NTNU – Trondheim
Norwegian University of
Science and Technology

Development of a Rainwater Harvesting System for the Village Ngumbulu, Kenya

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Preface

This report presents a master's thesis performed in the field of product development in 2014 at the Norwegian University of Science and Technology.

In this project the focus has been on water, rainwater harvesting and developing products in marginalized communities. A rainwater harvesting system with both tangible and non-tangible parts have been developed in the village Ngumbulu in Kenya, where the initiative is still ongoing.

Hopefully, the project has planted some seeds that will germinate in the future.

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Part 4 - Solutions

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Abstract

This report shows the development process of a rainwater harvesting system for the village Ngumbulu in the mid-eastern Kenya. The report is sectioned into 5 parts:

Part 1 – About

This part gives an overview of the project itself with goals and methods set to use in the development process. The focus lies primarily on participatory design and to develop the product in a sensible and sustainable way.

Part 2 - Mapping

The mapping part gives a thorough introduction to the area in question showing existing water sources and the current situation. Thereafter a user analysis is performed showing their demands and desires towards the final product. The primary needs are related to cheaper alternatives, local production possibilities and knowledge about rainwater harvesting in general. Resources available and technological aspects of rainwater harvesting are also presented to get a complete overview before developing concepts.

Part 3 – Development process

This is the actual concept development part where several applicable options are explored and evaluated. Concepts were divided into two separate systems, one for those with iron sheet roofs, and one for those who have not. The final concepts were thereafter prototyped and tested in Ngumbulu.

Part 4 – Solutions

The final solutions are here explained and elaborated on, both in terms of function and usage but also with directions of how to manage and bring the solutions forward. Installation and manufacturing manuals have been made and presented on the proposed solutions.

Part 5 – Assessments

This chapter sums up the previous chapters also giving reflections and possibilities for the future. In this chapter there is also a toolkit for use in similar projects relating to the actual conduct of development projects in marginalized communities.

Abbreviations and vocabulary

Beneficiary	Receivers of development assistance
The developer	Referring to the author of this report
Development	When regarding the rainwater harvesting system, the process of creating a product. Not to be confused with national or regional development as used in "developing countries".
Field trip, field study	Referring to the trips to Ngumbulu area in October 2013 and April/May 20014.
GDP	Gross Domestic Product
KES, Ksh	Kenyan shilling 1 USD = 86.2 KES 1 NOK = 14.4 KES
NDC	Ngumbulu Development center
NGO	Non-Governmental Organization
Ngumbulu area	Common name for the villages, Ngumbulu, Tinganga, Kikuyuni, Kithito, Kath-angathini, Mombuni and Mekelingi.
Ngumbulu	Usually referred to as "Gombolo" in Norwegian media
NOK	Norwegian Kroner
NTNU	Norwegian University of Technology and Science
PD	Product Development
PDS	Product Demand Specification
POI	Point of Interest
USD	United States Dollar
User	Villagers, NDC, Aid in Action
Water point	Source where water can be found

Part 1 - About

1 Introduction

Products are greatly influenced by goals and limitations in the development process. This chapter introduces the project giving an overview of mission, task list and the overall process of development. The fist section presents the report itself and how to read it.

1.1 For the reader

This report is written to provide both reflections and directions to parties involved in rainwater harvesting in marginalized communities. The report itself is an extensive summery of the work performed in the village Ngumbulu in Machakos county, Kenya, but contains lessons learned which may be useful in any similar area, in any product development project.

The report is divided into five main parts each with a theme reflecting the contents:

Part 1 – About

Part 2 – Mapping

Part 3 – Development Process

Part 4 – Solutions

Part 5 – Assessments

For Ngumbulu Development Center the most relevant sections may be the following: 3.3, 3.4, 3.5, 4.1, Chapter 5, 6.4, 6.5, 6.6, Chapter 9 – 12 and chapter 15. As printing is expensive it may be limited to: Chapter 9 – Chapter 11 and Chapter 15, which contains explanations of the solutions, installation, manufacturing and management advice.

For the complete picture it is recommended to read the entire report.

The report has utilized some contents from the project work of fall 2013. Even if most of the previous work is rewritten where this is of dominant factor the blue line at the top of each page turns green. Where only small bits are utilized the line is purple.

Directly underneath each chapter headline there is a notation of what issues in the task list is touched upon: "*Approaches issues # & # in task list"*

The reader should also be aware of some running personal reflections by the author in the report. The reflections are however made obvious not be confused with the body text.

1.2 Project mission and goals

The main mission of this project is to investigate and develop alternative water sources for the people in Ngumbulu. Moreover, in the work with this it is of critical importance to focus on how to perform the work with a sustainable and realistic approach. Meaning that an approach of participation from the actual beneficiaries and users must be upheld throughout the project.

More specifically the aim of the project is to create a solid base for rainwater harvesting in the area and develop good solutions that are anchored in the community's needs and desires. It is therefore an objective for the developer to get a closer understanding of Kenya and the area of Ngumbulu, both on a technical, economic and a social level.

The overlying goals of the project may be identified as:

1. Create a project that is in correlation with the literature of designing and developing in marginalized communities as well as taking into close consideration the actual needs of the public.

2. Develop sustainable rainwater harvesting solutions for the people of Ngumbulu to increase their access to water

To attain the goals the following approach was made:

- Gain knowledge from existing literature on how to design and work with developing countries.
- Using development methods from several sources and alter the methods to be most beneficial for the project.
- Perform two field trips to the area to see and learn the actual conditions and to identify the overlying issues.
- Develop close relations to the local development center (Purpose for Life foundation) and performing activities in cooperation with them.
- Investigate how the people in Ngumbulu deal with the current water problem and how it influences their daily life. This was primarily done using questionnaires, both direct and themed, in cooperation with a native speaker.
- Explore the Ngumbulu area in so called rapid rural appraisal (RRA) to identify facilities, possibilities and opportunities for local production and value creation in the society.
- Investigate how the community may be included in the development of a rainwater harvesting system to ensure long-term commitment and sustainability.
- Perform the steps in the project task list to develop a realistic and sustainable rainwater harvesting system.

It should be mentioned that the developer sees the project as an opportunity to empower and hopefully inspire locals, and to leave a positive impression of foreign students in the area.

1.3 Limitations

To create a sustainable and long-term project in a developing country requires time, resources and great local knowledge. None of which is possible to fully exploit during the short time period a master thesis offers. To mention a few influential aspects there are politics, cultural beliefs and traditions, limited and complicated supply chains and great financial limitations. Therefore the project aims to sowing seeds for future development in the community and create a positive effect on the utilization of rainwater harvesting technologies in the area.

1.4 Task list

MASTER THESIS SPRING 2014

FOR

STUD.TECHN. MAGNUS KILE ANDERSEN

Development of a rainwater harvesting system for the village Ngumbulu, Kenya

Climate change has resulted in more extreme weather conditions in Kenya with heavy seasonal rain twice a year. The region is subjected to large amounts of precipitation in the rain seasons followed by severe droughts lasting several months. Especially in rural areas inhabitants spend much time and effort in covering their daily water demand. Easier access to water leads to more focus on important tasks such as education, development and labor, which primarily women and children will benefit greatly from.

The assignment is conducted in cooperation with Aid in Action and Engineers Without Borders Norway. Aid in Action is a Norwegian NGO established by Anne Louise Hübert after a visit to a Kenyan village. Aid in Action aims to provide relief and assistance to sustainable development for disadvantaged people in, amongst others, Ngumbulu, Kenya.

Former investigations revealed opportunities in rainwater harvesting, thus this thesis will focus on developing such technologies in the small-scale segment for personal use or for a smaller number of families. The aim is to develop concepts for collection and storage of rainwater as an addition for the families. In addition, other possible solutions shall be investigated to increase the villagers' access to water in the challenging drought periods. Proposed solutions are to be sustainable, with long-term planning and be adapted to local needs with the possibility of local production and value creation. The work is a continuation of a project from fall 2013 by the same name.

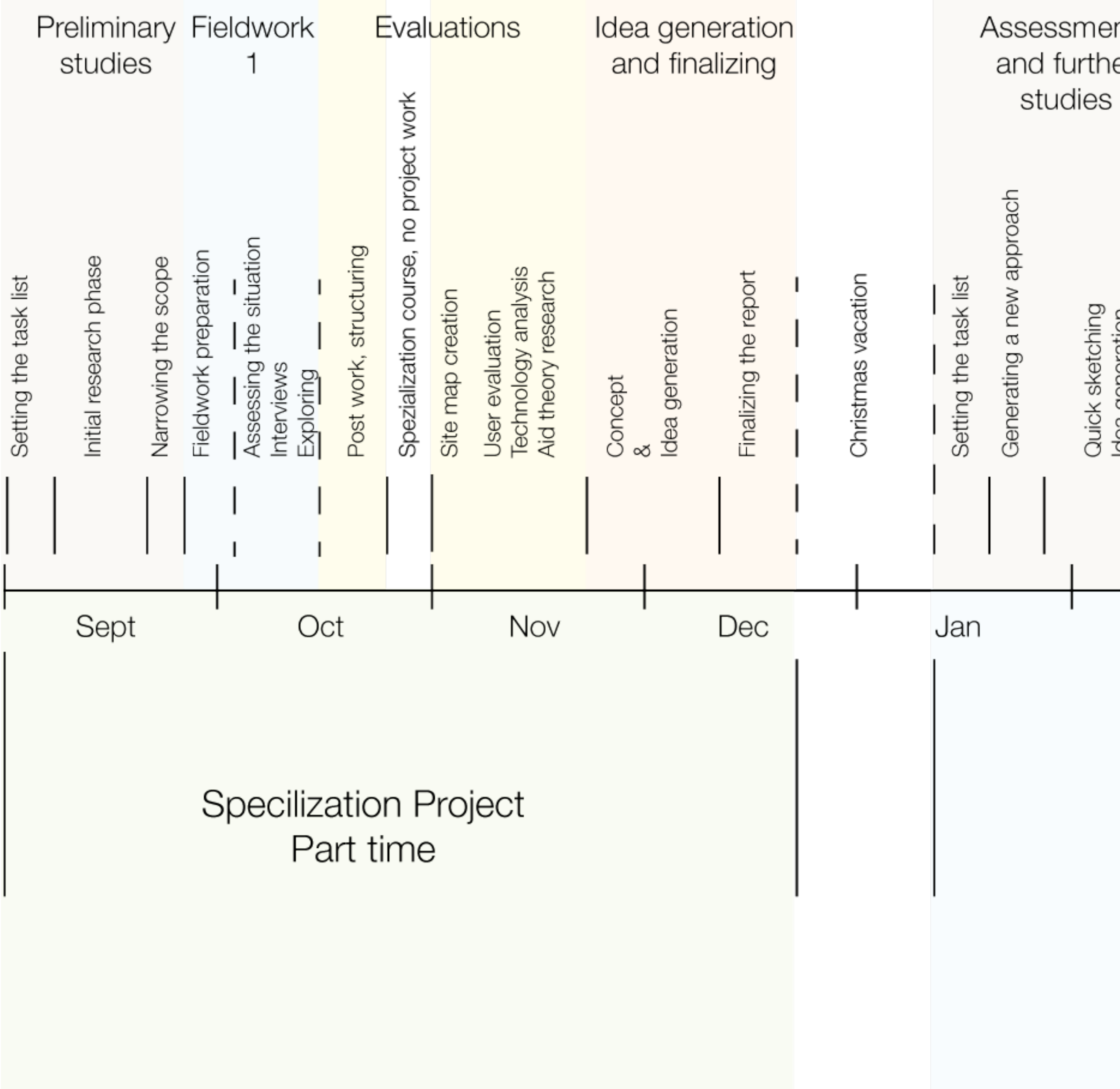
The assignment includes the following tasks and items:

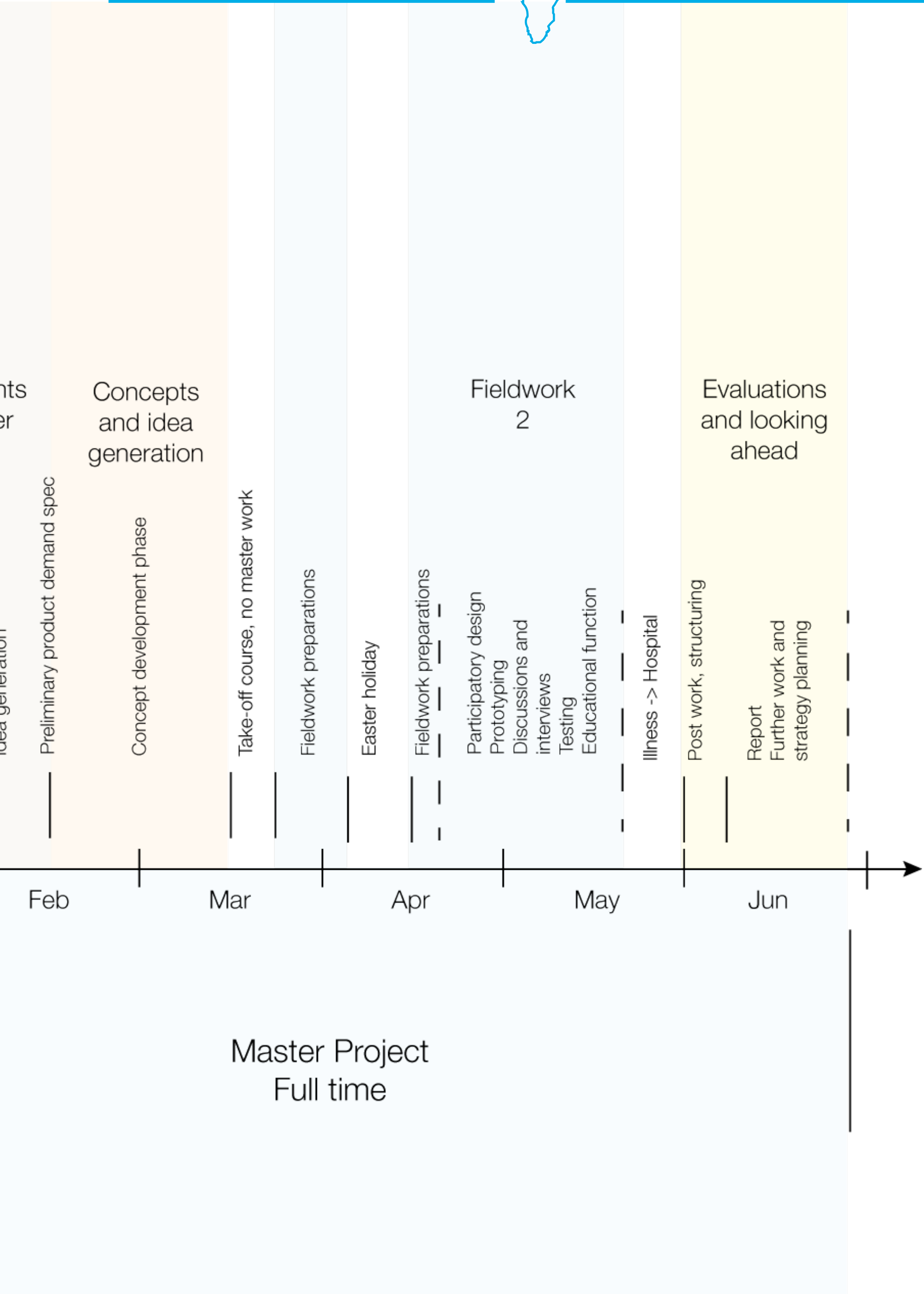
1. Analysis and description of the current solution (product, technology and market.)
2. Needs analysis for a user demand specification
3. Elaboration of existing technologies and availability of components and materials
4. Development of a product demand specification
5. Development, presentation and evaluation of alternative concepts
6. Selection and detailing of the best concepts(s)
7. Construction and testing of necessary prototypes
8. Evaluation and presentation of results and methods, particularly in regard to continuation of the project.

The assignment shall actively utilize PD – journal

1.5 Project timeline

The project timeline includes relevant stages in the project with the two fieldtrips as the highlights. Both project work (2013) and master thesis (2014) is included for overview purposes.




Concepts and idea generation
Fieldwork 2
Evaluations and looking ahead
Preliminary product demand spec
Concept development phase
Take-off course, no master work
Fieldwork preparations
Easter holiday
Fieldwork preparations
Participatory design
Prototyping
Discussions and interviews
Testing
Educational function
Illness -> Hospital
Post work, structuring
Report
Further work and strategy planning
Feb
Mar
Apr
May
Jun
Master Project
Full time

2 Development approach

Often product developers are encouraged to be radical in their solutions to develop an innovative new product. This is a good approach in western countries where the competition is high and the demand for something “extra” is always present. While designing and developing products in marginalized communities and developing countries, the approach should be rather different. The history of aid shows plenty of examples where lack of situational understanding lead to unsuccessful projects. A prime example is the Turkana Fisheries Development Project by the Norwegian Agency for Development (Norad) in 1980, where a 1.1 million dollar fish freezing facility was built to create an alternative source of income for the villagers. Nobody consulted the Turkana people, who don’t eat fish, and the facility was never started due to high energy demands and non-sustainable supply chains (more, similar stories may be found at “www.admittingfailure.com” by Engineers Without Borders). The stories tell us that what works in one place may be wrong in another, leading to an approach where the situational understanding and communication with beneficiaries must have the highest priority. The innovation and creativity may serve its right in finding smart, cheap and incremental solutions fitting the real needs of the local community.

2.1 Holistic development

In the work with developing a personal rainwater harvesting system, a holistic approach giving long term, sustainable results was strived for. The holistic approach takes into consideration all the elements that influences product development in the framework of humanitarian aid and development.

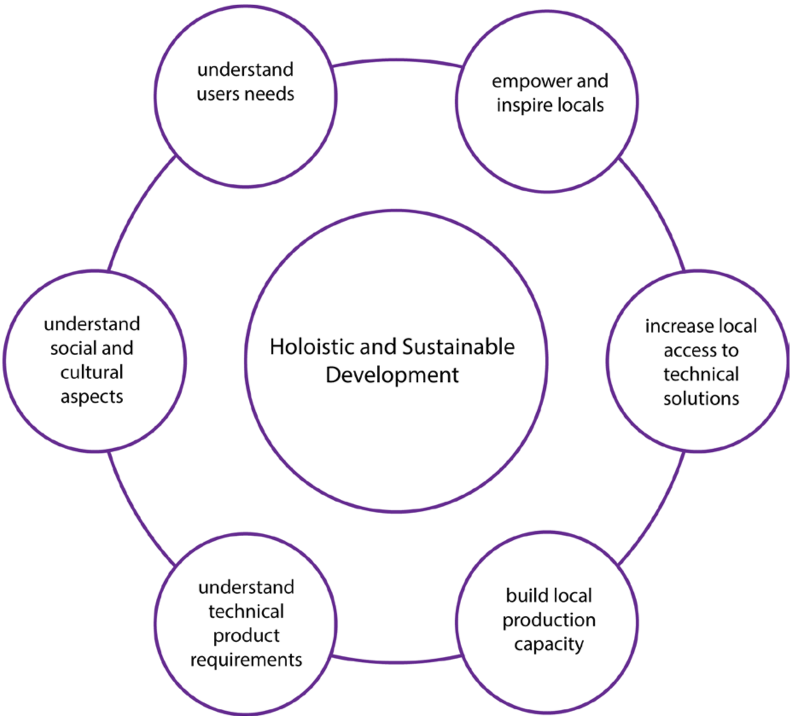


Figure 1 Holistic and sustainable development

Figure 1 shows what aspects are of central importance in this project:

- Understand users needs
- Empower and inspire locals
- Increase local access to technical solutions
- Build local production capacity
- Understand technical product requirements
- Understand social and cultural aspects

2.2 Participatory design

As one of the goals of the project has been to add value to the local community, participatory design has been an important factor. Participatory design focus on designing in close cooperation with the beneficiaries over a longer period of time to include, consult and empower the user. This is an important aspect of ensuring long-term commitment. Hussein (2011)[1] identifies the benefits in a design participation ladder where the highest level of participation empowers the beneficiary to use design methods to develop solutions that can improve quality of life.

To utilize the strengths of participatory design in this project has been a priority, however difficulties in achieving this were experienced. The main reason was the lack of time spent with the user, and the share knowledge the developer was able to obtain on the subject. To succeed with participatory design one must first identify the problem together with the user, then the user must be taught design skills which later must be used in real settings to raise their self belief in their own abilities. This is time consuming and demands a high level of skill from the developer. However even a low level of participatory design is useful to make the beneficiaries aware of the process, they feel included and will recognize the solution when they are later encouraged to invest. This was especially the aim of the second fieldtrip to the area, as much time was spent with the staff of the Ngumbulu Development Center to create a sense of ownership of the project.

In essence this project is primarily for the people of Ngumbulu and must therefore be anchored in the ones who are to bring it further towards implementation. All final results were therefore achieved in cooperation with the staff, and the developer gave away no solutions on beforehand. This ultimately lead to a stronger self belief in the staff as they towards the end of the stay came with several new ideas and reflections showing insight and ownership to the project.

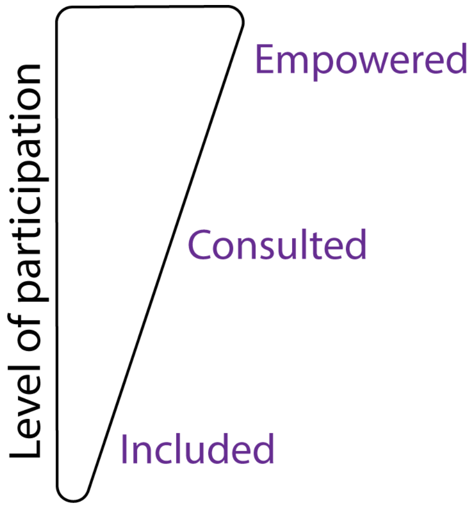


Figure 2 Participation ladder

Efforts were also made in making the villagers a part of the project of rainwater harvesting. The developer conducted several interviews with the people including all surrounding villages (Tinganga, Kathangathini, Kithito, Kikuyuni, Mumbulu, Mekelingi and Ngumbulu) to inform and discuss the matter of rainwater harvesting. Finally, a community meeting was summoned where solutions and concepts were shown encouraging the visitors to share their views and ideas. Due to short time, the fruits of this community meeting are somewhat unclear, however people gave immediate positive feedback.

2.3 Product development methods

Developing a rainwater harvesting system for the marginalized community in Ngumbulu requires a model that allows for a large degree of user centered design. Step-vise evaluation of concepts and ideas based on users needs is very important to ensure participation and empowerment of the locals. Also, the chosen model must allow for a great deal of intuition based on human interactions. The model that was seen most fit was the Stanford developed "Hunter model"[2] which follows the path shown in the illustration below

The arrows represent the direction the development process takes in the pursuit of the best idea, where each circle represent a generation of new ideas followed by a reasoning converging towards the best solution determining the new direction. The illustration show that the supposedly good ideas determine the starting direction, however the model encourages to break away from the path most traveled and allows for new approaches to the problem. This fits this project well as there are a number of existing solutions on rainwater harvesting, but it seems that new thinking is required for the Ngumbulu area as none of them are utilized here. To supplement the model several of the tools presented in the PD Hans Hildre[3] and the IDEO HCD (human centered design) toolkit[4] have been used.

