersen's manuals on sand dam design, written in the 1980s, all of which is considered "grey" literature, as it was not subject to peer review (documented in Annex I). Reflecting on this period, Ian Neal, the former technical manager of ED, remarked, "If you understand Erik's spillway design principles, you are a better man than me", indicating the scarcity of applicable literature to the practice of sand dam design.

The literature available during this time period was also focussed on the performance of sand storage dams individually, rather than an entire network of sand storage dams. This reflects the need which was felt at that time to validate the technology of a sand dam. For the local NGOs and communities, there was clear and visible evidence that around the sand dams, vegetation cover increased and water points remained hydrated. However, there was no scientific data to confirm this phenomenon, or indicate that the phenomenon was connected to sand storage dams. It was strongly felt by the local NGOs that having scientific "proof" confirming what they and the local communities observed, would make it easier to find more funding, and in this way achieve a larger scale.

Another example of the drive to validate this technology in order to achieve more structured funding and possibly a larger scale is the REAL project from 2004. This project, entitled Rehabilitating Earth and Arid Lands (REAL), had its primary focus on another RWH, namely contour trenches, but entailed sand storage dams as well. This project was carried out by WCT in collaboration with TU Delft, and strived to systematically measure and document changes in water levels in the sub-soil.

Figure 28 A package of "Sportsman" cigarettes folded open. The design of a sand dam and its measurements hand written on it

From my observations, working conditions were unfavourable for systematically recording the experiential knowledge of the local NGOs, and also applying existing knowledge. For example the office in SASOL, during this time period had only one computer, shared between a regular staff of four people. The community mobiliser and technical engineer's visits to the communities would often take several weeks, visiting around ten communities per trip. The conditions during these relatively long field trips, staying in tents without electricity or light, were not favourable for systematically documenting the conditions of seasonal rivers, selected sites, or consequent dam designs. I observed the presence of a level surveying tripod, which could have been used to enhance the precision of the estimates of expected discharge, by measuring the angle of the river bed. However, this tripod was considered too cumbersome to be transported to and from all the local communities in the remote areas.

The last observation considering the role of knowledge in 2005 is in reference to the first introductory anecdote of this chapter. The observations made on the main character in this anecdote, PW of WCT, indicate a stubborn and autonomous attitude. Pioneers such as PW were at the centre of many of the organisations involved in sand storage dam technology in 2005, but their experience and knowledge was hard to make transparent and accessible. This is confirmed by the initiative of MW of WCT, to offer internship and thesis opportunities to students from Van Hall Larenstein (NL) and TU Delft (NL), often with the objective of making the intuitive knowledge from the experience of founders like JM of ED/UDO, and PW of WCT, explicit and accessible. Of the struggle to document field practitioner knowledge, MW said “If they are not there anymore, their great knowledge will be lost”.

5.3 Situated action, Anecdote #4

5th April 2007, A27 towards Breda

MW and me were on the Dutch motorways when heading south on a grey April morning towards Heijmans BV. Headquarters, located in a town called Rosmalen. Literally, but quite surely also figuratively speaking, it was clear that MW was behind the wheel, as had become the usual. As a 67 year pensioner executive from HR Dept. Ballast Nedam Nederland and driving force behind a small but significant NGO called Westerveld Conservation Trust I felt relatively uneasy that I wasn’t really sure what the objectives of our visit exactly were. All she had said was that it was a really big one.

With MWs unintimidating posture, unpretentious presence, grey hair, and soft voice she could easily be mistaken for your favourite cookie-baking aunt. However I had learned to respect MW’s gentle, soft smile in meetings as a forebode to what most negotiation experts would characterize as “check-mate”. With that in mind I was still on the fence on whether I should ask about the precise nature of our mission, or rather sit it out and wait for her to take initiative in conversation.

I had just graduated on the subject of Environmental Impact Assessment for sand storage dams for WCT, and had somehow obtained the loosely defined position as an assistant for MW, doing legwork for her in seminars, presentations, and workshops and helping with writing and filing funding proposals. I didn’t really have many job opportunities, so I was glad MW had kept sending me forward to these seminars and possible donors as, to me still surprisingly, an advocacy expert. Judging from the fact that the call for these meetings was usually coming no more than a day or so in advance, it was maybe my improvisational skills, rather than my in-depth understanding and expertise, that had miraculously earned me that title.