"The aid business has a long history of projects backed by sponsors willing to invest millions in the future of poor societies. Their intentions were, and are, mostly good, but a number of initiatives have failed due to the lack of situational understanding by these good Samaritans. So as a mechanical engineer student completely new to development in marginalized areas it felt at times like balancing on the edge of a cliff. After all, you are touching people's lives…" - Magnus Kile Andersen, 2014

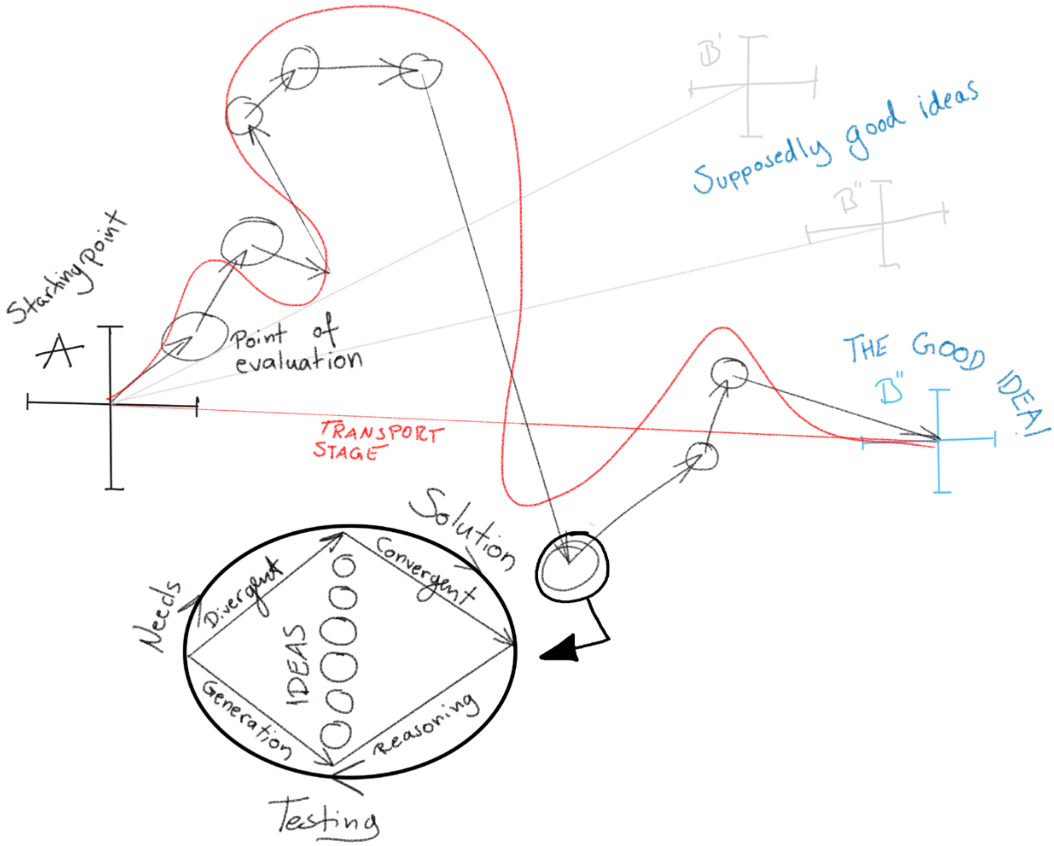


Figure 3 Hunter gatherer model


NGUMBULU
DEVELOPMENT
CENTRE

Part 2 - Mapping

3 Background- and general needs analysis

Approaches items 1 & 2 in the task list

Before initiating in product development in marginalized communities it is of crucial importance to have a wide situational understanding. This chapter gives the initial introduction to Kenya and Ngumbulu with focus on the current water situation in the village.

3.1 Kenya, an overview

Kenya, officially the Republic of Kenya, declared their independence from the United Kingdom in 1963 and is situated in the eastern part of Sub-Saharan Africa with the Equator nearly splitting the country in half. Kenya shares borders with Tanzania, Uganda, Ethiopia, Somalia and South Sudan with the Indian Ocean providing a 500 km coastline in the east.

Economy

Giving an overview of the Kenyan Economy is a rather complex affair leaving a trail of corruption and low infrastructural investments threatening the nations long-term position as the largest East African economy. The reality is a staggering 40% (2008) unemployment rate with approximately 47% (2005) of its population living below the poverty line. This is partly a result of inequalities in distribution of wealth with the top 10% of the population earning 44% of the national income, whilst the bottom 10% earns less than 1%[5].

Kenya is also largely reliant on loans and grants given by organizations and in bilateral agreements. As an example, Kenya is currently (2013) ranked the sixth biggest borrower of World Bank loans in Africa since its formation in 1945, with a cumulative total of 9.8 billion USD. Looking at loans granted during the past five years Kenya is the third largest borrower and has since 2008 alone received a total of 620 million USD indicating the country's heavy reliance on the institution[6].

The political scene

In the 2013 presidential elections the question of governance was left between two major coalitions, the Jubilee alliance and the CORD alliance. The two parties divide the major tribes, where the Kikuyu and Kalenjin support the Jubelee alliance-

Republic of Kenya	
Motto: "Harambee" (Swahili) "Let us all pull/pool together"	
Capital and largest city	Nairobi
Official languages	Swahili, English
Ethnic groups (42 in total)	16.9% Kikuyu
	13.5% Luhya
	12.5% Kalenjin
	10.2% Luo
	10% Kamba
	5.6% Kisii
	4.1% Meru
	26.2% other African
	1% non-African
Government	Presidential Republic
President	Uhuru Kenyatta (Kikuyu)
Independence	12 December 1963
Population (2013 est.)	44,037,656
Pop. Under 25 yrs	60%
Currency	Kenyan Shilling (KES)
Life expectancy	63,3 years
Litteracy level	87,4%
Unemployment rate	40%

Figure 4 Kenyan flag

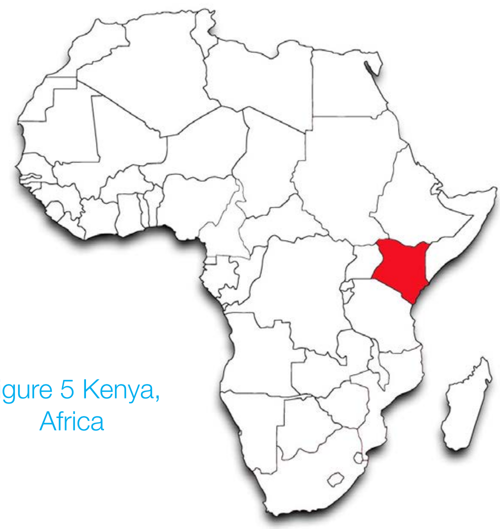


Figure 5 Kenya, Africa

and their leader Uhuru Kenyatta, and the Lou, Kamba and Luhya supporting the CORD alliance with their candidate Raila Odinga[7]. The Jubelee alliance won the elections with 50.51% against 43.70% leaving Uhuru Kenyatta as the country's new head of state. History shows that election of president and government is reliant on and influenced by tribal affiliations and in lesser degree by the political views and standpoints of the parties.

Water in Kenya

The limited access to water in large parts of both urban and rural Kenya (currently 59%[8]) is well recognized within the political scene of Kenya and is reflected in the Kenyan constitution and the National Water Policy. The past 7 years the budget in the water sector have allegedly grown more than 10 times and the sector have incorporated pro-poor financing mechanisms and other specialized financing resulting in increased access to water services for the rural and urban poor. The constitution of Kenya spells out, among other provision that water is vested in the people, that water (supply) and sanitation (services) is a right and that the development of water resources is a function of the national government. The government drafted, in 2012, a new National Water Policy outlining a strategy to increase the per capita water availability to above the international benchmark of 1000 m^3 by 2030[9].

The above mentioned facts could build a foundation for being optimistic on behalf of the Kenyan people and the villagers of Ngumbulu. However there are several and crucial challenges to be addressed before the people of rural Kenya will receive the benefits of the governments attention. One of the biggest challenges may be the share speed in which the government is able to operate. The people of rural Kenya need water today, and a promise of water security in 2030 is far too distant to raise any optimism. Another challenge is the great number of water sector institutions, which may have conflicting mandates creating opportunistic exploitation and severe under-performance. A concern, raised by the government, is the highly diverse technologies used in the rural water sector leading to the statement that "the share number of rural systems and water points renders regulation from national level impossible[9]". This may indicate that some of the rural sector will remain untouched regardless of the government's promises.

Ethnicity may also represent a hindrance for the Ngumbulu area. In everyday life ethnic identity does not play an important role in the interaction between different groups. However when there is a question of resources and state power, ethnicity is used as an instrument and a political strategy by the involved parties[10]. Given that the people of Ngumbulu are predominately Kamba, the sitting Kikuyu/Kalenjin government is likely to favor development of their own people first[11]. This is a controversial topic in which there exists diverse opinions, however it is something to be aware of when initiating development in Kenya at large.

3.2 Ngumbulu

The rural village of Ngumbulu is situated in the former Eastern Province of Kenya; now Machakos County close to the border of Kitui County approximately a 3-hour drive from Nairobi. Surrounding villages are often incorporated when talking about Ngumbulu, as the community is tightly connected and there are no distinct borders. Realizing this, Ngumbulu becomes a collection of seven villages inhabited by about 12 000 people. In this report the villages are mentioned in the same breath as Ngumbulu, however mentioned specifically by name if distinctions are needed. The river Mwitasyano to the east and the large stream of Mbakoni to the west frame the area. A population density- and overview map has been made to get a geographical understanding of the area, Figure 6 .

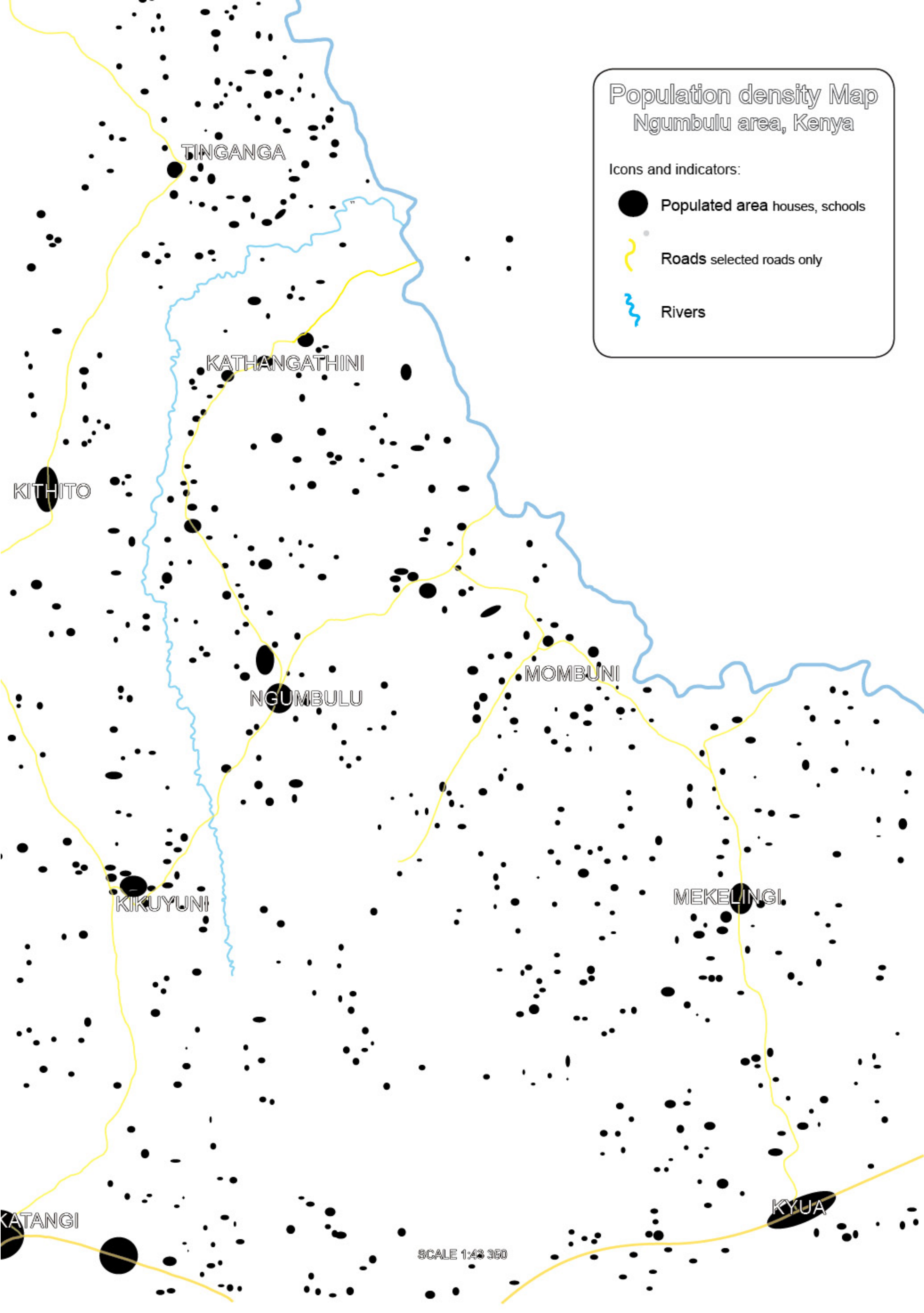
Ngumbulu has a hot semi-arid climate, which is recognizable by periodic droughts and heavy, but unpredictable rains[12]. The area lies at an altitude of 1100-1200 meters and shows little vegetation, with scattered trees, indigenous bushes and plants and dry soil. Given the lack of vegetation, the area is subjected to erosion during the wet seasons with heavy rainfall creating streams and flash floods running straight through the landscape. The area is in danger of desertification due to climatic variations and human activities[13] .

The people in Ngumbulu and the surrounding area are part of the Kamba (Akamba) tribe, fourth or fifth largest tribe in Kenya (varying with references) and are mostly of Christian belief (98%)[14]. They speak Kamba, the local language, among themselves but are also mostly fluent in Swahili and, to some extent, English.

A development center has been established in Ngumbulu by the local foundation Purpose for Life, which was founded a few years back by Mr. Samuel Makasi, a man with strong ties to the village and an urge to develop the area. The center has a few working members initiating projects in agriculture, poultry keeping, basket weaving and bread baking. Mr. Makasi and the center is also involved in water-providing projects, and will be the initiator and distributor for the rainwater harvesting system. The foundation has a tight relationship with the Norwegian NGO Aid in Action, which serves as both funder and co-initiator in projects.

In rural Kenya at large only 5% have access to electricity[15], and for the Ngumbulu area the number may be even lower. There are high voltage wires going to Katangi and the development center however few goes further, and with scattered households it may be hard even in the future to supply all with electricity.

Figure 6 Population density and overview map


Population density Map
Ngumbulu area, Kenya
Icons and indicators:
Populated area houses, schools
Roads selected roads only
Rivers
TINGANGA
KATHANGATHINI
KITHITO
NGUMBULU
MOMBUNI
KIKUYUNI
MEKELINGI
KATANGI
KYUA
SCALE 1:43 350

3.3 Current water situation in Ngumbulu

The water situation in Ngumbulu and the surrounding areas is a complex and severe matter. The landscape shows signs of semi-aridity, which according to locals have developed during the post-colonial times. The area was inhabited shortly after the liberation in 1963 at a time where green forests, wild animals and indigenous plants were a frequent part of the scenery. Farmers started cultivating large areas of the land as their British colonialists had taught them. Most of the vegetation was removed, thus a slow deforestation process started[16]. The aftereffect of this, in cooperation with climate change, is what the current generations in the area now desperately try to battle.

The ultimate problem is not the lack of rain, as there falls a relatively large amount each year (approx. 1000 mm). The problem is that there exists a severe duality in the climate, varying from drought periods in January/February and June/July/August/September to extreme rainfalls in March/April/May and in October/November/December. The longest drought period stretching from June to September, leaving four rainless months, presents severe difficulties in both agriculture and general living. In this period the river and its branching streams dry up completely.

Even in the wet season there are no certainties of rains, as there may rain for 2 hours one day, and then no more for a week. The rainfall is by all measures unpredictable and as there are no locally collected data, estimations must be taken from The World Bank as seen in the rainfall graph in Figure 7

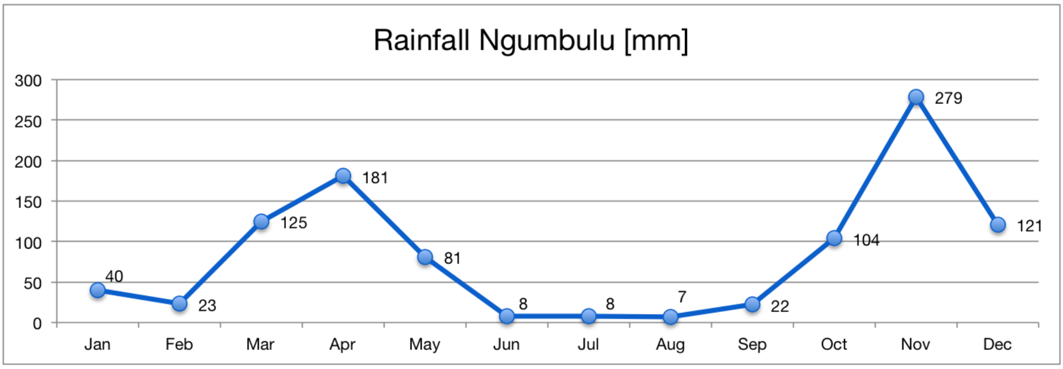


Figure 7 Rainfall Ngumbulu, The World Bank

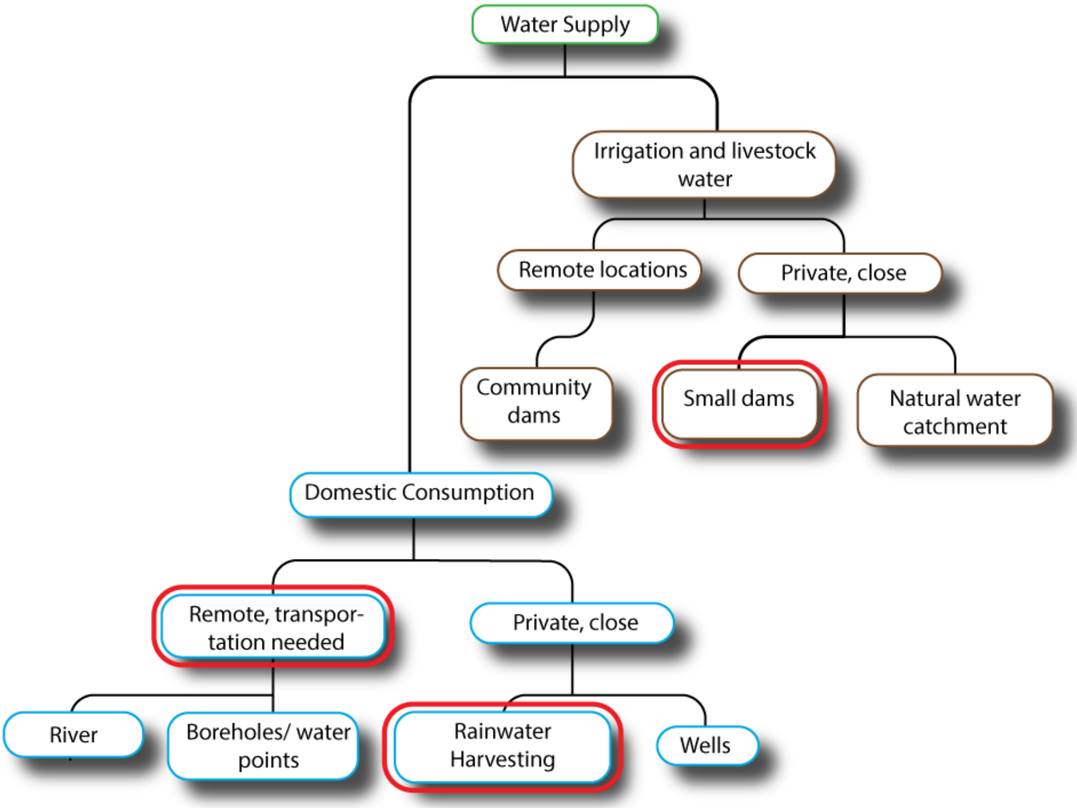


Figure 8 Water supply, Ngumbulu

For the inhabitants of the area each day is a struggle to find and collect water for drinking, livestock or for irrigation. And even if there exists some sources of water, problems like distance, long lines, breakdowns and poor drinking quality are a frequent scene.

Figure 8 shows the current water situation, where all these sources must to work together to mend the problem in the village. However the aim is to identify where the need is greatest and try to initiate improvements. The red outlining shows what is identified as possible improvement areas for this project.

The next page gives an introduction and discussion of current status to each end-point of the graph and the following map was made for this project to outline where the sources are located in the area.

Community dams

Villagers have constructed several community dams, often initiated by NGOs in various projects. The dams are generally big and dug by 30-50 villagers and some of the dams have water all year around. This provides a great addition for the few villagers living in close proximity of the dams, however others may have to walk far to reach these.

Small dams

A very few small dams have been located in the area taking advantage of landscape run-off for use in agriculture and for livestock. The dams dry out quickly but keep the soil moist for months after the rain season for the benefit of close by vegetation and trees.

Natural water catchment

As water is used both for agricultural purposes as well as domestic, natural catchment is a very important source of water. In the area there are little trees and vegetation, which is the natures own rainwater harvesting system. It is a fact that areas with severe drought issues may restore some of their natural state if replanting efforts are initiated. Ultimately this is seen as the root to the water problem in Ngumbulu and replanting efforts are initiated, however more is needed.

Transportation

Transportation of water is needed from community dams, borehole water points and the river, and is done either manually or with donkeys. Four jerry cans of 20 liters are usually strapped to the back of the donkey and lead to the water points often 4-5 km away, where multiple villagers wait in line for their turn to extract water. This is done in the wet season as well as the dry season and brings great exertions to the villagers. Women and children are the main executer of this chore, which makes the situation even more challenging.

River

The river Mwytasyano is the main water source in the village and provides water through holes dug in the riverbed. The water is not of good quality, and research has shown a great deal of contamination[17]. Usually the water is boiled, thus eliminating diseases. Being the main water point in the area people must walk vast distances to collect this water.

Boreholes and water points

Mainly three boreholes have been installed, one in Ngumbulu, Kikuyuni and Mombuni. Boreholes serve mainly the schools, and water distribution points have been shut down because of capacity issues (except for Kikuyuni borehole which is less strained and manages to sell water to the public). To install pumps and construct boreholes is rather expensive and require management and repairs, but provides good drinking water.

Rainwater harvesting

Roof rainwater harvesting is a poorly utilized resource in the area, much because of limited knowledge and availability. Some villagers have tried, however few have succeeded in their efforts, leaving a large potential in this technique. Some of the schools have to some extent realized the potential, but down-prioritizes this for the benefit of other sources, like the boreholes.

Wells

There are some wells in the area giving a good increase in domestic water for some. Few are able to coonstruct theese though, and only the ones living at a lower altitude is able to reach water through wells


Primary School
KATHANGATHINI
KITHITO
Kithito Primary School
MBAKONI
Rain Water Harvesting
Private
Rain Water Harvesting
Private
Borehole
Ngumbulu
1133 m
Gabion
Public
1118 moh
1180 m
Ngumbulu Secondary School
Pond
School
Water point
From Borehole
For School
Ngumbulu Primary School
Distribution point
From Borehole
Public
1170 m
Dam
Public
6
1149 m
Water point
From dam
Public
Manual Pump
Public
1132 m
NGUMBULU
Well
Private
Development Center
Purpose for Life
Well
Private
1141 m
Rain Water Harvesting
Private
Rain Water Harvesting
Damaged, unusable
Kikuyuni Secondary School
1174 m
KIKUYUNI
Water Point
From borehole
For school and distribution
Kikuyuni Primary School
Borehole
Kikuyuni
1151 m
Dam
Public
0
200
400
800
1200
1 : 20 000


Points of Interest Map
Ngumbulu area, Kenya
Magnus Kile Andersen, October 2013
Key Information:
Distances (straight line)*:
Katangi - Kikuyuni 3.5 km
Kikuyuni - Ngumbulu 2.6 km
Ngumbulu - Mombuni 2.9 km
Ngumbulu - Kithito 3.5 km
Ngumbulu - Kathangathini 3.2 km
Kathangathini - Tinganga 2.4 km
*Distances and altitudes on map for reference only
Icons and indicators:
Natural Water Sources ponds, dams, waterholes
Rain Water Harvesting selected only
Artificial Water Sources wells, boreholes, distribution points, pumps
Schools primary and secondary
Roads selected roads only
Rivers
INGENIØRER UTEN GRENSER
AidinAction
Waterhole
Public
1074 m
Waterhole
Public
Rain Water Harvesting
Private
MWITASYANO
Mombuni Primary School
MOMBUNI
Borehole
Unspecified location
MEKELINGI
Mekilingi Secondary School
Mekilingi
0 200 400 800 1200
1 : 20 000

3.4 Utilization of rainwater harvesting

Rainwater harvesting from roofs are seen as a potential improvement area in Ngumbulu, and a closer look at what is already established is useful to discover the problems.

As mentioned, some villagers have attempted to harvest rainwater from roofs, however few have so far been successful. Various gutters have been tried, but in many cases they are not sufficiently fastened to the roof or they have been destroyed by heat/weather. The roofs are also constructed in various ways, which gives the inhabitants a challenge in finding the best installation method.

Storage tanks present a big problem, as they are expensive and generally hard to get a hold of. Some use small cans which has capacity issues, and some have concrete or brick tanks that have a tendency to crack and become unusable after a short while. This was evident as several broken and abandoned tanks were seen in the village during the field trips. There may be a number of reasons for this, such as poor construction, lack of maintenance, wrongly mixed components or simply insufficient material quality to withstand the heat and climate. Most villagers have good possibilities for rainwater harvesting on at least some of their houses as iron sheet roofing is common.

The development center initiated in late 2013 in a project offering plastic tanks sized 5 000 and 10 000 liters to the villagers. The development center created a down payment plan for the tank, gutters and installation package with a total cost of 50 500 KES and 93 800 KES respectively. So far (April 2013) the center has sold 30 tanks and there are people on the waiting list for more. Unfortunately, the tanks are too expensive for most villagers and there have allegedly been some complaints from people saying the project only supports those more affluent.

Despite complaints, the general success shows great possibilities in this water source. Rainwater harvesting is where the potential for improvement is greatest, and therefore becomes the natural focus in this project.

Figure 9 Broken tank, and houses with iron sheet roofing, Ngumbulu

Figure 10 Gutters and reservoirs in Ngumbulu

3.5 Fundamental needs

When having defined the need for rainwater harvesting systems in the area, several additional, fundamental needs appear. These issues are more easily discovered when coming from outside, and are arguably the major reasons for why rainwater harvesting has not yet reach its potential in the area.

Need	Description
Availability of components	The limited availability of any hardware or tooling is a big problem. The closest town is several hours of walking away and is unreachable for most. If there is nowhere to get storage tanks, of course no tanks will be purchased.
Cheaper alternatives	There is also a need for cheaper alternatives for the less affluent. The ones who need rainwater harvesting the most cannot afford what is available.
Knowledge	Interviews with villagers revealed a limited knowledge about rainwater harvesting and how the technique may serve them. There is also a limited technical knowledge in the area based on the low level of technology and lack of efforts to repair broken equipment.
Data collection	There exist no data on rain or rainwater harvesting in the area. Because of this it is difficult for the development center to communicate the advantages to the community.
Proper installation	Lack of material- and wrong methods used in installation of both gutters and tanks is a consistent problem throughout the area.

The table shows that in addition to a technical solution there is a great need for more knowledge about the technique both for the development center and for the community at large.

The general overlying needs are defined as the following:

- A rainwater harvesting system especially developed to fit the needs of people in Ngumbulu.
- Facilitation for rainwater and rainwater harvesting data collection
- Educating the community in the advantages of rainwater harvesting

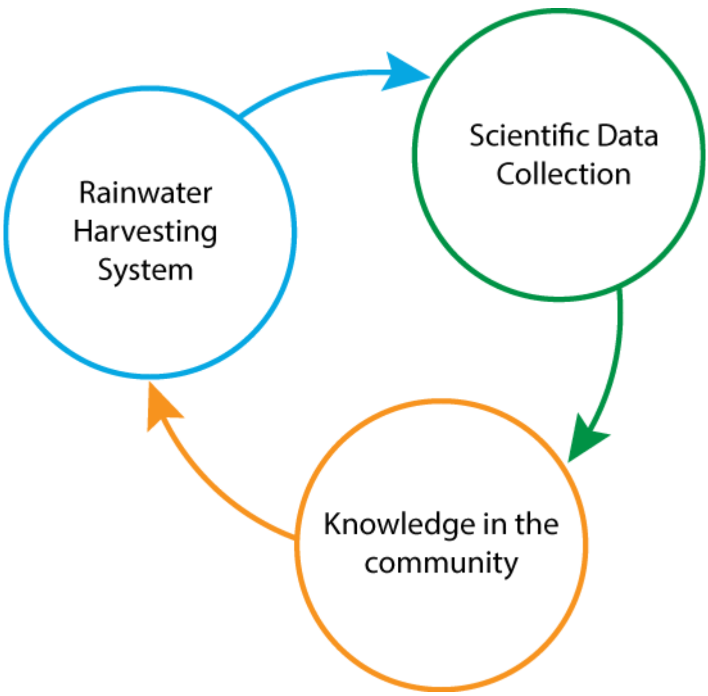


Figure 11 Needs diagram

4 A matter of resources

Approaches item 3 in the task list

Availability of resources is not a given in rural Africa. Sometimes there may be hours to the closest materials shop. A thurough mapping of what is available in Ngumbulu is necessary to understand the limitations further development is influenced by. Also the matter of keeping values close is important and touched upon in the next section titled “the micro-macro paradox”.

4.1 The micro-macro paradox

Performing development work in marginalized societies brings a great responsibility towards the local economy. The aim is to provide opportunities to the community, thus respect and considerations must always be given to local vendors and businesses. The notion of swiftly bringing relief to suffering people by bringing in products from afar is a popular aid strategy, but this short-term gesture often paralyzes local value creation. This is called the micro-macro paradox. Dambisa Moyo writes in her book Dead Aid (2009) [18]:

"…the micro-macro paradox. A short-term efficacious intervention may have few discernible, sustainable long-term benefits. Worse still, it can unintentionally undermine whatever fragile chance for sustainable development may already be in play."

Regarding rainwater harvesting in Ngumbulu, it should be seen as a possibility to lift both the beneficiaries as well as local vendors by buying their products. It is one of the primary goals of this project to use components that are locally available without the need of a great global system. Even if this strategy is time consuming and complex it is seen as vital to ensure sustainability.

4.2 Availability of components

In general Ngumbulu is a place lacking in opportunities for the general consumer. There are very few shops, and the existing ones usually offer only food and some smaller goods such as batteries, thin ropes and bottled water. An interesting aspect is that of 5 shops in the Ngumbulu market, 4 of them have completely the same selection of products. This phenomena is called "dua kali" and is seen throughout Kenya, where people are encouraged to start their own small business. However there lacks a certain fantasy in businesses creation, as there are hundreds of the same small independent shops, door welders, wood carvers and similar.

In Ngumbulu, and the other markets, only the basic products are found, and any other requests are directed to the larger town, Katangi, more than 6 km away. Even garbage is hard to find in Ngumbulu, as there are no dumps. Only food wrappings (in large quantas) are found along the roads. It is safe to say that if you want something other than the basics, you are forced to take the long road to Katangi either by foot or by bicycle.

In Katangi the situation is a little different, and you may find welders, cement shops, some timber and other construction materials. The quality of such is naturally rather poor, and the prices are expensive for the average villager. Often you see people preferring sticks and poles found in the nature rather than spending money on timber.

The closest big city is Kitui, approximately a 40 min drive eastbound. Here one can find most goods including large plastic tanks, flat iron sheets and prefabricated gutters.

A list of various materials is provided in the Appendix "Material price sheet" on page 160 to give a notion of availability and prices.

4.3 Labor

While discussing resources and availability one most also touch upon the availability of skilled labor and expertise in the area. Or rather the lack of such. Construction expertise is generally a problem in the outskirts of Kenya where no major companies have foothold. The reason is partly the previously mentioned “dua kali”, where people start their own business often based on self taught skill. There are plenty of examples of poorly constructed buildings in Ngumbulu and the surrounding villages and towns. This is often due to shortcuts in construction and severe cut backs on materials. To be safe, skilled labor must often be brought in from the larger cities like Kitui or Machakos.

However, if general labor is needed, people may be found everywhere as there are plenty looking for casual work such as digging or carrying.

Figure 12 Casual workers at a dam project in Kyua

Figure 13 Small shop in Ngumbulu and its owner

5 Rainwater harvesting, technical aspects

Approaches item 3 in the task list

Water harvesting in its broadest sense can be defined as the collection of run-off rainwater for domestic or agriculture water supply. It is an old and established technique for providing water all over the globe, as also in Kenya, however it has yet to reach its full potential here[19]. The following sections will show some examples of existing technologies, categories within water harvesting, and go more into detail of the most suitable option for Ngumbulu.

5.1 Categories and examples

The graphic shows a general categorizing of different scales and types of common rainwater harvesting techniques based on an outline given by Gould and Nissen-Petersen (1999)[20].

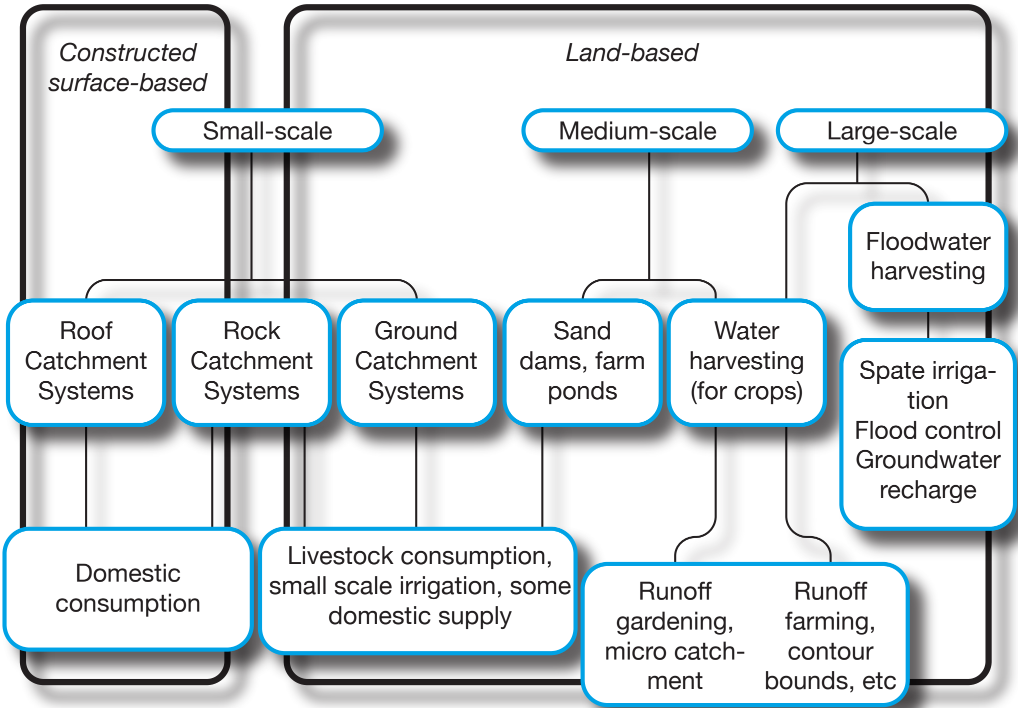


Figure 14 Rainwater harvesting categories

For this project the small- to medium scale systems are the focus, however more examples are incorporated for overview purposes. The images on the next page corresponds to the explanation sequence.

Roof catchment systems

Roof catchment systems are small-scale constructed-surface based rainwater harvesting systems. It is perhaps most common in urban areas where the rainwater is collected from suitable roofs of buildings. The water is lead in gutters or pipes into a storage tank in a variety of shapes, sizes and materials. The water from this kind of systems is in general good for consumption by humans but may have restrictions in capacity[21].

Farm Ponds

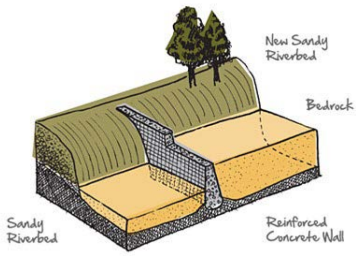
Farm ponds are established close to the farming fields and can be classified as a medium-scale, land-based harvesting system. The water in these ponds is commonly only suitable for irrigation and animals because of contamination possibilities. Water from surrounding hills and slopes run in natural or constructed trenches into a prepared excavation in the ground close to the farming fields. They are built with angled walls where grass or other plants are planted to keep the walls from eroding. Also the ponds could be filled with stones or cement to prevent the water from quickly eluding into the ground[22].

Sand dams

The sand dam is a (rather large) medium-scale land-based harvesting system. The solution is constructed on a seasonal sand river with a shallow underlying rock bed. A reinforced concrete wall (or a similarly robust and impermeable weir) is constructed upon the rock bed across the entire width of the river. When it rains the barrier temporarily stops the river flow and after two- to four seasons the sand riverbed has been raised to the height of the wall. This sand now contains 20-40% water that can be collected from digging holes or by a pump[23].

Groundwater recharge

Groundwater recharge is part of a rainwater harvesting system as it utilizes different techniques specifically designed to use rainwater to refill aquifers and underground water reservoirs. A commonly used technique is percolation dams (large-scale land-based) where water is stored in shallow artificial dams with permeable sandy, gravel of rock beds, so that it filters slowly through and into the ground/aquifers. Dams are generally 1-4 m deep, deep enough to prevent excessive algae growth and shallow enough to prevent anaerobic conditions developing at the bottom. Groundwater recharge effectiveness varies from 35 to 75% with an average of 50%[24] and is highly important to prevent boreholes and wells from running dry and become useless.



Dew and fog collection

Dew and fog collection is not directly a rainwater harvesting technique, however it is a way of harvesting the natural humidity in the air. Fog interception copies the function of the trees and other natural features. It utilizes large polypropylene mesh nets on ridges, erected perpendicular to the wind to capture water-loaded fog, which forms in humid months in mountainous regions or coastal areas. The mesh captures water droplets (1to 40 micrometer), which drip into a storage tank through a drain[24].

Figure 15 Water harvesting examples

5.2 Focus: Roof catchment systems

Based on the needs chapter it seems that the roof catchment systems are the most suitable option for Ngumbulu. There is a lot of potential for improvement in this category. The need for domestic water is high, mostly people have suitable roofs and there is a need for domestic water closer to home.

Even if the focus will primarily be on roof top catchment, there are possibilities in the other techniques that should not be forgotten. Improvement on existing water sources in Ngumbulu, and not yet utilized options is kept in mind during the development process.

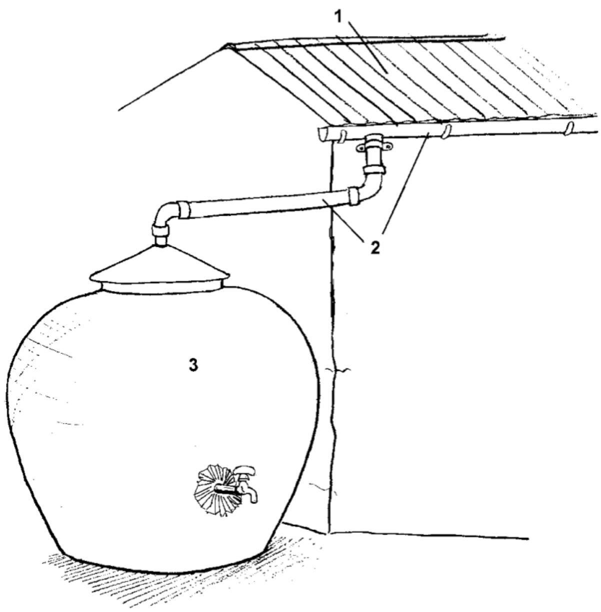


Figure 16 Roof top catchment, basic principles. Source: Worm and Hattum (2006)

5.3 Basic principles

The basic principles in roof catchment systems consist of mainly three sub-functions:

1. Catchment surface
2. Delivery system
3. Storage reservoir

Some also include the supply mechanism from reservoirs as a sub-function, but this will not be a focus here.

1 - Catchment surface

This first part of the system is in many ways what gives the technology its name. When there is precipitation the water falls onto a surface that facilitates harvesting and is therefore a crucial part of the system. There is a strong link between the properties of this surface, the intended use of the water and the amount wished to be stored. Is the water intended for human consumption it is important to use a suited surface avoiding pollution and possibly harmful materials.

2 - Delivery system

The delivery system is the mechanisms allowing the water to be transported from the collection area to where the water is stored. In small-scale systems this usually consists of a combination of gutters and pipes. For the effective operation of a rainwater harvesting system, a well-designed and carefully constructed delivery system is crucial because this is often the weakest link.

3 - Storage reservoir

The storage reservoir, or storage unit, is perhaps the most noticeable part of the rainwater harvesting system and is where the water will remain until time of use. This usually involves the highest investment cost, but is generally cheap in operation and maintenance[21].

There are several suitable materials that could be utilized such as cement, mortar, concrete and bricks, or ready-made products as plastic, fiberglass and steel. The storage unit also requires attention to evaporation and pollution minimizing both by the use of covers.

5.4 Environmental considerations

Environmental feasibility depend on the amount of rainfall in the area, the duration of dry periods and the availability of other water sources. The rainfall pattern is very important to determine whether a rainwater harvesting system may be used as either a primary or supplementary supply. Tropical climates with short (one to four month) dry seasons and multiple high-intensity rainstorms provide the most suitable conditions. As a general rule, rainfall should be over 50 mm/month for at least half a year or 300 mm/year to make the technique a suitable option[21]. If other water sources are extremely scarce, the rainwater harvesting may also serve as a great relief even if it is only used during the rain season. The description fits Ngumbulu well as the suspected rainfall here is approximately 900 mm/year and additional water sources are few and hard to come by.

The environment also impacts the design of the components as the wind and rainstorms may break the system if not adequately robust. The systems should be tested in the actual, or similar conditions as intended to be installed in.

5.5 Design considerations

Given that the environmental conditions for rainwater harvesting are fulfilled, several other issues needs to be considered to design a successful system. Figure 17 shows important aspects which all must be considered while designing a roof catchment system, both technological and social.

The importance of each aspect is different depending on the area and social situation of the project. In Ngumbulu the needs analysis revealed that the most limiting factor is the economy (budget) and the availability of materials. After these issues are considered, the gutters and tank size may be designed which in turn determines the potential supply of the system. The size of the family and their water usage will show how much of the need is covered by the rainwater harvesting. Subsequently, the realization strategy must be set and lastly the maintenance and management, which is crucial as the knowledge of how to do this properly is missing in the area.

In other words it is most appropriate to first cover the physical issues, and then see how much of the water needs are met. Naturally, all aspects influence each other and must be investigated simultaneously.

In addition to the mentioned issues, aspects like water quality, safety and market demand must be taken into consideration.

Water quality

Rainwater is generally safe and unpolluted before it hits the catchment surface, especially in rural areas like Ngumbulu. However the components of the system may contaminate the water if they are of hazardous materials or if the surfaces are not adequately cleaned. An important safety factor is to let the first water clean the system before it enters the tank. This is called “first flush” and must be facilitated for in the system by for instance letting the delivery system be divertible or allow for blocking of the water flow. Other important measures towards better quality are filters and reservoir covers.

Safety

Safety is always an important consideration, and especially where kids run around and may harm themselves on system components. If large tanks are used there must be adequate safety railings or locks on openings. If no such thing is possible the system shall not be taken to use.

Market demand

When designing a rainwater harvesting system the market demand is important, not to offer something users do not want. This may apply to areas where earlier projects have failed and left users skeptic to certain solutions. It must be stressed that this is a more important factor than some may realize, and a perfectly good system may be un-sellable if user and market is not considered.

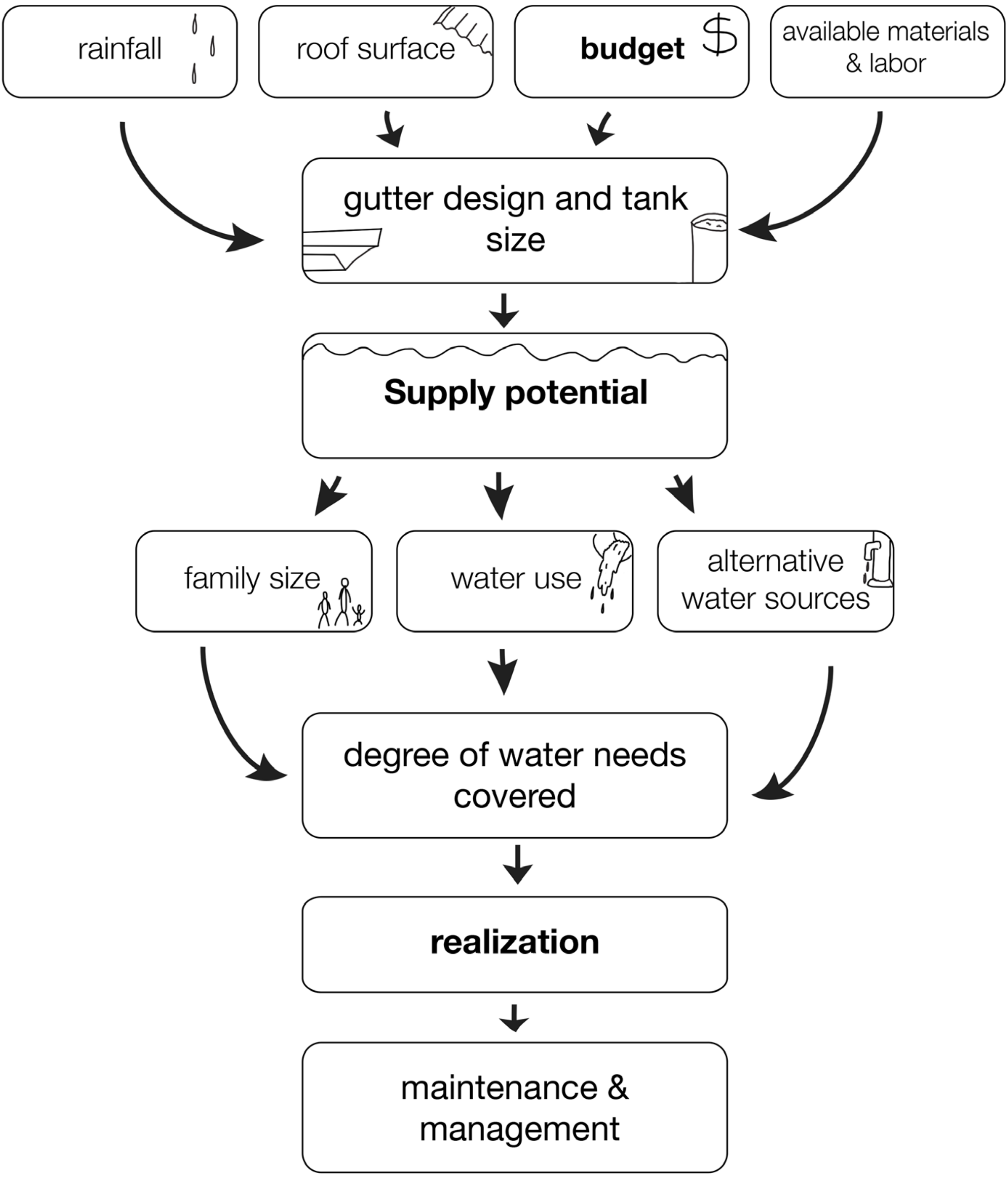


Figure 17 Design considerations

5.6 Supply potential and storage calculations

When calculating how much water a roof catchment system may supply, a number of factors come into play. The most decisive are the amount of rainfall and the catchment surface.

The potential supply is given by[20]:

Supply = rainfall x projected area x run-off coefficient

(1) S = R x A x Cr

The supply is given in m^3, the rainfall is given in m, the area in m^2 and the run-off coefficient is a pre-determined constant (how effective the roof surface leads water) without unit.

The supply can then be set up against the water needs of the family to see how many days the collected water may last.

Example

During one week it rains in total 50 mm on a roof of iron sheet (Cr = 0.8) measuring 15 m^2. The amount of rainwater that may be collected is:

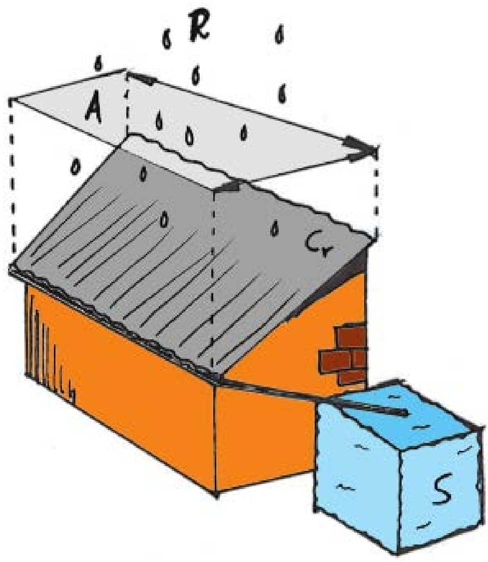


Figure 18 S = R x A x Cr

S = 0,050 m x 15 m^2 x 0.8 = 0.6 m^3 = 600 dm^3 = 600 liter

600 liters of storage is a rather large sized tank given the financial difficulties in Ngumbulu, and the water should therefore be used right away if there is expected more rain to come later (for instance in the beginning of the rain season). So how many days does the collected water save them from going to the river to get water? Take an average family of six people, who based on interviews collect about 80 liters of water per day.

Coverage = 600 liter / 80 liter = 7.5 days.

So, with a rather small home (3 by 5 meter) the family can collect 600 liters, which saves them from going to the river during the following week. This may have a big impact on the welfare of the family.

Optimal system

The relationship may be used to determine the optimal roof catchment system for a given family in Ngumbulu for them to last an entire drought season on the harvested rainwater.

For this calculation the length of the drought and family water demand is needed.