On the subject of short notice, this day was no exception. Heijmans BV, a very large Dutch construction company, had shown interest in a long term relationship with WCT where not only finances, but also expertise was to be brought into the rain water harvesting projects in Southern Kenya. And I had again been informed about one and a half days in advance of my role to play as technical expert. “Can you present our latest findings in layman’s language Coen?”, had been the question on the phone at 01:00 in the night. “And while you’re at it, I’ve just sent you the latest from TU Delft’s assessment of the REAL pilot project. Make sure all that’s in there too.” And so, while a proper day and night rhythm seemed to have plummeted on my priorities list even faster than the stock markets in the US on the news that very morning, I realised what was bugging me: it was the reports from TU Delft and what was written in them. Or rather what wasn't in them.

I had been guiding students for WCT while they were undertaking their BSc. Or MSc. internships or thesis fieldwork, and in doing so I have had the chance of observing MW determining the research proposals of students and even influencing the research agendas of departments of universities like TU Delft and VU Amsterdam. And most of the endeavour, if not all of it, had been aimed at validating the technologies such as sand storage dams and contour trenches, as employed by WCT to restore groundwater levels in rural areas. What was bugging me was that MW didn't seem to have any real interest at improving the technologies. As apparently had been the case as well with the reports that had caused me a sleepless night.

Staring at my empty coffee cup as if to squeeze the last bit of artificial clarity out of it, I asked – as casual as possible – about the reports from TU Delft that I had been reading that night. "All I got from those models is that the groundwater levels around the dams retreat much slower in the riverbeds than that they would without the dams…what's so new about that?"

What followed was an answer – accompanied with that almost invisible, but significant, gentle smile - that surprised me at the time and eventually took months, or maybe even years to fully sink into my tired, confused, and naive brain.

"Nothing."

Silence. A smile again. Changing lanes.

"For us at least."

I was thinking, so then why did I stay up all night to integrate this in my presentation if we already knew all this? Apparently I thought very loud, because MW continued:

"You and I know that the dams and the trenches work. The farmers, villagers, and their communities know they work. The local NGOs know they work. We all do because we have done it. We have built them, dug them, planned, or even designed them. We have seen the areas around it re-green, and we have seen tomatoes, bananas, and maize, where only cassava or just the illegal charcoal-burning used to be possible. It's not about that. It's about THEY know the dams work," she said pointing with the index finger out of the windscreen repeatedly, the way only angry mothers can when the children have been playing football in their Sunday-bests.

"Look", she continued, "The money is in the western world and the western world likes numbers. So we give it to them. Numbers are only believed by companies if they are made up by scientists."

I put my coffee cup down in the cup holder. Although I had observed MW often when she was on one of her rather sharp, but usually spotless runs-of-reasoning this was pretty much the first time I was at the far end of it. Companies?, I thought, how do companies suddenly come into the equation? We were a foundation…loosely consisting off a pensioner, a bunch of unemployed volunteers, some students, and in the field an artist who doubles as an engineer in thermo-hydrodynamics. We were as far off from being a professional organisation as the Netherlands was appearing to be likely to become a desert that rainy morning. And we were certainly not a company.

“Do you really think WCT is really going to make a difference in Kenya? With only a handful of projects?” Although I was never really sure, this was likely to be a rhetorical question. Why was MW bringing in companies? And – I knew her as a very passionate hard working supervisor – why did she suddenly appear so sceptical about what we were doing?, I wondered.

I had learned about development processes in my lectures very much as processes that become sustainable through participatory processes. The idea was always that the supposed beneficiaries participate in planning, design, and implementation, through which a sense of ownership is achieved, and with that a greater chance for prolonged effective management and maintenance. And all this magic was then supposed to be facilitated by local organisations such as Water User Groups and NGOs, to protect us from making green revolution-esque mistakes. Or at least, that is what my textbooks said. It didn’t say anything about companies, only that they are good at making GMOs, profits, and usually a mess.

MW steered the red Volvo station wagon that now had become our mobile board meeting room, to take our exit off the motorway. We were almost there.

“What we are developing is a product. We can’t save the whole of Africa..”, and then she mumbled, “I am not sure we should even think we should.”

And then, more firmly: “See it as open software. We are developing a product. We already made sure it works. Now we are making sure the rest of the world understands HOW it works by letting the boffins have a chew at it and write it all down. We are not looking to patent it, we want the knowhow to be for free. As a free off-the-shelve product, for everybody to sell as their own. Just like you can download a free piece of open coded software and use it to write something you can sell again.”

Companies. Products. Patent. Open software. By this time my drowsy mind was reeling. The image of the classical development worker had been subject to erosion for quite some time, but this was different, this was a landslide starting to move. Resistance seemed futile and I decided to play along: “If you are actually talking about an actual packaged sellable product, why aren’t we patenting it and selling it ourselves? At least we will have an influence on whether it is done in a right way.”

Traffic lights.

“It’s not about WCT, about you, about me, and not about money. Not yet, at least. You know small projects aren’t sexy. Small dams aren’t sexy. Engineering companies want big dams too show. Not too speak of politicians. That’s where the real budgets are. And they are being wasted on vanity. At the same time we are only getting 20,000 charity dollars here, then 40,000 dollars there. Dam for dam, pilot for pilot. That is all good, but it goes too little, too slow, too late. Amboseli is drying up, Tsavo East already is as good as desert. The glaciers on Kilimanjaro are only going to be there for – what?- one or two decades?

The NGO’s like SASOL and Excellent can only do so much. They are very good at working with the communities, and they understand how to build the trenches and sand dams. But if we really want to stop deserts from growing, the scale is not nearly enough. For that we would have to work 100 times larger. You would have to work at watershed scale. And NGO's like Excellent or SASOL simply don't have the capacity to do that - large engineering companies can do that! And engineering companies don't like small projects, they like big projects. So they build big, prestigious dams. Now we both know most large dams cause more problems than good. So, if we are gonna do this at a large scale we need those companies, and we need to prevent them from building one big dam. We need to give them the building blocks to make their large sexy scale projects and show off. But then with hundreds and hundreds of small dams. All tied together on watershed scale."

Whether it was MW's vigorous honesty or my lack of sleep I don't know. But I knew that I should listen and not talk. Because, although at the time to me this all sounded very alien to me, I knew something about her logic was right. Besides, we had reached the Heijmans BV. parking lot, and I was hoping that whatever else was coming from MW, it was coming now. Before we would leave the car and enter this meeting.

The red and white boom closed behind us.

MW, luckily spotting a parking spot at the furthest possible end of the lot, said: "Look. It's very simple. We have an expanding desert and a technology that can reverse that process. It just needs to be done by many, many more.

We let the universities make it scientific on how it works. Then we make sure the consultants show off with their GIS maps and what not kind of hydrological wizardry – and we let them plan and organise ahead. 1000 dams ahead. And for so many projects, we need a lot of trained local NGOs. Kenyan engineers who speak still the languages of the villages from where they came from."

With the engine switched off the silence was deafening. Could she be right? Was it possible to get enough funding to work at such a scale? And was making all that we already know into scientific data really so important for that? And, even if all that was possible, then still…would small local NGOs be capable of working next to large international companies with complicated knowledge systems?

"So. You asked what the general idea was for this morning?", she smiled.

I realised I had never thought of all this in this way. And that probably would be a lot of work to even try and answer these questions. I also knew I had about eight minutes left before I had to start my presentation.

5.4 Knowlegde – T2

Over the past decade, the amount of knowledge about sand storage dam technology has increased, while the accessibility has also improved, and both grey and scientific literature have expanded. The number of publications on sand dams increased after 2005, largely due to the collaboration of TU Delft and Acacia Institute with the local implementing NGOs. Research on single dams and single dam design has largely come to a close. Even the research on spillway design has reached a consensus about the preferred approach, that is, to build on the spillway incrementally. Research has moved on to socio-economic effect studies, and publications about hydrological effects of networks of dams can also be observed. This includes research based on integrating different technology for RWH, and adopting a watershed-scale approach.