The drought may last as long as 150 days (middle of May to middle of Sept.), and the following example

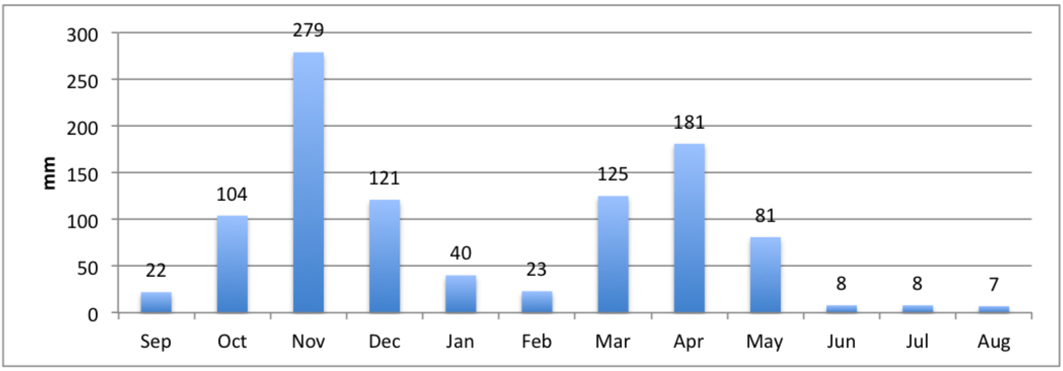


Figure 19 Rainfall Ngumbulu, Sept-Aug

calculates for a family of 6 demanding approx. 80 liters of water per day:

Total need drought: 80 liters x 150 days = 12 000 liter

The size of the tank must be 12 000 liter, and be full in the middle of may, to last the entire drought.

The most likely time when the tank is empty is at the end of august, when all the water is used, and the rain has not yet started. September is therefore the starting month of the graph in Figure 19, but for simplicity only the rainfall in March-May is included with a total of 387 mm of rain, equaling 0,387 m.

Neglecting usage in the rain season the needed catchment surface would be:

12 000 liter / (0.387 m x 0.8) = 39 m^2

This equals an 8 by 5 meter building with iron sheet roofs.

In reality the villagers will use the harvested water during the rain season as well, because the distance to the river is still the same. Therefore, to be able to have 12 000 liter in the tank at the starting point of the drought, the catchment area must be even greater and also the tank must be bigger to accommodate for the heavy rains in November.

The background analysis show that the villagers cannot afford such large tanks, regardless of construction method, and most does not have the roof area to support this. Therefore the best way may be to determine the potential supply villagers have on their roof, and in turn the optimal size of the tank for this particular catchment area.

Actual supply potential and storage size

The optimal storage size for any given household is determined by the potential of the catchment area, and not driven by the need of the family. This may be useful in order to see what storage capacity the families should aim for, so they do not invest in a tank that is too large for their catchment surface.

Given that people also use water during the rain season, the usage must be taken into consideration. The calculations aim to see where the discrepancy between water use and water supply is at its greatest.

Another family, also with six members needing 80 liters per day, has two suitable buildings giving a total of 28 m^2 for rainwater catchment. The tank size demand of this family will be calculated in this example.

Calculate the potential supply for each month using equation (1) on page 50. Set up a cumulative supply by step-vise adding the amounts throughout the year. In the same manner calculate the monthly- (in this case: 80 liter x 30 days = 2 400 liter) and cumulative demand. The two data sets are then set up against each other as seen in Figure 20:

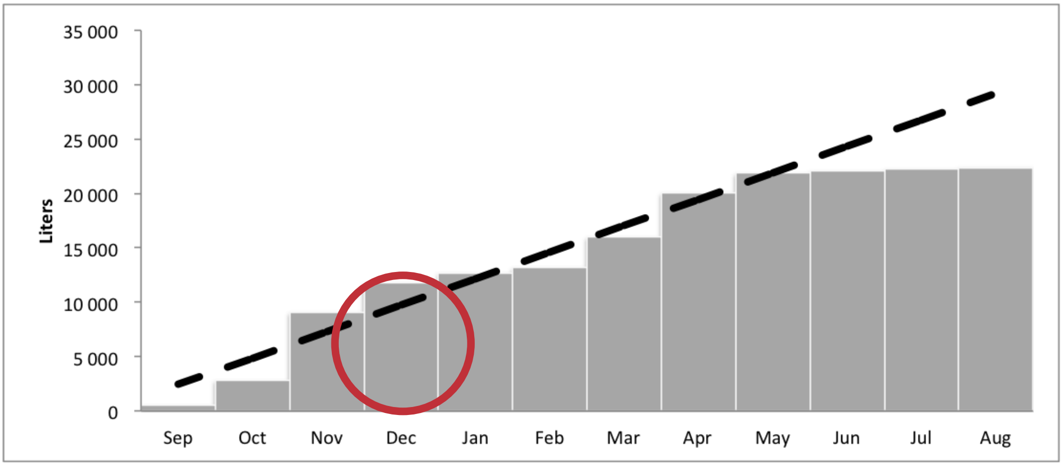


Figure 20 Cumulative supply vs demand

The optimal storage size is given by the largest discrepancy between the two, where the supply is greater than the demand. In this case this occurs in December where the supply is 2 050 liters greater than the demand (Supply was 4 500 liters but the demand was only 2 400 liters). Therefore the total storage volume the family should aim for is approximately **2 100 liters**. It should be noted that the available catchment area is not able to fully supply the family with water from rainwater harvesting, and especially in July and August other water sources must be used.

If the cumulative supply does not succeed the demand at any point, all the collected water is used. This is often the case in poor communities, because of small houses and bad economy. Each rainfall must then be looked at separately, like calculations in the example showed on page 50.

5.7 Advantages and disadvantages

When considering the possibility of using roof top catchment systems for domestic supply, it is important to consider both the advantages and the disadvantages. Even if it has been concluded that this technique is the best option for Ngumbulu, one has to be aware of the disadvantages not to get unfortunate results and disappointed community members. An overview of advantages and disadvantages are therefore given in the table below.

Advantages		**Disadvantages**	
Short distance	The water comes to your home, which saves time and effort in collecting from a far.	**Limited supply**	The size of the catchment area and tank limits the supply. Also the budget is a big limiting factor.
Simple construction	Construction of systems is simple and locals can easily be trained to construct and install components.	**High investment cost**	The cost of the systems is almost fully incurred during the initial construction. Financial management and down payment plans are often needed
Independent	Operation and maintenance of a household catchment system is not dependent on management from outside the family.	**Maintenance**	Proper maintenance is often neglected. Regular inspection, cleaning and occasional repair is essential.
Relatively good water quality	Rural rainwater is clean and is good for drinking provided that the system is operated properly.	**Vulnerable quality**	The water may easily be polluted if the system is not kept clean and in proper condition.
Environmental impact	Rainwater is a renewable resource and no damage is done to the environment.	**Sensitive to droughts**	Rain is often unpredictable and large tanks are needed if the water is to last the entire drought.

6 Specific needs and user analysis

Approaches item 2 in the task list

This chapter analyses the area at a more personal level focusing on the villagers daily lives and struggle with water. It is also necessary to incorporate other involved parties to discover important aspects to consider in further development.

6.1 Customer value chain analysis

The Customer Chain is a visual mapping design tool used at the start of a product development process to identify users or stakeholders and their relationships to the product being developed[25]. The customer is defined as all important parties who are involved with the effective delivery of the product to the end user and the support of the product throughout its life-cycle[26]. There may exist contradictory needs and demands that must be considered in the development process, which may be discovered through a thorough analysis of the value chain. In this report the term "customer" is transcribed to "user" as it is seen to be a more fitting description and corresponds to terms used in other methodology literature.

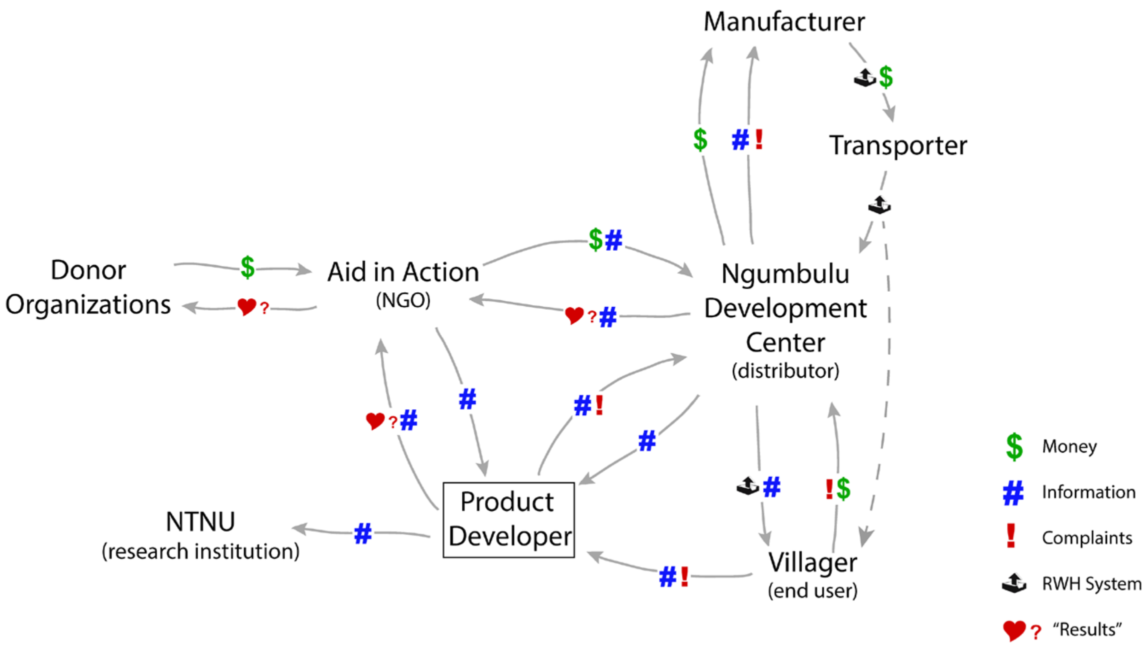


Figure 21 Customer value chain

The illustration gives insight in all the involved parties and the type of interaction they share. The analysis show that the money into the project comes from two "branches" with the donor organization at one end and the end user, villagers, at the other. The value creation lies primarily at the development center and the manufacturer.

6.2 User analysis

As seen in the Customer Value Chain there are three major users involved in the development process, Aid in Action, Ngumbulu Development Center and the villagers.

Aid in Action (NGO and funder)

The Norwegian girl Anne Louise Hübert founded aid in Action, at the age of 19, in 2008, after a visit to Ngumbulu. The organization focuses on sustainable development in marginalized communities where empowerment of the locals serves as an overlying goal. In Ngumbulu the organization has initiated several projects such as papaya planting, student funding, boreholes and green houses. The organization is small, with no paid management and relies on local partners to perform development work.[27]

Ngumbulu Development Center (executor and distributor)

Ngumbulu Development Center is run by the local organization Purpose for Life Foundation lead by Samuel Makasi. The center was opened in August 2013 and generally employs a staff of 7 people (all Kenyans), whereas 3 (in addition to the leader) are project workers. The center has close affiliations with Aid in Action, which also serves as their primary funder. Even if dependent on funding, the center has ambitions of being self-reliant with activities generating income such as chair and tent hire and selling of home grown produce. For the rainwater harvesting project the center serves as the executing party and will be responsible for furthering of the initiative.

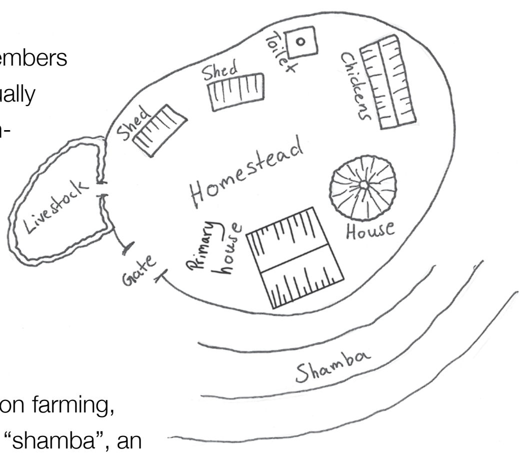
Villagers (end user)

The villagers in Ngumbulu are the primary- and end user of the rainwater harvesting system. There are great variations in wealth and purchasing power in the community and in line with the project aim; the most marginalized are the primary focus.

General living

The average family size is approximately 6-8 members living in the same homestead. The homestead usually consists of several houses within a fenced compound, with one or two large houses and several smaller. An important note is that most families have iron sheet roofs on one or several buildings, which is a great starting point in rainwater harvesting. See Figure 22 for an overview of a typical homestead.

Figure 22 Typical homestead



The family's household economy is usually based on farming, and each household (as a general) owns their own "shamba", an area of cultivating ground for growing crops. The villagers express that the household economy varies greatly with the seasons, leaving the latter part of the droughts

“A women said during an interview she had to carry a jerry can of 20 liters to the river four times a day to collect water. The walk was 4 km… one way…”

as highly challenging. At this point villagers must usually buy food from the markets and is forced to find either casual, unreliable work or borrow money. This project focuses on those who struggle the most, and the fieldwork showed that the limited income gives great challenges towards the rainwater harvesting system.

A large part of the day during the drought is used collecting and transporting water from various water points around the village. For some families as much as 6 hours are spent on this activity and the responsibility lie primarily on the woman, with assistance from the children. The distances people must travel range from 2,5 km to almost 7 km in the worst cases. The normal transport methods are manual carrying or strapping jerry cans to donkeys. This activity is highly exhausting, and the water collection could also present problems with assaults on women and children. Often the children are kept away from school to help with the chores at home while the mother is away. The villagers in Ngumbulu expressed the desires for relief in this work, even if it was just during the rain season. The river does not move, so the distances are the same, wet season or not.

Some of the villagers have tried to harvest rainwater, but few have really succeeded. People have problems installing gutters, and few have large enough containers to generate a noticeable supply from harvesting. However, the people in Ngumbulu are generally open for new projects and showed great enthusiasm when discussing the prospect of rainwater harvesting in the area. Next page shows an interview with a lady living in Ngumbulu.

6.3 Gender aspects

The role of adults are often quite separated in African countries, where the woman is in charge of domestic activities and the husbands chores is related to providing for the family. Today, in some areas, the husbands are on many occasions absent from home. Traditionally men trained the boys and undertook other family chores such as caring for livestock, clearing land and bringing meat or fish home from hunting or fishing trips. In the modern society in general and in the Ngumbulu area, men take salaried jobs outside the home thus shifting a greater share of household chores to women. Most of the men in the families interviewed during the field trips to the area took casual, day-to-day labor, and some were gone for several days without providing much for the family. Women are therefore the biggest contributors to development, and are in general eager to contribute in projects[28]. Thus women are also most likely to be the end-user of any domestic products such as rainwater harvesting equipment, and must be consulted in the development process. Typically, men plan and design the systems ignoring the needs of the actual end-user[21].

Figure 23 Village family building a new and improved home

Figure 24 Mother and child collecting water manually

Life in Ngumbulu

Living in Ngumbulu: Jane Kamba (37)

Jane Kamba (37) and her husband live in the Ngumbulu area with their children and grandparents. They are in total 9 in their homestead and have the following to say about various aspects of life:

Problems with water

Jane expresses concerns about providing water to her family.

- It is too far to the nearest water point. We use about four hours a day to fetch water. It is usually me with help from the children who goes. We have a donkey and get maybe 120 liters each day.

Economy

When asked about financials and supplies, Jane says they rely on their 12 acres shamba where they farm maize, beans and cowpeas.

- Whenever we don't have enough food we must buy from the market. If we manage to get a good harvest; whatever we don't need ourselves, we sell to others. Sometimes also livestock, if we can.

Jane says they would want to farm more, however this is difficult in terms of money, water and land. The husband takes casual work, but this is sporadic and hard to find. They also make some bricks during the droughts.

Development projects

Jane says she is happy to see that there are some projects started in the village and that she has almost only good experiences with such. When asked if she has been involved in any projects she says:

- No, we don't participate in any projects, but want to join!

The only negative thing she can come up with would be with some water projects with a concrete dam who broke, and some cement water tanks who have cracked not long after construction.

Hopes for the future

- I hope for good education for my children, to have enough food, good water and a healthy family.

This family is not among those who struggle the most in Ngumbulu but still there are many everyday issues that raises concerns for the family. Much of this is related to not having a good, reliant supply of water.

**This interview is a collaboration of several interviews performed in Ngumbulu. Names are fictitious and the photo selected amongst those taken during the field study.*

6.4 Needs and demands

The users have each a set of demands associated with the end-product and the project in general. They will largely determine the direction and focus of the development process.

Aid in Action

The demands from the donor organization is communicated by Aid in Action. The demands are quite general as the project is a master thesis and is done at no cost for the NGO. The following demands that are given

- Create value for the community
- Solutions to be based on investments, not donations
- Sustainable exit strategy – not long term reliance on funding from the NGO

Ngumbulu Development Center (NDC)

The development center plays a key role in the development and management of the system and has some demands that influence the solution. The following are identified as demands from the center:

- Possibility for local production of components
- Give the villagers a positive view of the development center
- Should be able to serve a large amount of villagers fairly quickly
- The solution must be able to be used in community awareness initiatives and education of the people in rainwater harvesting
- Solution should be able to be repossessed in case villagers fail to pay

Villagers

During both field trips a great amount of time was spent communicating with locals in Ngumbulu and the surrounding villages (Tinganga, Kathangathini, Kithito, Kikuyuni, Mumbuni and Mekelingi). The development approach of participatory design demands that locals are informed and included in the process. Despite shortage of time, discussions and interviews with more than 40 villagers was performed and even though most villagers shared similar views, it was important for the project to make people in all villages feel included. This is also important to avoid tension between the communities. The approach was in line with the IDEO (HCD) toolkit[4]

The demands and views are:

- Increase in domestic water (with emphasis on drinking water)
- Cheaper than what is available today
- Water must be available close to home
- A large degree of self-made components are desired
- There should be a range of options as there are great variations in purchasing power in the community

- Want a bigger storage tank than what they have today (jerry cans – 40 liter)
- Possibility to expand the storage size when the economy gets better
- Self-reliant maintenance to avoid extra cost

Most of the answers from the villagers were very general. This may either be because of little knowledge about the technique or that they were uncomfortable expressing their views. The general feel was that the knowledge level and familiarity to rainwater harvesting were fairly low and thus the answers reflected more upon their current situation than on the possibilities in the future.

6.5 Water consumption estimates

Water consumption will vary with area, ethnicity, time of year and a number of other factors. But an estimate is needed to give grounds to calculations and such while designing the rainwater harvesting systems.

A human being will suffice with 6 liters of water daily if there is a severe shortage of water[29], however with greater access comes greater consumption. An investigation from the Eastern-province of Kenya gave 9,3-12 liters in average[30], whereas surveys from the field work showed a normality of 80 liters for a 6-member family giving an average of approx. 13 liters per person.

It is important not to underestimate the consumption and therefore 13 liters is used as a daily consumption per person for domestic purposes. The average use can be deducted into more specific purposes as seen in the table below:

Usage	Per person daily	Weekly
Drinking	4 liters	28 liters
Cooking	2.5 liters	17.5 liters
Sanitation	6.5 liters	45.5 liters
Water demand	13 liters	91 liters

The allocation is estimated based on calculations given in Nissen-Petersen (2007)[29].

Weekly demands are a good indication on what is needed in a rainwater harvesting system, as there is most likely to rain at least once a week during the rain season. As an example, a 6-member family uses approximately 550 liters of water in one week.

6.6 User demand specification

The user demand specification organizes views, demands and needs of all the users[3]. The users are given notations to show who was involved in the demands:

A = Aid in Action, N = Ngumbulu Development Center, V = Villagers, S = Surveys

Demand	Extraction/description	User
No donations	The product shall not be based on donations to the villagers. Which again gives cost restrictions. This is an absolute demand.	A, N
Local production	Some components are to be produced locally to add value to the community.	A, N
Give good affiliations	The solution should create awareness and give people a good impression of the development center.	N
Relocation	The system must be able to be repossessed so it can be resold in case the villagers does not pay their installments	N
Education	The solution should facilitate for community awareness initiatives.	N
Cost	The solution must be affordable for the most marginalized members of the community.	N, V
Water close to home	The distance to the solution should be significantly closer to people's homes than where they get water from today.	V
Self-made components	The desire for self made components is directed towards the overall cost of the system	V
Bigger storage containers	The reservoirs should be larger than the available jerry cans of 40 liters	V
Modulation	Systems should be modular to be able to increase their supply as the villagers can afford it	V
Maintenance	Maintenance should be easy enough to allow for villager to do it themselves	V
Capacity	Weekly supply of 90 liters per person is a target. However, all increase is welcomed.	S, V

Part 3 - Development process

7 Concept development

Approaches items 5 & 6 in the task list

As discussed in chapter ”5 Rainwater harvesting, technical aspects”, there are several existing systems available, however none have yet to be utilized to a satisfactory degree in Ngumbulu. This is believed to be because none of them completely fulfill the demands for this specific area. The following chapter shows the development of concepts based on specific needs in Ngumbulu

7.1 A discussion of cost

The aim of this project is to find solutions for the less affluent and cost is therefore of high priority. The UN Development Program estimates that an overwhelming 50 % lives below the poverty line (1.25 $ per day) in rural Kenya[31], and there is further reason to believe that a large percentage live far below this line. It is a fair assumption that the inhabitants in the Ngumbulu area follow the same pattern, which means that the monthly income of half the population is approximately 37 $ or 3 000 Ksh. This is not necessarily giving the right impression as the economy in rural Kenyan households is often unstable and depends largely on the success of the crops. The normal western "monthly income" type of economy is not seen often and this may only serve as an indication.

During the second field trip questions were asked about what the inhabitants may be able to spend on a tank if they were to buy it this instant. Most of the answers leaned towards a cost of approximately 10 000 Ksh which equals a three months salary. Looking at what is already available such as bicycles (6 – 7 000Ksh) this seems to be a good aim for the harvesting system. However, since the economy varies, there must be presented options below this point not to exclude the most challenged in the community.

7.2 Product demand specification (PDS)

It is difficult to set specification demands on a product heavily influenced by social factors and in an area where few "rules" apply. However, such a specification can be a very good tool in organizing important aspects making sure nothing is forgotten in the development process. The PDS is a collaboration of user demands, technical and social limitations and intuition by the developer, thus most demands are negotiable and up for discussion, now and in the future. Only demands that are directly influencing the rainwater harvesting system is included, which means the educational and science (data collection) aspects are not included.

Explanations:

Intuition is used where the developer has not been able to test or discuss with relevant parties, or the demand breaks with common sense or security. Where this is a factor for a demand the notation "Developer" is given.

"Focus" shows what demands have played a prominent role in the development process, both social and technical.

Red = Primary focus

Orange = 2nd level focus

Green = adds value to the product, but is not given any specific focus

Group	Number	Type	Demand	Discussion	Extracted from	Focus
Cost	1.1	Total cost	< 10 000 Ks	Should the proposed solution be more expensive, close evaluations including the user must be performed. *The value does not take down-payment plans into account.*	*"A discussion of cost" "User demand specification"*	
Function demands	2.1	Capacity	Weekly supply of 90 liters per person.	Highly debatable as the user is generally happy about any increase in domestic water supply. Should be considered in cooperation with cost.	*"Water consumption estimates" "User demand specification"*	
	2.2	Modularity	Simple increase in storage	Modular systems where user easily can increase the capacity is desired	*"User demand specification"*	
	2.3	Water quality	Easy to keep clean and contain no hazardous materials.	Target values are WHO standards. However, a realistic approach should be made given the operation conditions. A minimum is that water is safe after boiling or similar treatment.	*"Design considerations"*	
	2.4	Covers	Reservoir to be coverable	The reservoir must be coverable to avoid contamination either by a lid, blankets or similar	*"Design considerations"*	
	2.5	Filters	Filters are to be installable on the system	This is non negotiable as filters are truly important for the water quality	*"Design considerations"*	
Environ mental demand	3.1	Location	Within the family compound, or in close proximity (100 meters).	For supervision and short distance carrying. Highly debatable if good solutions break with the demand,	*"User demand Specification" "Developer"*	
	3.2	Physical size	The system should minimize the impact on arid land.	Present installments should be utilized to minimize physical impact. No direct restrictions and may be discussed.	*"Developer"*	
Operatio nal demands	4.1	Operations	First flush to be diverted by one simple operation.	It is desirable that this is as easy as possible, and should not require a large effort from the user.	*"Fundamental needs"*	
	4.2	Multipurpose	Components to be utilized to other purposes	Would give the system an extra desirable aspect, however not a firm demand	*"Developer"*	
	4.3	Evaporation	Reservoirs should be easily coverable to avoid evaporation	Cover is either a lid, blankets or similar	*"Focus: roof catchment systems"*	

Group	Number	Type	Demand	Discussion	Extracted from	Focus
	4.4	Effort to make operative	Limited to before each rain season	Debatable, however as few as possible operations is to be needed before system is operative before each rains.		
Installation	5.1	Who	Buyer/NDC	The buyer should (with a minimum of training) be the main installer of the system to avoid cost. In special cases the NDC would be the installer, however this is not desired.	*"User demand specification"*	
	5.2	Methods	Simple methods and tooling like hammer, saw and knife only	The lack of technical knowledge requires simple methods of installation if buyer is to be self reliant on this matter.	*"Fundamental needs"*	
	5.3	Time (only applies to NDC)	Minimal	As little time as possible is desired if the NDC is to do the installation to reach a larger number of beneficiaries.	*"Developer"*	
	5.4	Where	No exclusions	The system should be installable and useable regardless of what preconditions the user/buyer has. All roofs, all compounds should be susceptible for the system. In special cases the demand may be altered.	*"Utilization of rainwater harvesting"*	
	5.5	Relocation	Possibility of retrieving and displacing the system	Displacing the system as a part of payment insurance is important. The system should be able to be retrieved; however should other arrangements be fit for the same purpose, the demand may be discussed.	*"User demand specification (NDC)"*	
	5.6	Tooling	Knife Hammer, Metal scissors, Shovel/pick	Different demands apply if installed by user or NDC. However simple tooling is important to ensure easy and proper installation.	*"Utilization of rainwater harvesting" "A matter of resources" "Fundamental needs"*	
Reliability	6.1	Durability	<10 years	The longer the component lasts, the better. Must be seen in relation to cost. Warranty is not a common demand in rural-African areas, however some indications on lifespan should be given. Rules should follow the system and demand only applies if adequately maintained. Target value, but is of course severely influenced by cost.	*"Developer"*	
	6.2	Robustness and efficiency	Keep efficiency during heavy rainstorms and tough conditions	The system components shall not break in the typical heavy winds and rainstorms that occur in Ngumbulu.	*"Environmental conditions"*	

Group	Number	Type	Demand	Discussion	Extracted from	Focus
Maintenance	7.1	Who	Buyer	There should be no need for additional support for regular maintenance. A minimum of training may be required to fulfill the demand.	*"User demand specification"*	
	7.2	Frequency	In the first days of rain season only.	Maintenance should be non-critical fixes or cleaning only during the entire lifetime. The less maintenance needed is better.	*"User demand specification"*	
Production	8.1	Methods	No welding or specialized tooling needed. Simple tools like hammer, saw and knife should be enough.	Due to lack of skilled labor, however if workarounds are seen fit, the demand is debatable.	*"Fundamental needs" "A matter of resources" "User demand specification"*	
	8.2	Availability of components	Ngumbulu> Katangi> Kitui	If imported by NDC Kitui is the farthest allowed. Katangi is preferred. For users Ngumbulu is the farthest allowed.	*"Fundamental needs" "A matter of resources"*	
	8.3	Local production	Components should to the largest degree be producible locally	Strived for, but debatable if not achievable. Indirect value creation will fulfill the demand; such as liberation of time and exertion for the villagers, thus the demand does not get top priority.	*"User demand specification"*	
Other demands	9.1	Market demand	Villagers to have good relations with the product	This demand is highly impressionable by other factors, however it is important to consider. This demand affects the affiliations to NDC as offering an unwanted product would lower their status in the society.	*"Design considerations" "Utilization or rainwater harvesting" "User demand specification (NDC)"*	
	9.2	Safety	Minimal safety hazard	The system (predominantly tanks) shall not pose a safety threat to humans in case of breaking or in any other situations.	*"Developer"*	
	9.3	Local independency	Management by NDC only	As low level of management from NDC as possible is desired to ease workload.	*"Developer"*	
	9.4	Global independency	No government support to be needed	The demand is given to avoid corruption and time-consuming appliance processes	*"Developer"*	

PS: There is another PDS in the appendix on page 161 which is to be ripped/cut out for overview purposes.

7.3 Separation

The demand stating no exclusions gives the necessity of separating into two systems. Not all inhabitants have suitable roofs; as for instance thatched roofs are not usable for harvesting. Therefore separation into “Roof top systems” and “Independent systems” is necessary.

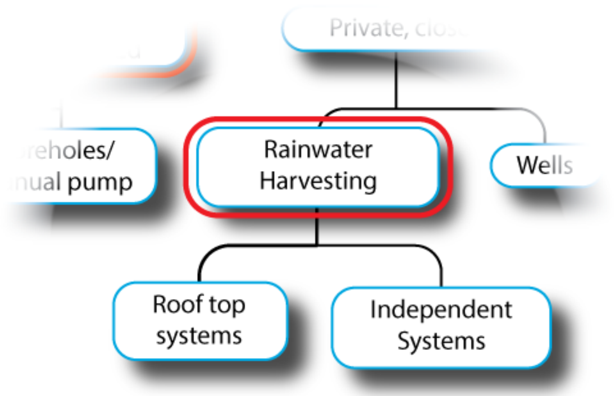


Figure 25 Separation

7.4 Explanations to development and evaluations

The development process is structured as follows:

1. A number of concepts are developed with basis in the product demand specification (PDS). The concepts are limited within the predetermined demands such as adequate water quality, possibility of filters and covers etc. but ranges between the measurable demands such as cost, durability, possibility of local production etc.

2. The concepts are thereafter briefly presented with pictures, whereas a more through description and pros and cons discussion is found in the appendix.

3. An evaluation is performed on opposing concepts based on the measurable product demands. Note that not all measurable demands are relevant for all concept ranges, e.g. safety and multipurpose is not included in “delivery system” evaluations.

4. The concept gains the scores 0, 1 or 2 on each demand, which is multiplied by the weight of the demands (for instance cost is weighted more than status). The weighting is different for each concept range, and is shown in doughnut charts. The total sum is then presented in a chart where the concepts are compared to a maximum sum of 200. Only the results are presented in the text, whereas the complete evaluation may be seen in the appendix. Note that the results are indicative since the points given are always debatable and is only a tool in finding the best solutions.

5. Lastly a conclusion is made based on the evaluation, pros and cons and general intuition, determining what concepts are to be brought further into prototyping and testing.

7.5 Roof top systems

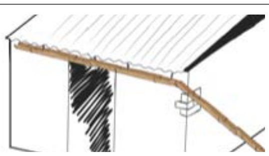
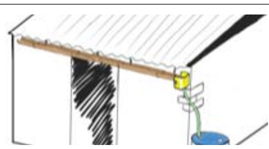
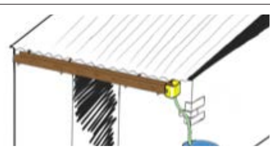
The two field trips to Ngumbulu revealed that most inhabitants have iron sheet roofing on at least one building. In many occasions most of the buildings in the homesteads are of this kind, leaving great possibilities in utilizing existing structures in rainwater harvesting. The iron sheet provides an optimal catchment surface with great durability and run-off coefficient. This leaves the delivery system and the storage reservoir as the primary focus for development, and the placement and installation of such. In reality, the two sub-functions, delivery system and reservoirs, are quite independent and does only to a small degree influence each other. Therefore they will be developed independently, however with the final connection between the two in mind.

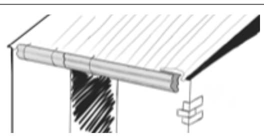
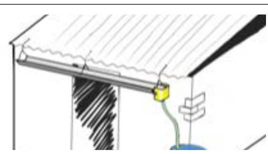
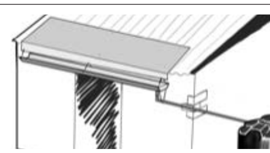
7.5.1 Delivery system

Design of the delivery system is a very crucial part of this project. The field trips showed that the locals struggle greatly in making gutters that are durable and efficient. This is both in regards to installation, the gutter itself and the drop outlets.

Concepts

Within the delivery system there are a two main sub-functions: gutter and drop outlet (downfall is another, however not included here), which are to a large extent reliant on each other. The following chapters show a variety of concepts seen to fit the predetermined demands of the product demand specification. For overview purposes the concepts are only briefly presented here, and more thorough explanations are given in the appendix on page 165.

All sisal	Sisal Jerry-can	Planks and tarp
		
Stem of sisal hollowed out as gutter. Cheap but not durable.	Cheap, not durable, jerry can outlet may be challenging.	Expensive, and hard to construct but durable.

Bent iron sheet	Flat iron sheet gutter	Pre-made iron gutter
		
Durable, available, known in the community, expensive.	Durable, local production possibilities, expensive.	Very expensive, for comparison purposes only.

Evaluation

Evaluating the concepts give an indication on what may be useful to bring further into testing and realization. For the delivery system the demands 1.1, 6.1, 6.2, 7.1, 7.2, 8.3 and 9.1from the PDS are seen as decisive factors as seen in Figure 26.

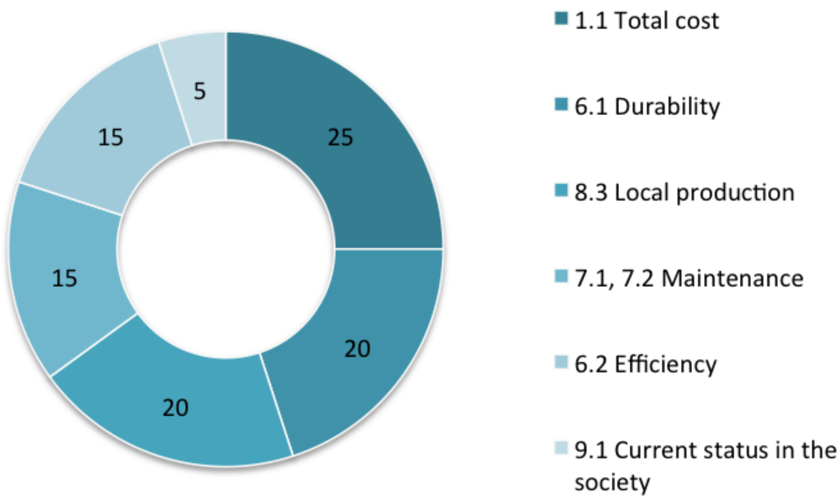


Figure 26 Delivery system weighting

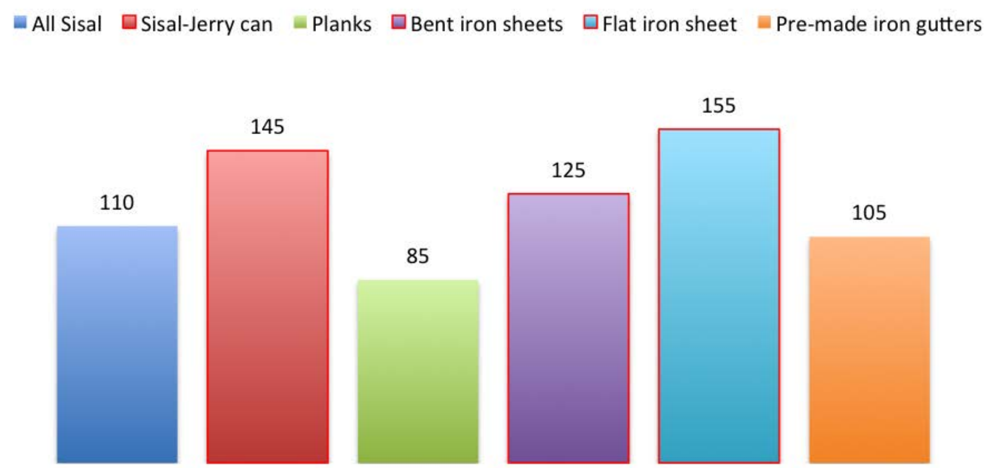


Figure 27 Delivery system evaluation scores

Figure 27 indicates that the Sisal-Jerry can (145), bent iron sheet (125) and the flat iron sheet gutters (155) are the most promising concepts. The complete evaluation may be seen in the appendix on page 180

Conclusion

The investigations and evaluation of the delivery system gave some interesting results and the following concepts are taken further into prototyping and testing.

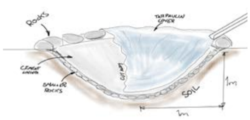
- Sisal-jerry can
- Bent iron sheet (jerry can drop outlet)
- Flat iron sheet (jerry can drop outlet)

7.5.2 Storage reservoirs

The storage reservoir is one of the biggest issues in Ngumbulu. Tanks, whatever types, are expensive and may be very hard to locate or construct. There exits an enormous variety of tanks which makes the development process more of an investigation on what may be most suitable to introduce in this area.

Concepts

Given the focus on the less affluent, smaller reservoirs seem to be most fitting. Smaller reservoir may have a higher cost pr liter, but the introduction cost, which is often the limiting factor, is lower. Tanks may be constructed above and below ground, but the impact on the compound, installation time and cost makes this option seem less as an opportunity in Ngumbulu. Therefore focus is mainly, but not limited to, above-ground tanks. More thorough descriptions may be found in the appendix on page 165

Hole in the ground	Jerry cans	Blue drum	Black tanks
			
Small scale dams dug next to homes. Erosion problems. Tarp is needed, complicated to cover and may be unsafe for children	Well known in the community. Durable but with capacity issues. Cheap initial cost.	Durable, highly regarded in the community. Capacity issues, cheap initial cost. Movable and multipurpose possibilities. 200 liter	Durable, very popular. May be hard to find but lightweight and easy to transport. High initial cost. Sizes 100 - 24 000 liters available.

Galvanized iron tanks	Concrete tank	Ferro-cement
		
May be made locally but skilled labor needed. Corrosion susceptible.	Widely used. Requires skilled labor and takes time to build. Cheap, but low status in the community.	Widely used. High skilled labor needed. Cheap pr liter but low current status.

Water pot	Cemented oil drum	Water bag
		
Used in other parts of the world. Relatively cheap but requires skill and time.	Low initial cost, allows for local production. May be hard to find discarded drums.	Vinyl fabric. Requires high skill if made locally. May be cheap but has durability issues.

Evaluation

Evaluation of the reservoirs is a complex matter as the varieties are so great. A ferro-cement tank may for instance have different attributes depending on size, while the size of a blue drum is fixed and a larger quantity is then needed to be comparable. However, as smaller tanks may be a preferred solution, a standard was set on 500 liter. Mostly this affects the price estimation seen in the appendix on page 174. It is worth to notice that capacity is excluded from the evaluation, as all reservoirs may be adjusted for this, either in size or in quantity.

For the reservoir the following demands are seen as decisive: 1.1, 4,2, 5,2, 5.3, 5.5, 5.6, 6.1, 7.1, 7.2, 8.3, 9.1 and 9,2 as seen in Figure 28

Figure 29 shows that the Cement lined oil drum (150) has great potential. Also the black plastic tank (140) and the blue drum (130) gain great scores. It should be noted that the jerry cans (125) and the water pot (115) also has potential.

The complete evaluation chart may be found in the appendix on page 181

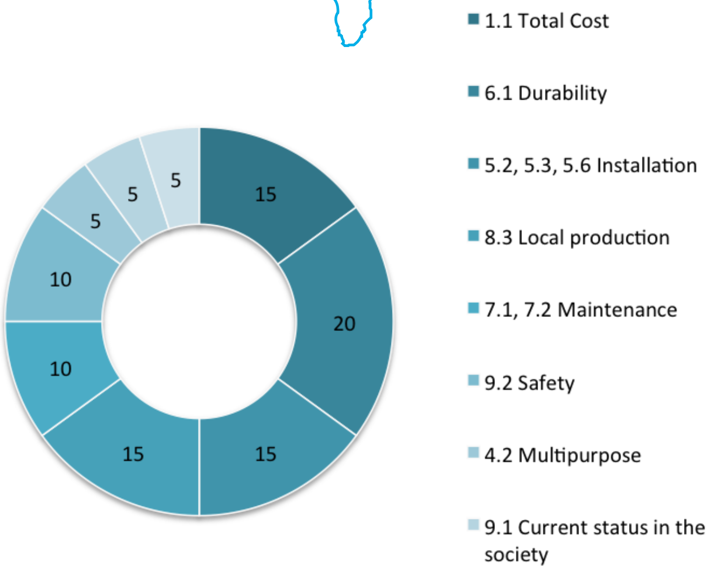


Figure 28 Reservoirs weighting

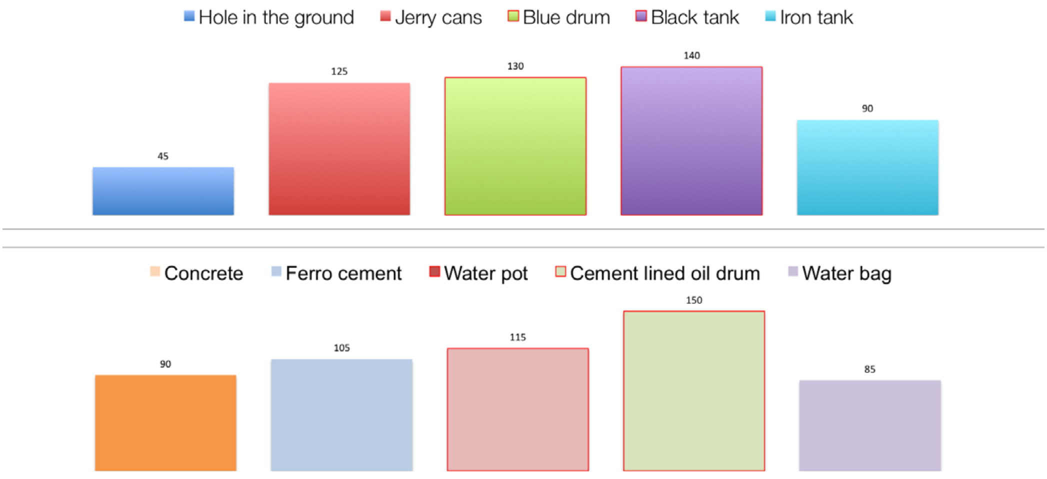


Figure 29 Reservoir evaluation scores

Conclusion

A decision based on the evaluation, pros and cons and intuition took the following reservoirs further into prototyping and testing.

- Cemented oil drum
- Water pot
- Blue drum
- Black tank

The jerry cans were excluded because of the small sizes available (40 liter max) and are therefore seen as an addition only, not a main reservoir. The water pot was included because the developer wanted to explore its possibilities further.

7.6 Independent systems

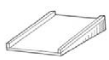
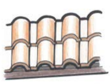
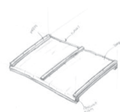
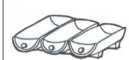
There are homesteads in Ngumbulu that have no suitable roofing for rainwater harvesting, which gives the need for an independent system. There is in fact a link between the ones having no suitable roofs and general income, as people tend to rebuild homes using bricks and iron sheet roofing when their economy strengthens.

Concepts

The following sections show a brief introduction to concepts developed for this purpose. Some of the presented concepts are made for this project, whereas some have previously been developed for similar projects with similar goals.

Catchment surfaces

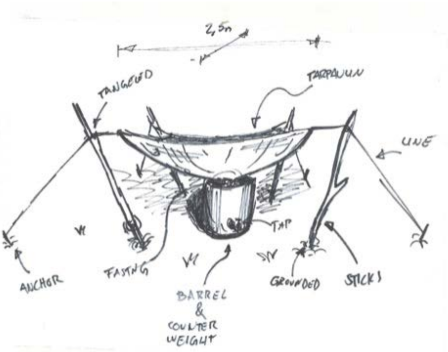
The independent systems are largely dependent on the catchment area. This area may be constructed with different materials and in different configurations. The following will present a variety of such, selecting a couple that are most likely to be usable in the systems.

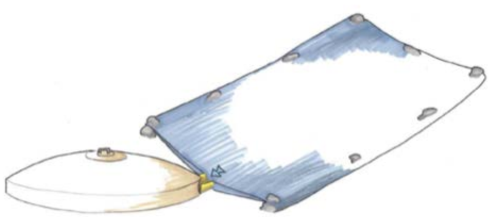
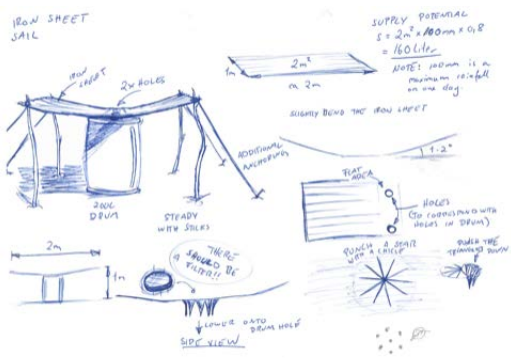
Iron sheet	Concrete	Ceramic tiles	Sisal stems	Tarpaulin	Overlaid planks	Planks and tarp	Cut in half plastic drums
							
Medium expensive but good durability and availability	Too large permanent construction	Low availability, difficult construction	Cheap but poor efficiency and durability	Somewhat expensive but easy to work with	Poor availability, expensive	Poor availability, very expensive	Very expensive

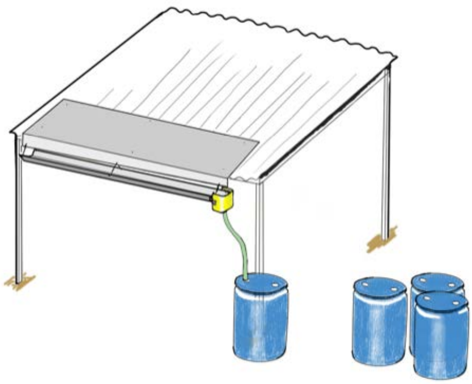
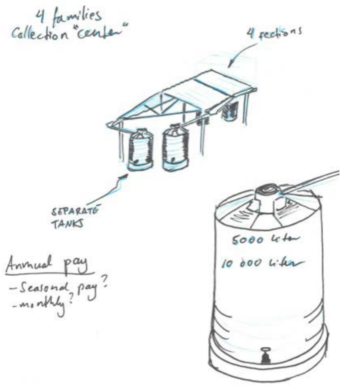
Considering the specification of the system only two surfaces, the iron sheet and the plastic tarpaulin, seem to be usable in this system. The iron sheet is seen to be a very reliable surface and is fairly easy to locate in Ngumbulu. It is also well known in the area, and even if the price may be relatively high (700Ksh for a 1x3 m sheet) it is seen as one of the best alternatives. The tarpaulin comes in two qualities where the see-through costs around 150 per m^2 and the more robust (and preferred) black tarp is about 300 per m^2. The tarp is not used for the purpose of collecting water in Ngumbulu now, however it is utilized for this in other places of the world.

Complete systems

The table shows an overview of the generated concepts, whereas a more thorough explanation is given in the appendix page 165

Tarp and drum	Tarp and water bag
	
Tarp suspended in four poles found in the nature. Blue drum functions as anchor and a hole in the tarp is fastened to one of the two capped openings in the drum. Durable initially cheap reservoir but has capacity issues. Tarp is ineffective in strong winds and may rip easily.	Tarp suspended in four poles with a hose in the middle bringing water to a water bag. Durability issues with tank and tarp is ineffective in winds. May be cheap, but as of now components must be imported. The concept was previously developed by Norwegian engineer Henrik Bull. .

Laid out tarp	Drum top catchment
	
A tarp is laid out on the ground anchored by rocks and longitudinal poles. The landscape must be sloped towards a concrete tank in the ground. High capacity but expensive and possibly low durability and high user operation demands. Developed by engineer Kaja Flottorp.	Uses iron sheet as catchment surface fastened in corner poles and anchored with string. Blue drum is used as reservoir. Has capacity issues, but is initially cheap and durable. No need for extra operations during rain season. Easy to clean.

Permanent stand	Catchment center
	
Independent stand for catching rain equipped with gutters and tanks. Very robust and durable but is very expensive because of all the extra equipment needed. May not be suitable for the most economically challenged in the community. High installation effort demands. May serve as shading for vegetables	Catchment center for several families to invest in together. Each family gets their portion of the roof and a reservoir. The concept was initially developed to be cheap, however the total relative cost per family is still at the level of the "permanent stand" because of management and security demands.

Evaluation

Factors deciding for the independent systems are 1.1, 4.4, 5.2, 5.3, 5.5, 5.6, 6.1, 6.2 and 9.3. In this concept range there are factors like independence, physical size and efforts to make the system operative, which is not seen in the other evaluations. Figure 30 shows the weighting of the criteria.

Figure 31 shows the outcome from each criterion put together and set up against each other. As it can be seen, the Drum top catchment (180) system gained the best score. Also the tarp and drum, permanent stand and the catchment center gained good scores, and should not be forgotten.

The complete evaluation chart may be found in the appendix on page 181

Conclusion

Based on the evaluation exercise, intuition and pros and cons, the most promising concept for independent system is the Drum top catchment. The concept was chosen primarily because of good durability and less operation demands, and will be taken further into prototyping and testing.