Grey literature has also moved on from the limited availability in 2005. When looking at the manuals produced by ED in 2010 and 2014, it can be observed that practical, applicable, but very detailed documents have been produced on how a sand dam is sited and constructed. The 2012 publication of RAIN Foundation is similarly detailed and precise, but also displays an emphasis on knowledge beyond single dam site selection. This manual takes account of addressing parts of watersheds and seasonal rivers with suggestions about spatial planning throughout that seasonal river or watershed for multiple dams. For example, it indicates that at the end of the catchment where the seasonal rivers are widest and have less gradient, sand dams are less likely to be cost-effective, whereas closer to the foot of the hills, where sediment is more likely to be coarse enough for water retention, sand dams are more likely to be an appropriate technology.

The literature produced by ED is an indication of their organisational ambition to be sand storage dam pioneers, and move towards being a knowledge-based organisation which also makes knowledge transparent. This ambition is also shared by the other implementing NGOs, as indicated by Muntinda from SASOL, who, when interviewed, said “We [SASOL] want to implement less, and be considered consultants”.

Compared to 2005, another change with regard to knowledge is witnessed with the appearance of the 3R Principles. They display an integration of a broad range of RWH technologies, and do so in an implementation-oriented form. The 3R Principles are described in publications commonly referred to as the “3R Books”, published by Dutch NGO/consultancy Meta-Meta, under the flag of the 3R Consortium. The publications provide a comprehensive source of information on RWH technology which is accessible for implementing NGO teams, including when in the field, and also establishes a common terminology, facilitating easier exchange of knowledge and understanding.

The publications from Acacia Institute are based on the 3R Principles, and apply those principles to spatial dimensions using GIS maps, and available data on biophysical conditions, such as slope, soil type, vegetation cover, etc. In the reports, this information is combined with different strands of RWH solutions, and their respective requirements from their environment, as systematized by the 3R Principles. The results of this landscape-based approach are, in the terms of Acacia Institute, the "3R Suitability Maps", and they are intended to assist implementing NGOs in their decision-making process. During the interview with Lieselotte Tolk of Acacia Institute, she indicated that the Suitability Maps were based on a data grid from remote sensing too coarse to precisely do site selection for RWH structures such as sand dams. Thus, despite the introduction of this new and helpful knowledge for implementing NGOs, community knowledge is still crucial for proper site selection in SSD implementation.