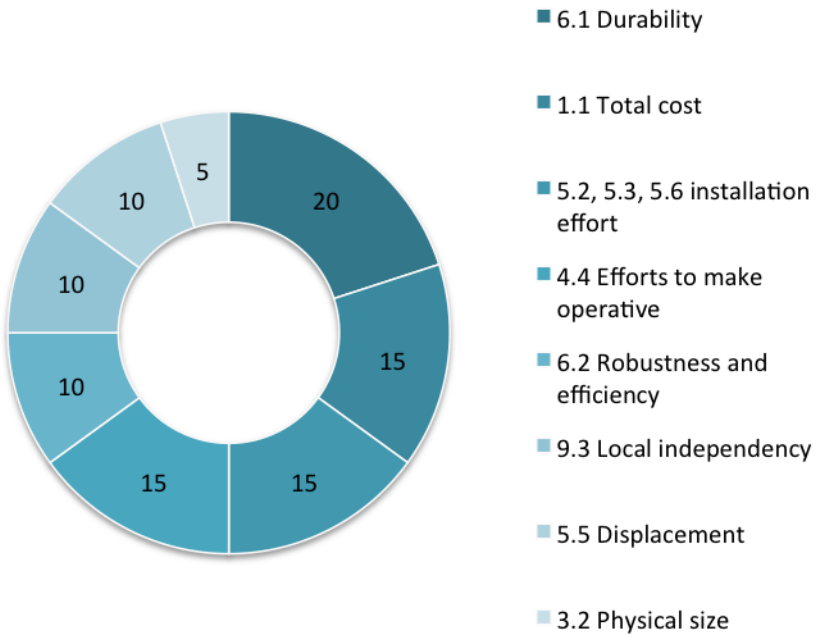


Figure 30 Independent system weighting

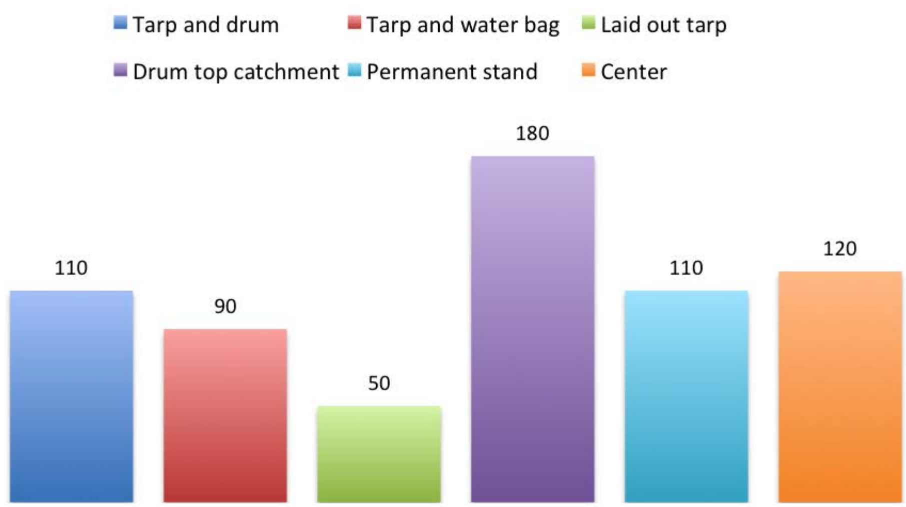


Figure 31 Independent system evaluation scores

8 Prototyping and testing

Approaches item 7 in the task list

The development process in chapter 7 left a range of possible solutions, but the theoretical approach gives many uncertainties and the listed options must be physically tested to better understand their viability and potential:

- Sisal gutter
- Bent iron sheet gutter
- Flat iron sheet gutter
- Drop outlet
- Cemented oil drum
- Water pot
- 200 liter blue plastic drum
- Black plastic tank
- Drum top catchment

The developer performed the construction and testing together with the staff at Ngumbulu Development center.

8.1 Gutter systems

Sisal gutter

The sisal gutter can be a good and very cheap gutter option, but may be hard to make. An almost 4 meter long sisal stem was purchased for 60 KES from a farmer and brought to the development center. The top of the stem is usually not straight and was cut away, also the bottom 30 cm must be cut off due to rot. This left approximately 2 meter which would be the length of the gutter. This is a maximum of any stem, and the most usual is that 1.5 meter would be fit for gutters. To open the stem, a cut is made halfway through every 20-30 cm along the stem and a chisel is used to break open the pieces. When the whole stem is opened the insides are thoroughly cleaned out. This was time consuming as the stringy insides had to be completely removed, all the way to the harder bark, to prevent rotting. The difficult part was to keep the opening straight, as the fibers of the bark twists along the stem. The whole process took approximately 1.5 - 2 hours, trial and error included.

Figure 32 Sisal gutter - image sequence

Even if the manufacturing process was somewhat time consuming and difficult the gutter is seen as a good option because of availability and cost. In many ways this gutter is best for smaller buildings and as a supplement to more permanent gutters. For instance chicken houses or small storage buildings could be equipped with a sisal gutter to utilize more catchment surfaces.

Bent iron sheet

The bent iron sheet ended up being less prioritized than the other gutter options. There were difficulties in installation and as a large part of the sheet had to be used, the cost would be rather high. The conclusion was that if you had leftover iron sheets from roofing or similar, you may use it as a gutter but it would not be a part of the final solution.

Flat iron sheet gutters

Flat iron sheets were bought from Kitui to see if this was a good opportunity for local production of gutters. One iron sheet was cut longitudinally into four pieces and knocked into shape with a hammer and pieces of 2x4" timber. Both a V- and a square shape was constructed and tested. The V-shape was a little quicker to make but is more subjected to clogging and the installation wires tightened the opening more easily. As the square shape only gave a couple more minutes work, it was seen to be the better

Figure 33 Flat iron sheet gutter - image sequence

of the two options.

Installation and testing of the square gutter showed excellent performance and gives great possibilities for local production. The total construction time, after a couple of tries, was about 10 minutes.

Drop outlets

Three types of drop outlets was constructed and tested; a 5-liter jerry can, a liter-sized water bottle and an oil-can. All were constructed similarly by cutting a “hatch” and threading it onto the gutter with the opening facing downwards. The hatch is used to prevent water from spilling as may best be seen on the photo of the oil-can. All the canisters worked well and it was discovered that the jerry can seemed to be best for the wider iron sheet gutter, whereas bottles and oil-cans were also good for the sisal.

Figure 34 Drop outlets - image sequence

Downfall

The downfall is the final component leading water into the reservoirs. The design is dependent on what type of drop outlet is used.

The following downfalls were located and tested:

- Stick
- Mbaiki stem (hollow)
- River sugarcane (hollow)
- Twisted rope
- Hosepipe

Figure 35 Downfalls, selected

Testing showed that if the selected drop outlet if fit for a hose, and the buyer can afford, this is the best solution. However, the twisted rope turned out to be a very good alternative when combined with a jerry can or bottle drop outlet. The Mbaiki stem and the river sugarcane were hard to make fit, and the stems were also too heavy and too short. The stick was inefficient in winds as the water runs on the outside.

8.2 Reservoirs

Cemented oil drum

The cemented oil drum got good results in the evaluation and a test drum of 200 liters was constructed. The results were very promising as the construction method was simple and fairly quick. The drum was initially old and rusty inside and not fit for water storage. After the plastering with approximately 2 inches of cement at the bottom and 1 inch on the walls the drum was now completely waterproof. The drum became heavier than anticipated, thus not as mobile, but if gently rolled it was movable by one person.

The cemented oil drum showed great potential for reuse of discarded drums and will provide a cheap option for the villagers. It is simple and quick to make and is very durable.

Figure 36 Cemented drum

Water pot

The water pot did not receive a particularly good score in the evaluation, however there was potential in the solution because of low estimated cost vs capacity. The pot was constructed by a mason from Kitui and transported to Ngumbulu. The pot was initially meant to contain 150 liters but would then be too heavy to transport, and a 60-liter pot was made. The cost of one pot was more than anticipated, almost 1750 Ksh for materials and labor, which is a lot more per liter than for instance the blue drum. The pot was also extremely heavy even if only 60 liters, and it took 5 men to lift it of the truck. This excluded the possibility of making them anywhere else than at the final location, which is against the repossessing demand. Also it is too complicated for the average villagers to make themselves.

Figure 37 Water pot

Because of the cost, weight and complexity the pot was discarded as a viable option for the villagers at this point. There may be some possibilities in this for a separate business but for the development center it was agreed that the pot does not meet the requirements.

Blue drums

The 200-liter blue drums was been introduced to the community at an earlier stage of this project and became an instant success. As of now, more than 150 drums have been sold, which show that availability is key for this reservoir. The testing was therefore limited to interviews with people who had and had not yet acquired a drum.

Figure 38 Villagers with blue drum

All villagers having bought a drum were very happy with it and were keen to get more it available. The ones who had no drum claimed it was either because of limited economy or that the reservoir had not yet been made available to them. This shows that the blue drum is a good solution for the community.

Black tank

The black tank has a similar story to the blue drum. As mentioned, in 2013 Aid in Action invested in 5 000- and 10 000 liter tanks for the community members and approximately 30 have been distributed so far. These tanks are however rather expensive and the first field trip revealed some dissatisfaction among the average villager as only the more affluent could afford them. The blue drum was introduced because of this, but again, they have capacity issues.

Villagers was therefore presented tanks in different sizes (and prices) and asked what they would afford if they were to buy them tomorrow with down-payment. Most villagers answered a 1000 liter black tank at the rate of approximately 9 000 KES and therefore this tank seems to be a better solution for the average villager than the 5- and 10 000 liter size.

Figure 39 Villagers with black tank

Figure 40 Building the drum top catchment system

8.3 Drum top catchment

The drum top catchment system is an option for the ones without iron sheet roofs and often the most marginalized in the community, thus the aim was to use as few and cheap components as possible. Initially the plan was to use only four poles, one iron sheet and a blue drum, but the construction would be too unstable. To ensure stability in strong winds, the corner poles were put into the ground and a cross over pole was attached at the top with wire as seen on the picture. The iron sheet was hammered flat at the middle so that it would bend transversely. Some difficulties were experienced with this as the sheet was more agile longitudinally and the hammered part had a tendency to pop back out. However after some work the sheet was in the correct shape and was placed on top of the drum and the pole frames. As the iron sheet bulged, wire was used to tie it into place. Further, the top of the drum was half way cut open to allow for water to enter. The initial idea was to only use the two small openings equipped with a cap, but this showed to be impossible. Two holes were then simply cut in the iron sheet to serve as drop outlets which worked well during testing.

Testing showed great possibilities in the concept and even if a couple of more components were needed than initially anticipated, the solution is simple and cheap to make. It was concluded that the concept fits the set requirements and will be part of the proposed solution. The concept would also work well with the cemented oil drum as a cheaper alternative.

8.4 Conclusions

The testing gave valuable information on the viability of the solution and gave both the developer and the NDC staff important practical experience with the concepts. The most important findings were perhaps the great potential in the flat iron sheet gutters and the cemented oil drum. But also the discarding of the water pot and the difficulties with the bent iron sheet gutter was a good discovery.

After testing the rainwater harvesting system will now constitute of the following components:

Individual systems:

- Drum Top Catchment

Rooftop systems

- Sisal gutter with bottle or jerry can drop outlet
- Flat iron sheet gutter with jerry can drop outlet
- Cemented oil drum
- 200 liter blue plastic drum
- 1000 liter black plastic tank

It should be noted that testing in real life conditions for a longer period of time is needed to see the long-term performance of the solutions. However, all the components have a relatively known life expectancy in this climate and lifetime is seen to be at least 10 years on all except the sisal and the wooden poles on the drum top catchment, which both need to be replaced (maybe) annually.

As a product line is now ready for pilot projects, the next chapters will more closely present the final solutions and the intended realization and implementation.

Part 4 - Solutions

9 Proposed solutions

Approaches item 8 in the task list

As discovered in the background- and general needs chapter the water problem in Ngumbulu is complex, and there are several aspects in addition to the lack of water itself that must be addressed. The main focus has been to develop the rainwater harvesting system however other fundamental needs have always been in mind. Lack of data on rain intensity and the potential in harvesting techniques was also focused on while developing the system. In addition there is a great need for increased knowledge about the techniques to fully exploit its potential. The three needs/solutions are intertwined and must work together to optimize the total effect of rainwater harvesting.

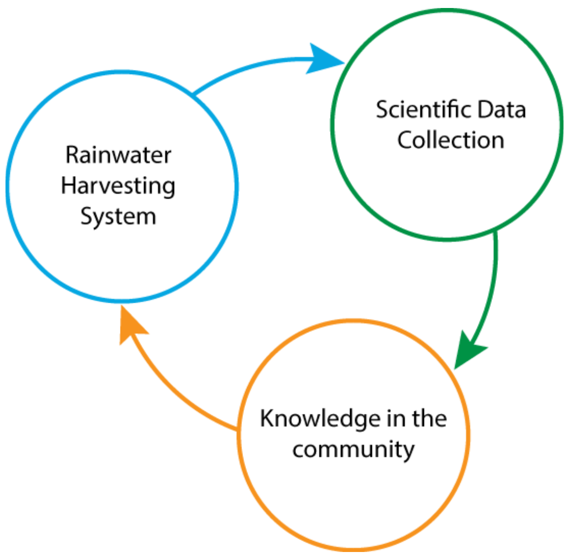


Figure 41 Solution circle

9.1 Rainwater harvesting systems

The concept development phase showed the rainwater harvesting system must be twofold, one for villagers with iron sheet roofing, and one for those who have thatched (or similar) roofs. The following chapters give explanations to how the proposed solutions are intended.

Roof dependent system

The roof dependent system consists of two sub-functions, the gutter system and the reservoir. The two are more or less independent which is beneficial for the user in terms of modularity and possibility of upgrading the individual components.

Sisal gutter

A sisal gutter is made from the stem of a common plant in Ngumbulu, the sisal, and presents a good option for those who are more economically challenged, or those who need gutters for a number of smaller buildings. Villagers can make the gutters themselves following the instructions in chapter 11.2 on page 120. Constructing their own gutters may also increase the feel of ownership, thus increasing the probability of taking good care of the product. The manufacturing process is not entirely straight forward and it is recommended that the development center runs workshops with the community to show the proper techniques. Sisal gutter-making may also present an extra source of income for handy villagers such as carpenters and wood carvers. It is advised that the development center identifies possible candidates for this and gives instructions and help if needed.

The sisal gutter is not a very durable gutter so the need for repairs may be great, and it is suspected that gutters must be replaced after each dry season. However, if the usage and maintenance directions given in chapter 10.3 on page 116 is followed these efforts may be minimized. It is also crucial that gutters are installed correctly, if not it is likely to fail in heavy rain and winds. In chapter 11.1 on page 118 correct installation procedure is explained and should be followed.

The cost of gutters will vary with the stem that is available, however a 2 meter gutter will cost approximately 60 KES, which is almost 1/6th of the pre-fabricated gutters available today. The initial cost is often the greatest hinder for most, and even if durability is poorer it is a very good option.

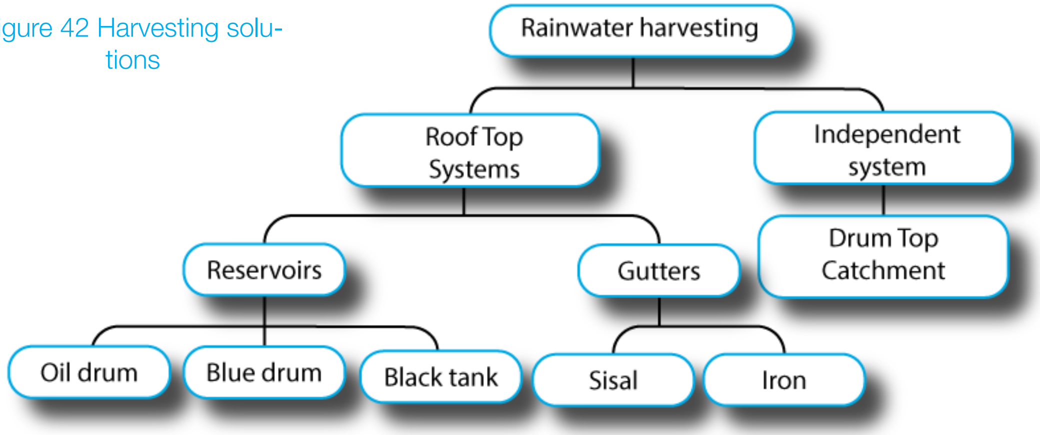
Self made iron gutter

The other gutter option that was developed shows great potential both for villagers and for the development center. The self-constructed galvanized iron sheet gutter is very effective, durable and requires less maintenance, and is predicted to be a high demand product in the area. This is based on discussions with the villagers where the gutters, with price estimates, were presented.

The gutter is a potential business opportunity for the development center and a revenue model is presented in the appendix 18.7 on page 183. The center is looking to find sustainable projects that are not reliant on outside funding. This is such a project, and by cheap manufacturing tools and methods, each gutter may generate a small income to be put into further expansion of the business. One 2-meter gutter costs approximately 125 KES in materials and may be resold at 150 KES (less than half of the prefabricated gutter), which will generate 25 KES per gutter for the center, not considering labor and tooling. The given revenue model is a suggestion for the development center, however some altering may be necessary with more investigations on the matter. Manufacture instructions may be found in chapter 11.3 on page 121.

The life span of the gutter is suspected to be 10 years or more if installed and maintained properly.

Figure 42 Harvesting solutions



Installation instructions are given in chapter 11.1 on page 118 and the maintenance can be seen in chapter 10.3 on page 116

Cemented oil drum

The oil drum lined with cement inside is primarily an option for the villagers to construct their own cheap reservoir and to reuse discarded drums. However the prospect of business for the development center exists, if a large number of old drums can be found and bought cheaply. Usually the drums can be handed in for recycling at larger companies, but if the development center is able to intercept this hand-off, drums may be plastered with cement and resold to the community. It is highly advised that both Aid in Action and NDC makes an effort in achieving this because of the great possible income for the center.

Old drums may be bought for 500 KES with cement at 275 per drum, which gives a 200 liter reservoir for less than 1 000 KES, even with labor and transport included. This manufacturing may be put in connection with gutter manufacturing, creating a cheap option for villagers. In addition, the drums are expected to be very long-lived, up to 30 years, if handled carefully and shielded from the sun. Manufacturing manual may be found in chapter 11.5 on page 123.

200-liter polyethylene drum (blue drum)

Blue drums are the most reliable and durable option for the villagers, and have already had a good impact in the society. The drums cannot be produced locally but has so many other advantages that it is still seen as the best option for the community. Especially the durability and mobility of these lightweight reservoirs makes them very suitable for the African environment. Naturally there is an element of transportation and that the center needs funding to buy them, however this should be seen as an opportunity to strengthen the local economy. It is highly advised that the drums are bought from shops in Katangi, even if this gives a small additional cost. This is to ensure that values stay locally as explained in chapter “4 A matter of resources”. The drum costs approximately 2 200 KES and is suspected to last a minimum of 10 years if properly taken care of.

1000-liter polyethylene tank (black tank)

This tank is seen as the best solution for a larger reservoir, which is desired by a number of locals. The tank is very durable, has a high status in the society and is easy to transport (and retrieve, if needed). By offering smaller tanks (than 5 and 10 000 liter), the development center will presumably raise their status in the community even further, as it demonstrates the wish to serve all society levels.

The tank costs about 9 000 KES to buy; however ordering a larger number could force a better price. This is initially not seen as a business opportunity for the center as the locals need to buy these as cheap as possible, however it is up to the center to evaluate this. To ensure a long life, the tanks must be used and maintained according to the instructions given in chapter 10.3 on page 116.

Complete roof top catchment system

Naturally, several of the villagers would want to buy complete systems and not just single components. Examples of complete systems are therefore provided to visualize how they might look when installed and ready for use. The construction of the homes impacts how many gutters are needed and/or if several smaller tanks are better than one larger.

The reservoirs may also be used as storage for water collected from other sources, however it is recommended that river water is kept separate to reduce the risk of polluting good drinking water.

To show the specter of the solutions one low cost, one midrange and one top system is shown:

1. Low cost system: Sisal gutter and plastered oil drum reservoir

Item	Qty	Cost [KES]
Sisal gutter	2	60
Jerry can	1	100
Installation wire	-	40
Rope	1	40
Plastered oil drum	1	1 000
Sum		1 300

Example building:

Roofing: Lean-to

Length: 4m

This is a low cost option and is also recommended to use for additional catchment if the main house is fitted with one of the more expensive options.

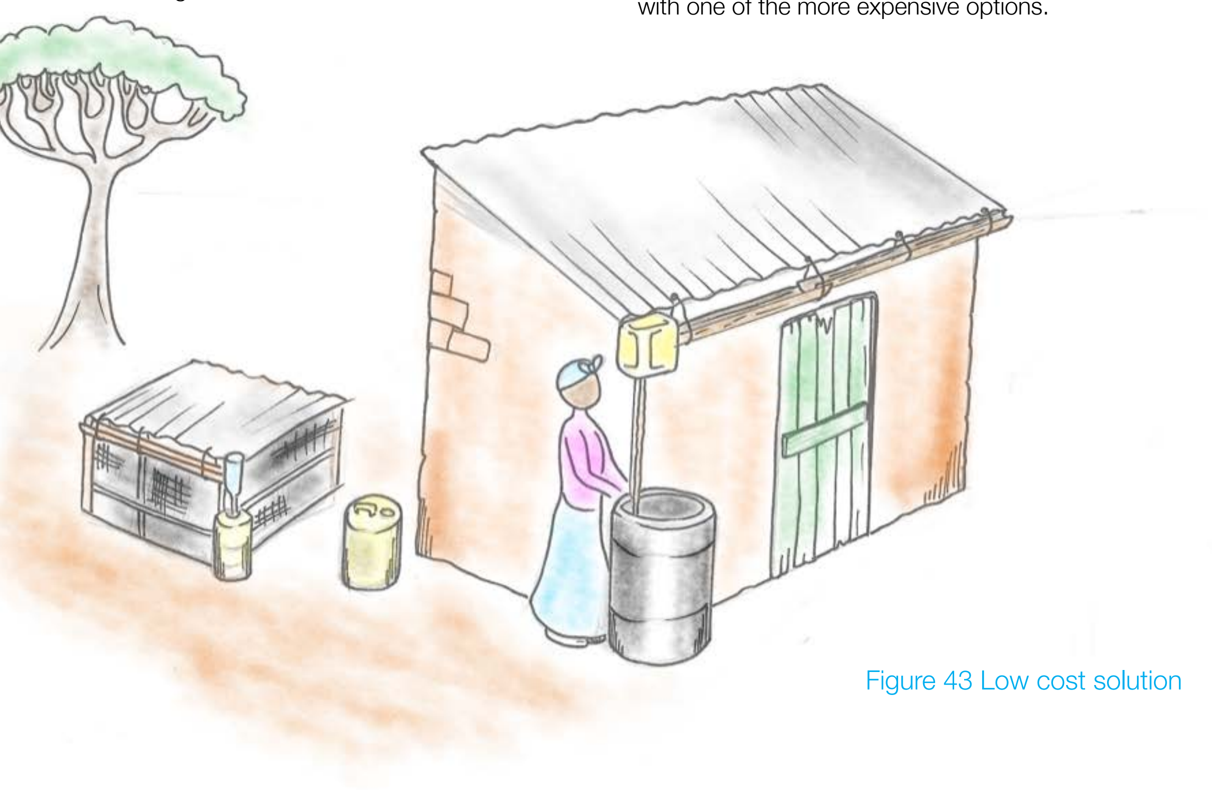


Figure 43 Low cost solution

2. Mid-range system: Iron sheet gutters and blue drum reservoirs

Example building:

Roofing: Gable

Length: 6 m

Item	Qty	Cost [KES]
iron sheet gutter	3	150
Jerry can	1	100
Installation wire	-	60
Rope	1	40
Blue drum	1	2 200
Sum one side		2 850
Sum two sides		5 700

This home has a gable roof, which means both sides must be fitted with gutters and reservoirs to exploit the entire catchment surface.