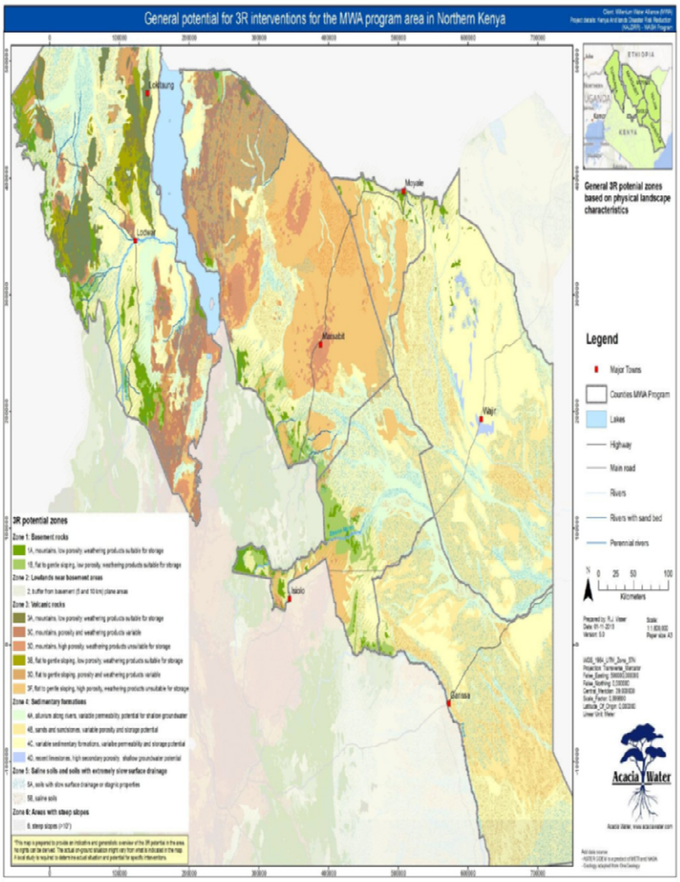


Figure 29 Rain Water Harvesting suitability map,

Between 2014-2015, the researcher attended eleven webinars, as described in Ch. 2, concerning RWH, ground water management, and water point mapping. These webinars were attended by a varied audience of practitioners from implementing NGOs, consultants, and academics. In each webinar there were three or four speakers, presenting the findings from their latest reports, or their daily practice in the field. These webinars opened up new ways of knowledge exchange, which had not been possible in T1, connecting people from different locations, areas of expertise, and time zones. They were open to anyone, and attendees could ask a question in an open chat box. These questions were addressed by the moderator, who posed them to the respective presenters. Attendance was usually between 30-50 attendees, of which roughly one-third was usually active. The webinars generated new connections between different implementing NGOs. For example, during one webinar a presenter from an implementing NGO in India, and another presenter from an NGO in Uganda, both logging in from their field offices, recognised the similarity between each other's practices, of which they had not been previously been aware.

5.4 Summary

When comparing the role of knowledge in 2005 and 2015, and how it contributed to the scale of sand dam implementation, we can observe an increase in availability and accessibility of both peer-reviewed and grey literature. However, I have observed little evidence of the application of this knowledge in the practical site selection processes of SSDs...

Chapter 6: Analysis

In Ch. 3, 4, and 5, data has been presented from the three domains of interest to examining scale, according to the conceptual framework in Fig. 3: Technology, Organisation, and Knowledge (Ch. 1). This information will be analysed in this chapter by aggregating information into plausible generative processes from which hypothetical explanations of the observed scale of sand dam implementation can be developed.

6.1 Aggregating Information into Plausible Generative Processes

6.2 Technology

In terms of technology, the sand dams are relatively simple. Even a damaged or poorly designed dam improves water availability in the area. From the perspective of local communities, sand dams are therefore perceived as successful, they are trusted and highly demanded. On the other hand, sand dams are not sophisticated enough to attract the interest of international engineers, which hinders their involvement in a bilateral organisation, and consequent additional funding.

There is not enough specific hydrological data available for the local areas. This can cause NGOs to build oversized dams, an inefficient use of resources. At the same time, the lack of data makes the involvement of local communities essential, since they become the best available source of knowledge. The sense of ownership by local communities is further increased by the fact that they dedicate significant amounts of their work and time to the construction of sand dams – it takes three months to build a sand storage dam, and all the work is done by hand.

The areas where the dams are built are remote and hard to reach, which brings additional complications to the site selection process, limiting its transparency and the possibilities of supervision. The remoteness of the locations also makes it impossible for the construction to be divided in stages (i.e. gradual spillway height increase).

Table 1: Generative Processes in the technological domain

Generative Processes in the Technological Dimension		
	Process	**Outcome**
1.1	Low-tech solutions are not perceived as interesting by international engineers.	• It is difficult to get them involved in a bilateral organisation with additional funding.
1.2	Sand dams are built in areas which are remote and difficult to reach.	• Spillway height is not increased in stages. • The supervision and transparency of site selection processes is limited.
1.3	It takes 3 months to build a sand storage dam and everything is done by hand.	• Large time and labour investment results in a higher degree of ownership.
1.4	There is not enough hydrological data available.	• Participatory process is therefore mandatory. • Local communities need to be involved in site selection process. • NGO's build oversized dams.
1.5	The technology of sand dams is not very sophisticated.	• Even damaged and poorly designed dams perform suboptimally but still provide water.

1.6	Sand dams are perceived as a successful technology by the locals.	• Local communities trust the NGOs who facilitate the construction. • The demand from local communities for sand dams is high.

6.3 Organisation

The international linkages have grown stronger in recent years, as former participants of student exchanges (TU Delft) and the Westerveld Conservation Trust projects in Kenya became employees of international organisations. Still, most of the organisational responsibilities for the building processes are executed by local NGOs, whereas the Dutch organisations take mainly the role of facilitators and advisors.

The remoteness of the areas where dams are built makes monitoring more difficult for both local and international NGOs. For the local organisations, time constraints are another factor limiting proper monitoring and evaluation. On the other hand, these NGOs generally enjoy trust and support of the local communities, and there are therefore not forced to change their way of working.

The link between the local NGOs and the communities is crucial for the acceptance of the interventions and the creation of ownership. For this reason, tribe language is used during the participatory processes. At the same time, however, this decreases the transparency of these processes towards the donors, who only receive reports in English.

Funding has a significant influence on the organisation structure. Average price of a sand dam is around $20,000 – 40,000. It is however difficult to predict the exact price for a dam in terms of how much water it will deliver per dollar, since the hydrological data is scarce. Furthermore, the dams bring benefits other than drinking water, for instance the long term effects on the ecosystem, whose value is not immediately visible and does not translate into revenues. It takes 3-5 years for a sand dam to start operating regularly, which makes these structures even less attractive for the investors.

Another series of consequences originates from the fragmented nature of the funding. Resources are commonly provided for the construction of one dam, which closes the opportunity to think and plan on a bigger scale (e.g. interaction of multiple dams within the same watershed). Similarly, the monitoring and evaluation is realized per project rather than from a long term systemic perspective. This is reinforced by the fact that the small donors who are most typically involved in the financing of dams tend to be less strict in their requirements for project reporting.

Local NGOs have to compete for the same funding, which hinders cooperation and sharing of knowledge or data. Another reason that limits their collaboration is the fact that they operate in different geographical areas. However, joining forces would open bigger funding opportunities.

Table 2: Generative processes in the organisational domain

Generative Processes in the Organisational Dimension		
	Process	**Outcome**
2.1	The community is involved in the organisation in the long term.	• The sense of ownership by local community increases.
2.2	Local NGOs are limited in time.	• The monitoring and evaluation system is not properly organised.
2.3	Sand dams are built in areas which are	• It is hard for the Kenyan NGO

	remote and difficult to reach.	management and Dutch NGOs to unravel the black box of participatory process.
2.4	Dutch NGOs take mainly the advisory role.	• The implementation is left to their Kenyan counterparts. • The cooperation is less intense.
2.5	The demand for sand dams from local communities exceeds the supply from local NGOs.	• There is no necessity for local NGOs to improve their way of working.
2.6	Funding is mostly provided by multiple small donors.	• Small donors have less likely stringent monitoring and evaluation demands. • Insufficient monitoring and evaluation decreases the self-learning capacity of the local NGOs.
2.7	Funding is mostly provided for a single dam.	• Regarding one sand dam as one project makes it less likely for local NGOs to plan several dams ahead.
2.8	Local NGOs compete for the same funding sources.	• This lowers the likelihood of them working together, learning from each other or exchanging data.
2.9	Dams have both drinking water and ecosystem service function.	• It is hard to quantify the gains per financial investment.
2.10	It takes 3-5 years for a sand dam to mature.	• The result of a financial investment cannot be seen immediately.
2.11	Participatory process is conducted mainly in local language while reporting happens in English.	• Lack of transparency towards donors.
2.12	Sasol successfully trains and educates its people even at Dutch universities.	• They cannot always keep the skilled and well trained people in the organisation.
2.13	Former highly educated Sasol personnel are employed in local government structures.	• This creates a loyal regional network.
2.14	Former students involved in Ex-Change and WCT projects have currently `key' positions in international organisations.	• Local NGOs have stronger linkages to international NGOs.
2.15	There is a spatial divide between local NGOs and their respective districts.	• There are fewer opportunities for collaboration. • The chance for big institutional funding is lower.

6.4 Knowledge

Local NGOs that work on the problem of water scarcity were often started by individuals. What these pioneers have in common is high energy and motivation. However, these personalities are also typically less good in communication and knowledge-sharing, which makes their skills hardly transferable. Thus, by relying on these individuals, knowledge can eventually get lost. This is further reinforced by the fact that local NGOs have no need to document their work. It was only the success of the dams and new funding opportunities that started the process of systematization of knowledge on both technology and organisation used. These manuals are however rarely used by the local workers.