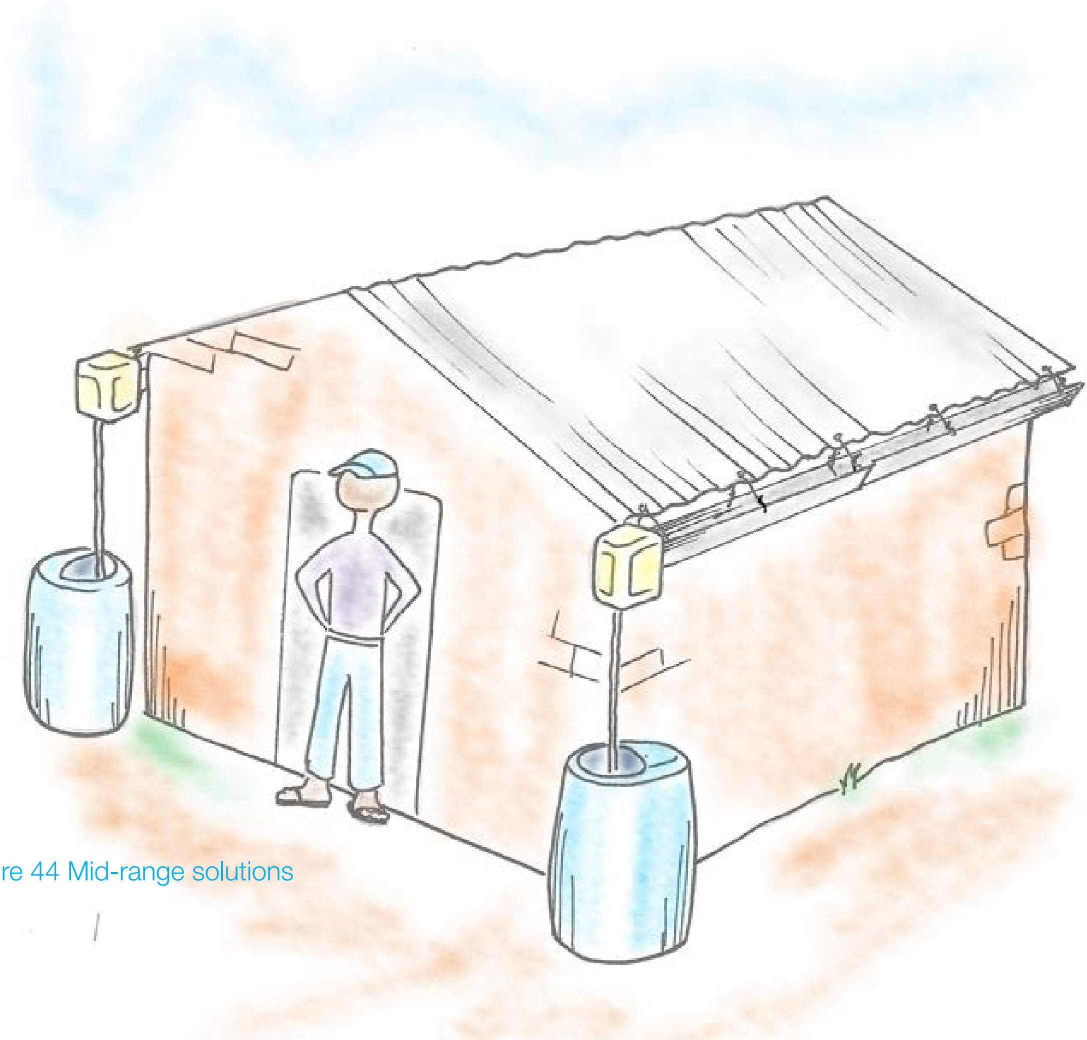


Figure 44 Mid-range solutions

3. Top system: Iron sheet gutters and 1000-liter black tank

Example building:

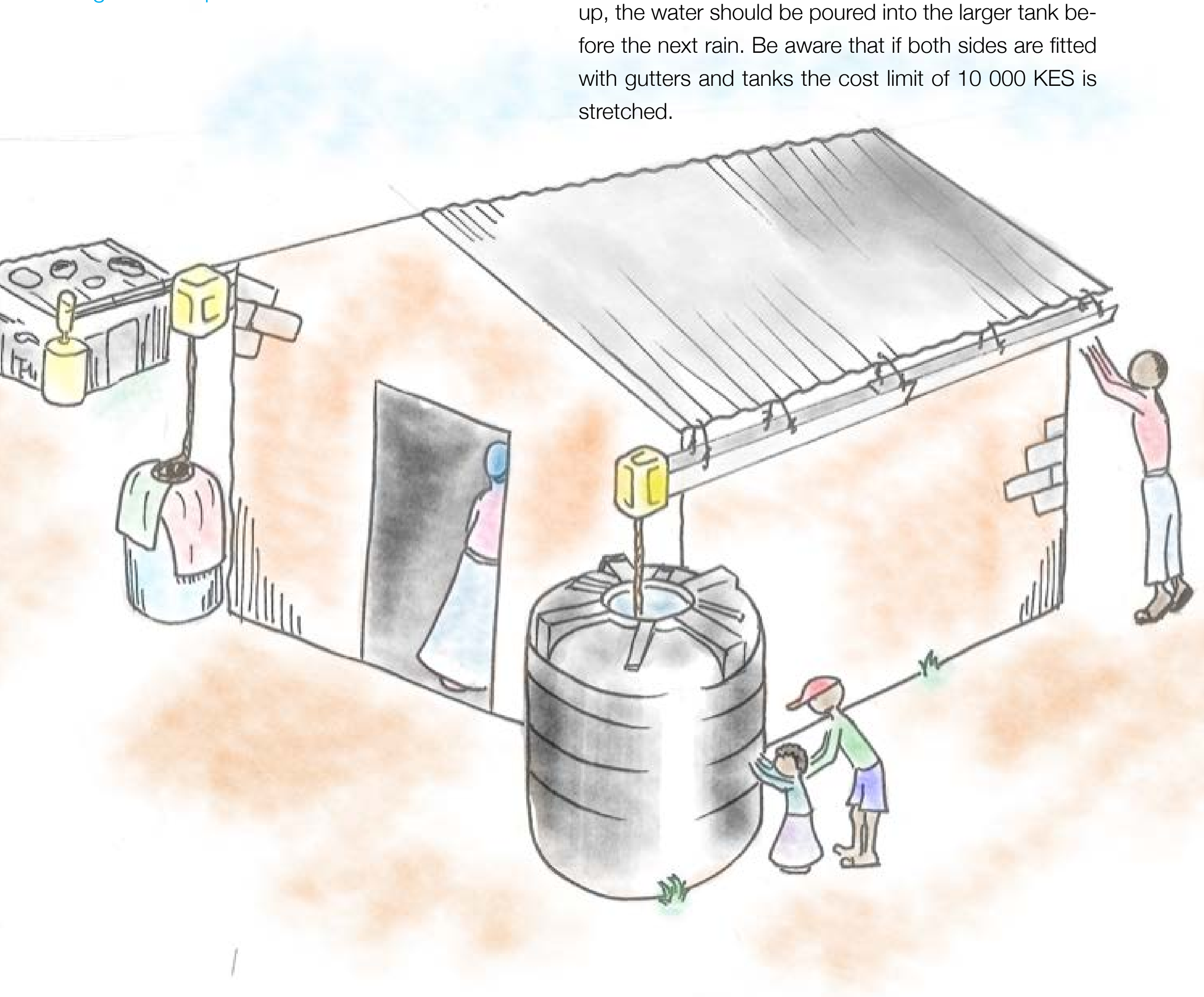
Roofing: Gable

Length: 6m

Item	Qty	Cost [KES]
iron sheet gutter	3	150
Jerry can	1	100
Installation wire	-	60
Rope	1	40
1000 liter black tank	1	9 000
Sum one side		9 650
Sum two sides (+drum)		12 500

The most expensive option is also seen as the best. On the example building one side has a black tank whereas the other has a blue drum. When the blue drum is filled up, the water should be poured into the larger tank before the next rain. Be aware that if both sides are fitted with gutters and tanks the cost limit of 10 000 KES is stretched.

Figure 45 Top solution



Drum top catchment

The drum top catchment system utilizes an iron sheet attached to two timber pole frames to serve as an independent catchment surface. The concept was developed to fit the needs of those who have no suitable roofs for harvesting water. It is a concept where robustness and easy construction has been the focus. Even for those with iron sheet roofs this system may be used as an additional supply.

Because of the sturdy construction it is believed that the system will withstand winds and heavy rains well compared to alternatives based on tarpaulin. Also the robustness against rough climate and low level of operation needed makes this a good fit for the villagers. It is important, though, to shield the system against children and farm animals as they may play with or knock down the construction. Repairs are suspected to be occasional only, with cleaning as the only frequent maintenance needed. To be more certain about life expectancy, some testing on corrosion should be performed.

This is a product that is unfamiliar in the community, which means that the development center needs to show and demonstrate the principles to potential buyers. The system is to be assembled by the villagers themselves and there may be need for workshops to show the best practice for this. Manufacturing guidelines may be found in chapter 11.6 on page 124.

The concept is based on the plastic blue drum, but most containers are fit for the purpose. The important thing is that the opening in the reservoir is large enough for water to enter, and not spill, and that the iron sheet may rest on top of the reservoir. A cemented oil drum may fit perfectly if a cheaper alternative is needed. Both configurations have been included in the presented cost analysis.

In addition filter must be provided for the drum, which may be clothing laid over the opening.

Item	Qty	Cost [KES]
Iron sheet	1	730
Poles	6	free
Installation wire	-	20
Blue drum	1	2 200
Plastered oil drum	1	1 000
Sum (blue drum)		2 950
Sum (oil drum)		1 750

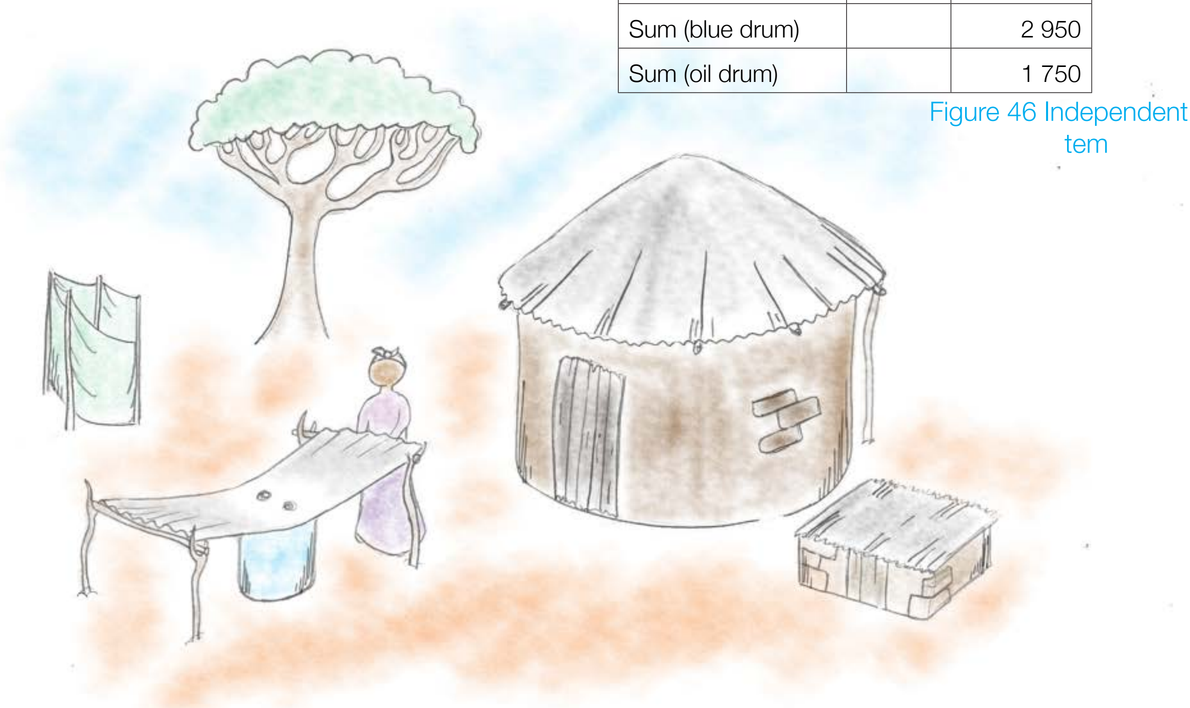


Figure 46 Independent system

9.2 Data collection, Rainwater harvesting test unit

There was discovered a need for more accurate data on the true potential of rainwater harvesting in Ngumbulu. The technique itself is somewhat known but there is little evidence of exactly how much one may collect during the rains, only estimations from the World Bank exists, which accuracy may be questioned. Knowledge about how to optimize the system to raise the potential supply is also limited in the area.

A rainwater harvesting test unit was therefore constructed at Ngumbulu Development Center during the second field trip to the village. The unit was developed using local knowledge and local manpower, and was the outcome of a participatory design process involving the developer and the staff members at the center. The idea of a rainwater harvesting test unit was adapted from the University of Gaborone, Botswana, where they perform roof catchment studies on such a unit[29]. Note that the unit is only for data collection by the center, and is not intended for use by villagers.

The test unit is equipped with a 3 000-liter polyethylene black tank and an iron sheet roof surface measuring 6.4 m^2 effective catchment area. Self-made iron sheet gutters fastened with wires directly onto the roof functions as delivery system. Final cost of the unit and associated equipment was 38 400 KES and was funded by the Norwegian student innovation promoter Spark NTNU. Additional construction details

may be found in chapter 11.7 on page 126.

The initial purposes of the unit are:

- Perform rainwater harvesting data collection
- Educate the community on rainwater harvesting potential
- Demonstrate proper installation and maintenance of systems

The first point is elaborated on in the following chapter. The second and third is included in the next chapter: 9.3 “Community awareness initiatives”.

The picture shows the test unit at a final stage, only the inlet to the tank remains. The blue drum and the rope is part of a demonstration of how to perform rainwater harvesting given to the villagers at the end of the field trip.

Figure 47 Rainwater harvesting test unit

Data collection

With the test unit the development center may now get some most needed data on how much water one is able to collect. Studying the local potential of rainwater harvesting is important to provide the community, or other involved parties, with accurate information. The development center may now give advise to buyers about reservoir sizes and gutters, avoiding unnecessary expenses for the beneficiary. The data will be used to:

- Measure amount of rain that may be harvested during each rain showers
- Calculate weekly supply of water from harvesting, seeing if the families' needs are covered.
- Measure total harvested water during the rain season
- Advising community members on what reservoir size they need

To collect data from the unit the following steps are to be followed:

1. Create a data sheet (spread sheet or paper) noting the date, time of measurement, the total amount of rainwater in the tank, amount of added water since last measurement (subtract todays total from last total), additional comments, tapped amount. Use the below table layout.

Date - Time	Total amount of water in tank	Added amount	Comments	Tapped amount (if applicable)

2. Ensure that the tank is completely empty before each rain season.
3. After each rain shower, measure the amount of water in the tank by using a clean stick measuring the length of the wet area (multiply this with the radius of the tank times pi squared to find the m^3. Multiply again with 1000 to get liters). Note on the data sheet.
4. Each week, on the exact same day (i.e. Mondays at 10.00) measure the amount of water in the tank. This is to get the weekly supply from harvesting.
5. After each rain season report the total amount of rainwater harvested. Important: do not use the water from the tank until the rain season is complete. In the event of overflow, note the tapped amount carefully on the data sheet to keep track of the total amount.
6. The harvested water may now be used for any purpose seen fit by the center.

Dividing the measured amount of water in the tank by the area of the catchment surface, one finds the amount of water that may be harvested on one square meter of iron sheet roof with the type of gutter system on the unit. This may simply be multiplied by the size of any roof (in square meters) to find its potential.

Example:

After a heavy rainstorm there was collected 500 liters of water in the tank. This implies that for each square meter of roof; 500 / 6,4 = 78 liters of water was collected. A family has a roof of 12 square meters and wants to know how much water they can collect. It is now easy to inform that they can collect; 12 m^2 x 78 liters = 936 liters during the same rain storm (this is provided they have similar gutter system as on the unit).

The exercise may also be performed for weekly supply. Then you use the measured amount of water that was added during the week and calculate and use the same calculations as above. Similar may be done for the total rain season.

Rainfall measurements

Rainfall measurements are a precondition to study and collect scientific data on rainwater harvesting. The rainfall determines the potential amount of water that may be harvested during: one specific rain, weekly and the entire rain season.

The following steps shall be undertaken to complete successful measurements:

1. Acquire or make a rain gauge
2. Place the gauge in a location away from buildings and trees. This is to avoid water splashing into the gauge, or obstacles hindering rain to enter the gauge. Approximately 10 meter clearance in every direction is advised. Fasten the gauge firmly to a stand so the gauge does not fall in heavy winds.
3. Create a data sheet (spread sheet or paper) noting the date, time of measuring, and the amount of rain (in millimeter or inches).

Date	Time	Rainfall

4. Do measurements every day at the same time. Usually mornings are the most convenient. Note in the data sheet.

Important: Do measurements even if there has been no rain to create serious data collection.

9.3 Community awareness initiatives

The third part of the solution-trio is “knowledge in the community” hereby entitled “community awareness initiatives”. The name comes from Ngumbulu Development Center who has this as one of their primary agendas. The importance of raising general knowledge in marginalized communities are some times forgotten in aid projects much because of limited time and a “quick in and quick out” mentality. The result is non-sustainable short-term effects in the community and the remains may be limited to broken equipment and distrust among the locals[32].

In this project the development center is in a unique position to educate and empower the local inhabitants because of high regards and former successful initiatives. The center knows the people and is able to reach them in a way foreign aid organizations may never achieve. Realizing this, the developer will only post ideas of ***what*** initiatives the development center may perform, and not so much ***how*** they should do it.

The top priority should be educating the people of how much benefit the rainwater harvesting systems may give them. As described in chapter “5.6 Supply potential and storage calculations” on page 50 it is a fairly simple task to calculate the theoretical supply potential on any given roof surface, which should be communicated to the public. Here the data collection will play a vital role in convincing the people, as specific data have not yet been available. Even if people have difficulties in relating to this, it was experienced during the field trips that people might get an epiphany just by saying “water comes to your home, why go to the river to collect it”. Religion may also come into play as the argument “God gave you water at your house, it is meant for you to take it” gives a strong encouragement to harvest rain.

So how to get the message and knowledge across?

There are mainly three ways of actively doing this in Ngumbulu:

- Community meetings (functions)
- Workshops
- Children education

Community meetings (functions)

Functions are a great way of informing people about new opportunities and knowledge. By letting teachers inform the school kids about time, place and topic of the function one may reach a great number of people quickly. Thereby set up topics for each meeting limiting them to one or one half hour. Topics that should/could be used for rainwater harvesting educational purposes are:

- Education on the benefits of rainwater harvesting
- Demonstrate the basic principle of a catchment system
- How to calculate supply potential on your own home
- Proper usage and maintenance
- How to ensure good water quality

At the end of the second field trip in the village a function was called to inform people about the new discoveries and to educate about rainwater harvesting. More than 80 people showed up, both villagers and school kids, from all the surrounding villages and got a well-planned and thorough introduction to rainwater harvesting and to the ideas. Many also noted diligently to inform others from their village who were unable to join. This shows that functions are an effective way of giving information to the public, however they tend to be a one-way communication, which must be kept in mind. How to perform a function is explained in the "toolkit" in section 15.7.

Workshops

Workshops may be a good way of interacting with the public and giving more practical knowledge. As opposed to functions, the workshops are for a more limited amount of people (5-10, if manageable, more workshops of this size may be held at once) and are often related to a physical task or discussions. The workshops that should/could be held in Ngumbulu are:

- Installation of gutter systems
- Manufacturing of sisal gutters
- Construction of Drum top Catchment systems
- What problems do you have with rainwater harvesting?
- What other initiatives may we do to solve the water problem?

During the workshops it is important to encourage openness and allow for discussions and questions. Also, some level of trial and error may be beneficial for the user as an educational factor. However, it is important not to misguide the participants, and always make sure the correct knowledge has reached through. If the people fail in installation efforts or do manufacturing wrong at home, the system may not work properly and valuable water will be spilled. How to perform workshops are explained in the aforementioned "toolkit".

Figure 48 Great turn up at the function (find the Norwegian)

School field trips and educational days

The American president John F. Kennedy said: “The youth of today are the leaders of tomorrow” indicating the importance of educating children and young adults. Students in Ngumbulu must therefore learn the importance of utilizing rainwater at an early stage so the knowledge will become a natural part of the society in time. The development center has strong affiliations with schools in the area and is in a unique position to perform this important task.

Educational days can be arranged based on the same topics and exercises suggested in the function and workshop sections. However, a more creative and fun experience for the kids should be strived for. For instance students may be tasked to create their own small-scale rainwater harvesting systems as part of the natural science course. The rainwater harvesting test unit should/could play a vital role in this as school field trips may be arranged for classes to come and get educated before they take on their own projects.

Figure 49 Explaining the drum top catchhment system

Figure 50 Teaching shool kids and villagers about the principles of rainwater harvesting

10 Implementation and use

Approaches item 8 in the task list

This chapter gives overall guidelines of how to ensure that the rainwater harvesting system becomes a success. Directions on management, how to ensure good water quality and how the system should be operated and maintained are given to help both end-user and managers.

10.1 Management

Ngumbulu Development Center will be the main distributor and initiator, and will therefore be the manager of all activities involved with the harvesting system. This section is limited to the actual supply and demand of the system itself, and not management of workshops, functions or other educational initiatives.

The tasks towards the end user will be:

- Initiating pilot projects
- Adjusting the supply towards the demand
- Advise buyers on what system fits their needs
- Facilitate and follow up on payment plans and additional demands
- Guide on installation and repairs

Pilot projects

Even if the proposed solutions consists of fairly well known components it is recommended to initiate a pilot project where a group of village families (10 - 20) becomes testers. This is to ensure everything is working as intended before distributing in larger numbers. Especially marginalized villagers may get a discount on the harvesting systems provided they report on installation difficulties, durability issues or other aspects that may occur with the system over time. This allows for the development center to test how transportation and other managerial tasks may function in reality, without risking unhappiness among the buyers. When the center is confident that everything will work for the first “shipment” the pilot projects may be ended.

Supply and demand

To know how many tanks, gutters etc. should be at hand; the development center should do surveys on the expected demands. This may be done by calling villagers to functions and inform them of the rainwater harvesting systems who may in turn sign on an “interested” list. A representative may travel to each of the surrounding villages, and those who show up will get the first priority in buying. This will give an indication on how large the first “shipment” will be.

Advise on buying

Some villagers may not be aware of what combination of gutters and tanks they need. Especially this is suspected to be the case with villagers considering buying the big 1 000 liter plastic tank. To determine if they should buy this, or for instance two or three drums instead, the development center should follow the steps in the provided “proposal chain” Figure 51. An example of how to go through the chain is given in the appendix on page 186.

First the buyer informs about the size of his catchment surface (if not iron sheet, propose the drum catchment system), which decides the length of gutters. Calculate the potential supply during a heavy rainstorm (as done in the “supply potential” chapter). The buyer informs about family size and the needs are set up against the potential to see whether all the water will be used during a short amount of time.

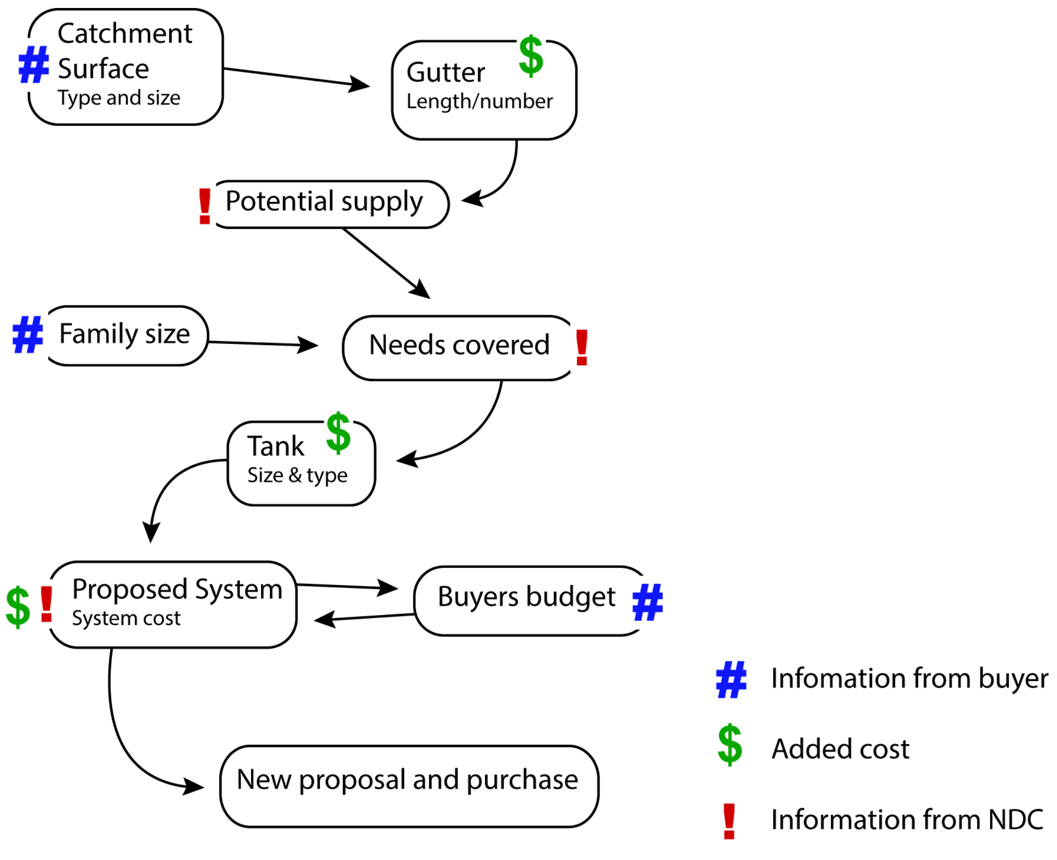


Figure 51 Proposal chain

Then inform of the tank size (in general driven by the supply potential) and give a total proposal of gutters and tanks (remember to add installation wires etc.). The buyer will check his budget, if ok then buy, if not, cut down on the gutter and tank to match the budget. At times the process will be more dynamic, but the proposal chain gives good indications on what to consider in the process.