Table 3: Generative processes in the knowledge domain

Generative Processes in the Knowledge Domain		
	Process	**Outcome**
3.1	The local initiators of rainwater harvesting technologies are all characteristically against the grain – pioneers.	• Organisations started to exist. • These personalities are less fluent in knowledge sharing.
3.2	Initiators have internalised their craft but it is difficult to make this craft explicit.	• A lot of knowledge has actually been lost.
3.3	Implementation of sand dams by local NGOs is perceived as successful by the local communities.	• Local NGOs do not perceive the need for scientific validation of their ways.
3.4	On a large scale, rainwater harvesting contributes to climate change adaptation.	• This argument proved to be an effective means to gain funds. • This potentially sounded promising but proved to be frustrating for local NGOs.
3.5	Practical literature as manuals or guidelines was developed and improved.	• These publications bring funds but they are rarely used in practice.
3.6	Local NGO staff is trained in Dutch research institutes.	• They can act as knowledge brokers between local NGOs and international research communities.
3.7	Dutch NGOs do not spend enough time in the field.	• This hinders the co-creation of knowledge.
3.8	Internet became available.	• Knowledge exchange through webinars is possible.

6.5 Scale

Generative processes about the scale achieved can also be observed, from the generative processes aggregated from the empirical information regarding the three domains, technology, organisation, and knowledge.

In relation to the domain of technology, the technology of SSDs has stayed largely the same. Thus, it can be asserted that the technology has proven itself replicable, fitting with Seelos and Mair's characterisation of scaling as replication (2014). Further, Seelos and Mair describe the scaling process of replication as taking place when resources are scarce, which is consistent with the situation described over the period 2005-2015.

From the domain of organisation, a process of organisational closure can be observed, as the organisational activities have not changed over the period 2005-2015. This further supports the characterisation of scaling, among RWH organisations in Kenya, as replication. The consistency in the findings related to organisational activities and technology over the period of 2005-2015 indicates a robust relationship between these two domains.

In relating knowledge generation and integration to the observed scale, there is an observable effort from both the Kenyan and Dutch NGOs to achieve a higher degree of knowledge integration, especially regarding site selection processes. However, there doesn't seem to be a robust relationship between the organisational efforts and ambitions regarding this integration, and an observable outcome. The utilisation of local knowledge through the interaction of local NGOs and CBOs has an essential role in constituting the replicative pathway of scaling which has already been observed. However, Seelos and Mair also provide another characterisation of scaling which specifically refers to scaling through knowledge transfer. The data in this research does not support a claim that this process is taking place, because the interview data indicates that a lack of knowledge transfer has been experienced by interview participants. Meanwhile the high level of replication indicates that utilisation of potentially transferred knowledge has scarcely occurred, especially among implementing organisations.

Another characterisation of scaling by Seelos and Mair, that of scaling as increased productivity, which largely refers to increased efficiency, could also possibly be taking place. In order to support this, it would be necessary to show that efficiency has been achieved by mitigating disabling mechanisms to scaling. However, the information which has been collected is insufficient to support this claim.

Chapter 7: Conclusion

In this thesis I set out to investigate the sand dams of South-East Kenya and the NGOs that implemented them over the last ten years and the scale by which they have been doing this. In this chapter, first a topical and a methodological conclusion will be presented, followed by a thematic and methodological discussion and recommendations for researchers as well as practitioners.

7.1 Scale of Sand Storage Dam Implementation

From 2005 until 2015, there has been a steady increase from 30-50 sand dams per year to 100-130 sand dams per year. This process of scaling can largely be categorized as a numerical increase predominantly occurring through the process of replication.

At the core of this replicative scaling process lays a robust relationship between the organisational effort undertaken by the Kenyan NGOs and the desired outcome of these efforts being well performing sand storage dams in the Kitui, Machakos and Makueni districts. The term robust relationship refers to the fact that the NGOs "have been doing the same with the same result" for over a decade.

When further investigating what caused this steady increase in scale and how this has happened through replication, I find that the inherent properties of the technology of sand dams require specific organisational effort. This manifests in the process of site selection for sand dams in seasonal rivers. The performance of a sand dam in terms of yield of water depends for a large part on its location. The location of a sand dam is mainly determined through hydrological data, for instance the maximum discharge in a seasonal river, which is very rarely available from reliable official sources. Therefore – in order to determine a proper location for a sand dam and design it accordingly to the properties of the location – the implementing NGOs have to obtain this data from another source: the local communities for which these dams are being built. The site selection process is facilitated by the implementing NGOs and the CBOs through intensive participatory processes. The intricate local knowledge about variables such as soil types, erosion processes and dry season water availability is obtained from the local community, often in local language.

The strength of the local NGOs lies in quite a special combination of skills. On one hand, it is the ability to locate, design, and construct a functioning technical structure – in essence a civil engineering structure – with limited funding, time, manpower, and tools, and based on limited available hydrological data. On other hand, obtaining the data necessary for the tailor-made designs demonstrates the ability of local NGOs to reward the trust put into them by the rural communities by engaging in often unpredictable and intensive participatory processes. In other words, the local NGOs need to be partly community mobilizers and facilitators in participatory processes, where at the same time being technical civil engineers. It is this specific combination of skills displayed by the local NGOs that is responsible for the success of the sand storage dams in Kenya.

I conclude that the organisational closure conditions implementing NGOs have reached are largely due to the participatory site selection processes being the core causal mechanisms that helped secure the observed steady increase of scale.

7.2 Methodological Conclusion

In this thesis, I described the phenomenon of the scale of sand storage dams in Kenya, and explained this scale with the help of the notion of causal mechanisms and organisational closure competencies. I applied these concepts along the lines of the example set in the methodology demonstrated by Seelos and Mair (2010; 2014), where they try to find explanations for the scaling process of the Aravind cataract hospital in India. In this section, I reflect and draw a conclusion on how this methodology has helped me to arrive at the conclusions stated above.

Much literature dealing with scaling or upscaling processes tends to view upscaling of a certain practice as a process of change, and mostly as a positive development. Therefore, there is a tendency to look for "success" factors. This in turn is often driven by the question of whether the determinants for the "successful upscaling process" can be applied or even replicated into other similar processes.

Although there is often an ideological motivation behind this, to have an intervention that is a promising solution to a certain problem, fitting with the scale of the problem, these attempts do not always help to us to explain and understand how a certain scale of solution came to be. This is because the predetermined search for success factors might overemphasise the importance the researcher adheres to enabling mechanisms – the observable processes at play which cause a desired effect – and underemphasize what Seelos and Mair termed as counterfactuals. These are the causal mechanisms which are not enabled, or even have a disabling effect: "That which might have occurred and have had a desired influence on the outcome, but didn't happen." (Seelos and Mair 2014)

In order to explain my view on Seelos and Mair's notion of mechanisms and counterfactuals, I offer a metaphor of a person using an escalator. The person, in this example, makes an effort to go the next floor by walking up. However, if the escalator is one that actually moves in the opposite direction – down – the result might very well be that the person is perceived as stationary. If in this case I would view the actual direction of travel – up – as a success, I would be hard pressed to find success factors constituting this, since there would not be a success to investigate. Chances are that I would not have an interest in investigating the research problem. However, if I would start my research by observing a stationary person walking in a certain direction without the notion of success or failure, I would find the open invitation to start investigating which counterfactual – in this case the escalator moving in an opposite direction – was at play and *how* it was contributing to a situation of stability: the person being stationary.

In similar fashion, I conclude that without the methodology applied in this thesis, I would not have come to the conclusion that the scale of sand dams in Kenya is largely caused by a situation of stability: the robust causal relationship between the consistent and consequent efforts of the local NGOs and the desired outcome, i.e. functional sand storage dams. Were I to view upscaling as a process of change I would have also looked for changes in technology, organisation, and knowledge, and not have found them, turning my thesis into a rather disappointing exercise. But looking at a certain scale and asking how this scale can be explained, I was able to draw conclusions about a situation of stability and how this stability has come to be.

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Annex 1: Grey Literature and Websites

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