Conditions

With the purchase there should follow a set of demands, general information and an agreement between the center and the buyer. This is already a part of NDC's policy and is a good way of raising the probability of villagers taking care of their purchase. Also down payment over 5 years should be continued, however strong advice on paying the whole sum in one should be given, as down payments require follow up and manpower from the management.

Follow up

It is crucial that villagers who have bought components are given the proper follow up. Should they struggle with installation, repairs or have questions about water quality, it must be clear to them that the development center will be available to help. In the future, when numerous systems have been distributed, there may be need for more manpower to reach the beneficiaries. Suggestions of a water committee was raised in Ngumbulu during the second field trip, however at the time, it was seen unnecessary. If needed, one person who can be trusted may serve as an extension of the development center in each village. This person will be responsible for reporting broken systems and should be taught proper installation methods to help those who struggle. Of course there is a question of compensation, which the development center must consider.

10.2 Ensuring good water quality

In areas like Ngumbulu the rain is generally unpolluted and safe before reaching the ground. Therefore the water quality is only affected by the catchment surface, the delivery system and the storage reservoir, where there are a number of things that can be done to ensure good quality.

The most common source of contamination is dirt and faces on the catchment surface. This may come from birds and small animals, but also from droppings on the ground turning to dust and brought to the roof by winds. Also leaf debris, insects and dirty containers are common contaminations in rural areas.

A certain degree of microbiological and chemical contamination of roof rainwater run-off is inevitable. It will, however, generally not cause any health problems if the roof, gutters and storage are properly maintained and regularly cleaned and inspected [21]. Also there are water treatment techniques that may improve the water quality if uncertain of the safety of for instance long-time stored water.

First flush cleaning

The most important safety factor is to let the first water wash all components, and not letting this water enter the storage reservoir. This water can contain a large number of bacteria and other contaminations, and should be diverted and used for other purposes than drinking (washing clothes, small scale irrigation). It is recommended that 4 liters per 10 m^2 of roof surface should be diverted[33].

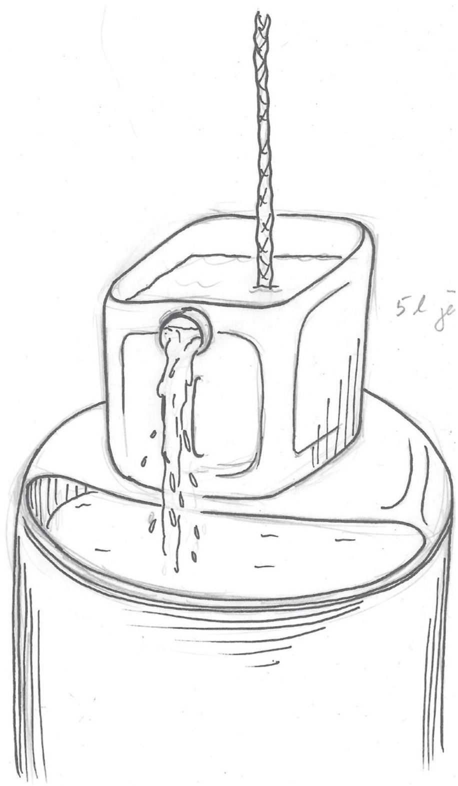


Figure 52 Fixed volume first flush

There are several techniques to divert the first flush water. The absolute best way is by manually stop water from entering the reservoir by either moving the tank itself or by taking away the downfall (rope, hose). However, sometimes it will rain when the villager is not around to move the reservoir or reapply the downfall, thus a lot of water may be wasted. Therefore there are some mechanisms that may help buy some time for the user to get home.

Fixed volume

A fixed volume method is considered to be simple and recommendable for the people in Ngumbulu because it is automatic and robust. A chamber of set size is filled with rain until it overflows and the cleaner water continues into the tank. Often this chamber is a part of the downfall pipe, however Ngumbulu needs a simpler way. A simple and cheap way is to cut open a 5- or 10-liter jerry can, placing it on top of the storage container and putting the downfall rope inside. By placing the can so that the hole is at the most elevated part, the water will overflow and pour into the opening of the reservoir as seen on Figure 52.

The solution is seen as a mechanism for buying time so the user can get home and put the downfall rope back into the reservoir, and remove the container of first flush water.

Note: The solution should be tested and verified in real conditions before suggested to the community.

There are other possible techniques to divert the first flush, like the SafeRain system, fixed mass and other mechanical installations, but none seem to fit the cost, durability and simplicity that is required here.

Filters

Filters are used to keep debris and insects out of the reservoir and will contribute to cleaner and healthier water. The lack of regular filter material in Ngumbulu leaves a piece of clothing a good option. It is important to clean the fabric well before use and that the threads are not too fine stopping the water flow. It is advised to test the filter before use.

Filters may be placed at different places along the catchment system. Options may include:

1. At the end of the gutter (Figure 53)

2. Inside the cap of the jerry can (Figure 54)

3. Over the inlet on the reservoir (may require the downfall to be shorter). This may also function as a lid on the drums (Figure 56)

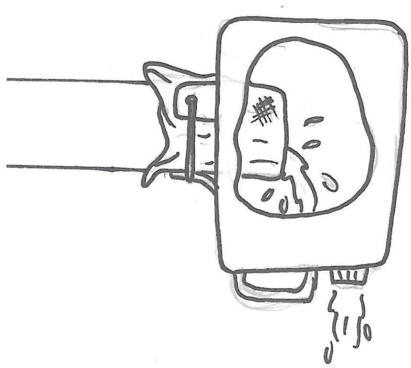


Figure 53 Filter on end of gutter

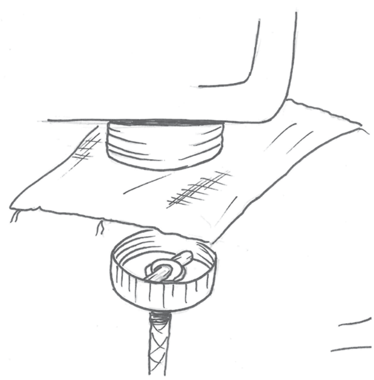


Figure 54 Filter in cap

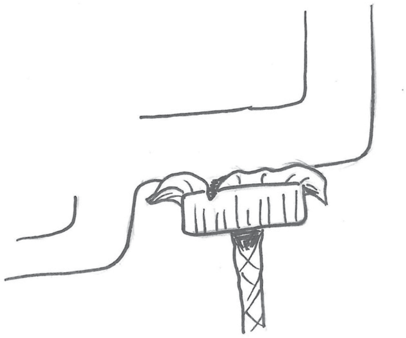


Figure 55 Filter in cap

Figure 56 Filter on top of reservoir

Experimenting is needed to determine what filter placement is most convenient for the used system configuration.

Provide cover and shade

It is very important to cover the storage reservoir so that insects and other contaminations does not enter while the water is stored. If mosquitoes start breeding in the tank, there may be a health risk (malaria) for people. Also air born chemicals or fecal bacteria may enter and render the water un-drinkable. Direct sunlight should also be avoided, both for water quality and for the tanks durability. Sunlight and heat may give breeding ground for bacteria, and for large reservoirs no disinfection effect from UV will occur[17]. Therefore a shed should be made, cover made from old clothes (or similar) or the reservoir should be placed away from the sun.

Water treatment

If there are uncertainties about the quality of stored water, treatment may be necessary. However, treatment only makes sense if done properly. There are several ways of treatment, and a few of thenmseem applicable in Ngumbulu.

Chlorination

Chlorination can be an effective way to purify the water, however it will affect the taste. If a large tank is suspected to be severely contaminated, apply the chlorine directly into the tank, stir and let stay for 24 hours. Otherwise, chlorine can be used in smaller containers to be sure. There are different chlorination applicants both liquids and tablets. Be sure to follow the instructions on the container!

The cost is approximated to be less than 100 KES for treatment of 1 000 liters of water for liquid chlorine. The tablets may be ten times more expensive[34]. The Ngumbulu Development Center could retrieve large quanta's of chlorine for distribution to buyers of rainwater harvesting systems.

Boiling

Boiling of water is a common way of treatment and is generally sufficient for making it safe to drink. This is seen as a minimum and has saved many people from getting sick from water both in Ngumbulu and other marginalized communities. The water may be boiled on the same fire as when making food thus saving fuel and time.

Solar Disinfection

Another way of killing off harmful bacteria is to put water in clear plastic bottles and let them lay in the sun for about 6 hours. The sun will both heat up the water and use UV radiation to kill the bacteria. As it is possible to find clear bottles in Ngumbulu this is seen as a potentially good way of ensuring good drinking water. The bottles must be cleaned before use, and be as little scratched as possible. Two sets of bottles may be utilized so that there is clean drinking water available every day.

Follow the instructions on Figure 57.

Extra considerations

It is common to cut a larger opening in the blue plastic drum for easier access to the water. When doing this with a saw there will be a lot of fine (and coarse) polyethylene dust entering the drum. This dust may be dangerous to consume and must be cleaned off before the drum is used for water storage.

Figure 57 Solar disinfection manual. Source: LUZI and MEIER-HOFER (Fundacion SODIS and EAWAG/SANDEC)

Do not put treated water into a dirty container!

10.3 Usage and maintenance manual

If various components of the system are not regularly inspected, possible problems are not identified or necessary repairs are not performed and the system will cease to provide a reliable, good-quality supply of water. The following timetable of maintenance and management requirements gives a basis for usage and maintenance. It is advised that the NDC provide villagers with this list:

Regular use and maintenance

1. The reservoir should be shielded from the sun, and especially any container made from cement shall be kept out of direct sunlight to avoid cracking.
2. Roof surfaces and gutters have to be kept free of bird droppings. Gutter system must be regularly cleared of leaves and other rubbish.
3. The water in the reservoir should regularly be inspected for contamination and debris.
4. The downfall flowing water into the reservoir should be disconnected during dry periods. Then a short period after rain begins and the system has been flushed (first flush), it can be moved back so the water flows into the tank. This is to ensure clean water.
5. The tank should regularly be inspected for leakage. If leakage has occurred, try to fix it or contact the development center, they will assist you!

Infrequent and annual tasks

The following annual or infrequent tasks are important for the maintenance of the rainwater harvesting system. Some technical assistance may be required:

6. At the end of the dry season, the roof surface, gutters, drop outlet and installation need to be checked and repaired if necessary. Try to fix it yourself first, then contact the development center if assistance is needed!
7. Removal of deposits from the bottom of the tank is necessary and should preferably be done annually.
8. After repairs have been carried out inside the tank and after deposits have been cleared out, the interior should be scrubbed down with a solution of 3 parts vinegar to 1 part water, or 1 kg baking powder to 9 liters of water. Finally clean with a wet, clean (!) cloth before using it again to store water.
9. If the sisal gutter is utilized, it is recommended to uninstall and keep away from the sun in the dry season.

11 Installation and manufacturing

This chapter deals with installation and manufacturing of components. The development center will be responsible for the implementation stage and the following may be seen as an advisory.

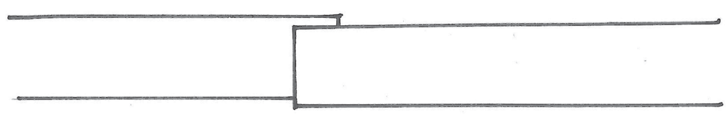
11.1 Gutter installation manual

Installation of the gutters is a crucial point in the rainwater harvesting system. If this is done insufficient great amounts of water will be wasted. As previously discussed this is where most inhabitants in Ngumbulu struggles the most and thereby simple and reliable ways of installation is to be preferred.

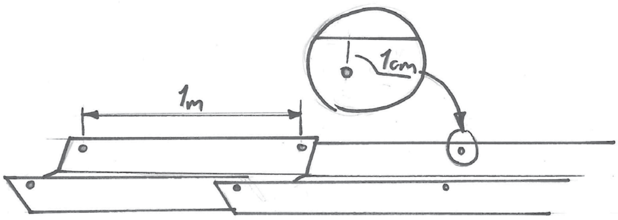
In theory there are many ways of installation, however regarding the houses in Ngumbulu there is in fact only one effective solution. The issue is the great variety of construction methods of roofs. Some have rafters made of sticks, some have timber, and some may not have rafters at all but keeps the iron sheet in place with stones. Some may have fascia boards, but this is however rare in the area. Therefore the only suitable way of installing the gutters is directly onto the iron sheet roofing with wire. Wire is chosen, as it is durable and can prevent the gutter from swinging in heavy winds.

Follow the given steps to install the gutter, it is advised to be two people in performing the installations:

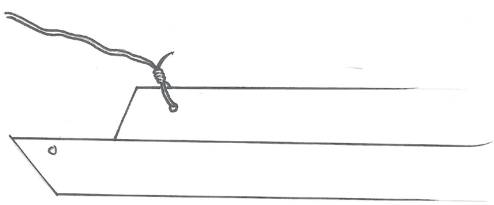
1. Lay the gutters next to the roof where it is to be installed. If more than one gutter piece is to be installed, make sure to overlap by a couple of inches to prevent the water from spilling.



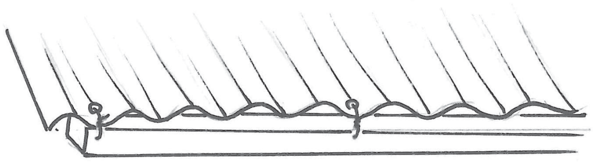
2. Punch holes, using a nail, with approximately 1 meter distance along the entire length of the gutter. Make sure to punch a hole at the overlaps going through both gutters. The holes are made at the same location on both sides of the gutter, approx. 1 cm from the top.



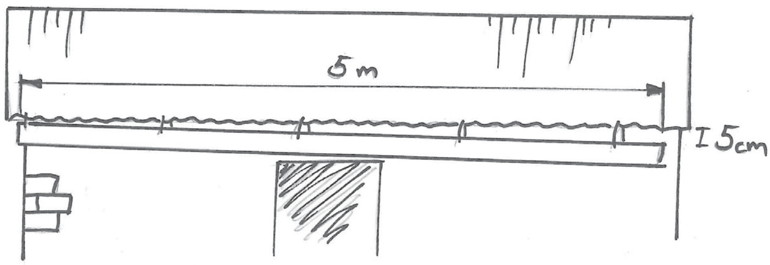
3. Starting at the opposite end of where the drop outlet will be, thread the wire through the gutter hole closest to the wall, and tighten.



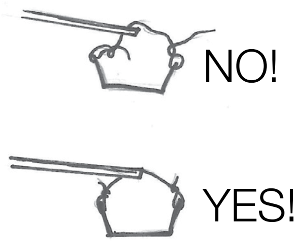
4. Punch a hole with a nail in the iron sheet roof approximately 2 cm into the sheet, and thread the wire through. The hole is best punched at the “valleys” in the sheet to add stability. Finalize by threading the wire through the second hole in the gutter and tighten. The gutter shall on this point hang very closely to the iron sheet on the roof.



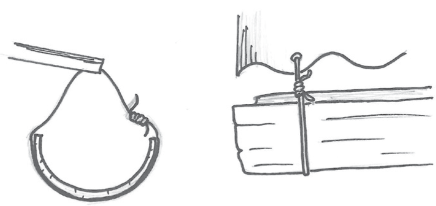
5. Continue in the same manner with the remaining holes. Important: Create a gentle slope towards the drop outlet. Check the slope by pouring a little water into the gutter. It is advised not to have a great distance between gutter and roofing, as the water will tend to overshoot. A mere 1 cm distance for every meter should be sufficient. This means a 5 meter gutter shall not have much more than 5 cm distance between gutter and roofing. However, not all roofs are level, so remember to test whether the water runs correctly towards the drop outlet.



6. The final hole shall be made in very close proximity to the drop outlet.
7. Be sure to tighten the wires properly. Loose wires give loose gutters that swing in the wind and may break more easily. This point cannot be stressed enough.



Sisal gutters are installed similarly, however instead of punching holes, a cradle should be made out of the wire as seen on the illustration.



11.2 Sisal gutter manufacturing

Outcome

Approx. 2 m gutter, and one smaller gutter if the stem allows for it

Time: 1,5h

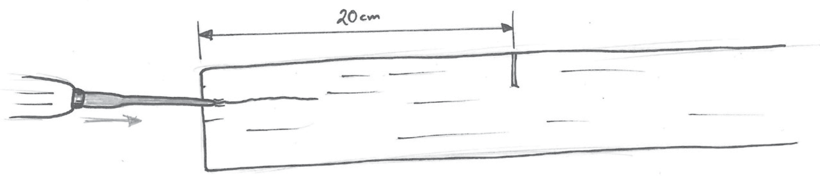
Cost: Sisal stem = 60 KES giving approx. 30 KES per meter

Items needed

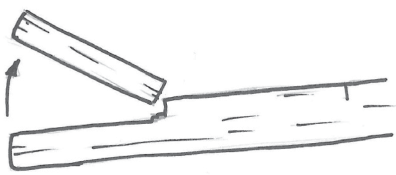
- 1 sisal stem
- 1 saw, or sharp knife and a chisel
- 1 metal strip tool

Steps

1. The sisal is harvested when it has become dry and mature.
2. The branches are removed, leaving just the stem itself.
3. Cut away the very bottom of the stem to get a straight surface without cracks.
4. Cut the stem where it starts to bend too much. The rest can be used for smaller gutters later.
5. Use a saw or similar to cut a quarter down transversely across the stem, approx. 20 cm from the end.



6. Use a chisel or a knife to cut longitudinally from the end towards the transverse cut. Remove the bark. Continue with this until there is an opening along the whole stem. Be aware: the fibers on the stem twist, so be sure to keep the opening straight.

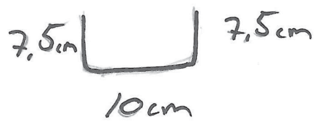


7. Use a knife or similar to cut the walls down to make the opening as big as possible.
8. Use a knife or a bent metal strip to remove all the soft inner fibers. The fibers will soak and rot if not entirely removed. When the hard bark is reached the gutter is complete.

11.3 Flat iron sheet gutter manufacturing

Outcome

4 Square iron sheet gutters, length 2 meters



Time: 10 min per gutter

Cost: Iron sheet: 500 KES

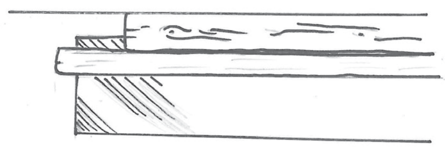
Per gutter: 125 KES, Per meter 62,5 KES

Items needed

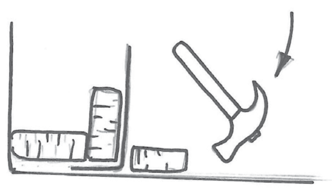
- Flat iron sheet (1x2 meter)
- Metal-cutter/scissor
- Hammer
- 1 long 2x4 beam
- 1 spacer beam (2x4 is preferred)
- 1 Small square timber piece
- Measuring tool
- Pencil or similar for marking

Steps

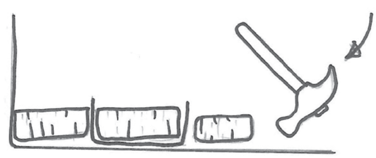
1. Take one flat iron sheet of 2 by 1 meter. They are usually sold per meter length in 1-meter width.
2. Find a flat hard ground surface next to a wall to perform the construction.
3. Cut longitudinally with a width of 25 cm. 4 gutters will come from this.
4. Place the thin side of a 2x4 beam along the metal strip, leaving approx. 2 cm outside the beam.
5. Place the strip and the beam towards a wall with another 2x4 or similar used as a spacer.



6. Keep pressure on the beam holding the metal strip firm towards the ground. While bending the free lying metal upwards, use a small square timber piece and a hammer, hammering the metal strip towards the 4x2 creating a sharp bend. Continue the whole length of the metal strip.



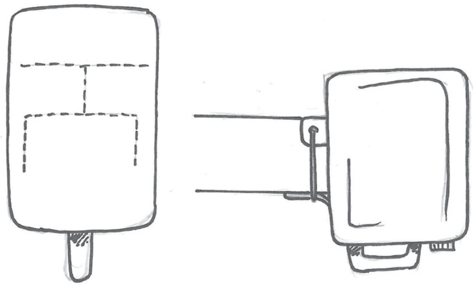
7. Turn the gutter, and perform the steps above. Note, the wide side of the 2x4 beam now holds down the metal, and the newly made wall of the gutter will be in between the wooden spacer and the 2x4.
8. When finished, use force to manually shape the gutter if needed.



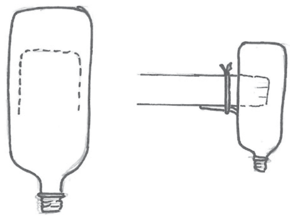
11.4 Drop outlet and downfall

1.4 Drop outlet and downfall

Jerry can



1. Cut the pattern seen on the illustration on the back wall of the jerry can. Measure against the gutter first to make an accurate insertion.
2. Bend the flaps outwards and stick the can onto the gutter.
3. Punch a small hole in each of the smaller flaps, going all the way through the gutter wall, with a nail.
4. Insert a piece of wire, fasten around the bottom flaps and tighten.



Bottle drop outlet is constructed in the same manner, however it is sufficient with only the bottom flaps.

Downfall

1. Take a thick (0,5 cm or more) twisted rope which reaches from the gutter to the ground
2. Insert a small stick at one of the ends.
3. Cut a hole in the jerry can cap just big enough for the rope to easily go through.
4. Pull the rope through until the small stick lays inside the cap. Make sure it is resting towards the bottom of the cap and is not stuck in the walls.
5. Screw the cap back onto the can
6. At the end of the rope tie a heavy object, a small rock or a stick, to keep the rope straight and steady. Carefully clean the object, and make sure it is not of a toxic material.

If the chosen downfall is a hose, it is simply stuck into the bottle, as the 1-inch hose is a perfect fit for this. Is however a larger hose used, punch a small hole in the hose and the bottle and thread a wire in both to secure the downfall.

11.5 Cemented oil drum

Outcome

One 200-liter reservoir

Time: 1 week until ready, effective work time approximately 3 hours.

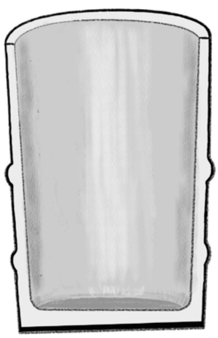
Cost: Drum: free-700 KES (depending on condition), cement: 275 KES

Items needed

- One rusty oil drum
- Approx. 20 kg cement
- Sand
- Water
- Square steel trowel (or similar)

Steps

1. Mix a 1/8 of a bag of cement with coarse river sand in a ratio of 1 part of cement to 3 parts of river sand (1:3) and water.
2. Smear the mixture onto the inside of the oil drum in a 1 cm thick layer and let it dry for a day.
3. Next day apply a second coat of mortar 1:3 being 2 cm thick onto the interior of the drum and smoothen it.
4. Within the same day, mix cement with water until it becomes a slurry and press it onto the interior plaster with a square steel trowel or similar.
5. Keep the oil drum under shade and sprinkle the plaster with water 3 times daily for a week.



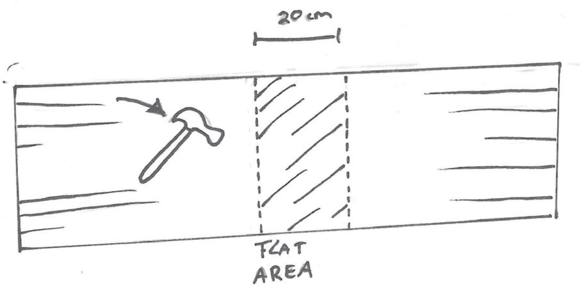
11.6 Drum top catchment

Items needed

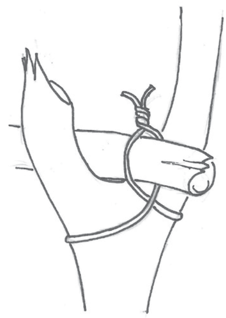
- One reservoir (Blue drum or oil drum)
- One iron sheet, preferably 1x3 m
- 4 corner poles with a v shape at the end, approx. 1,3 m
- 2 cross over poles, approx. 1,2 m
- Wire
- Hammer and a nail (or similar)

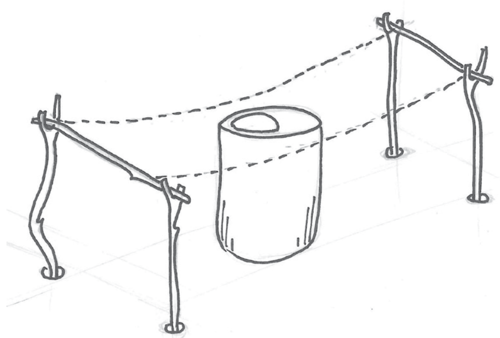
Steps

1. Use a hammer or similar to hammer a flat area of about 20 cm at the center of the iron sheet. Make sure the sheet can now bend transversely.

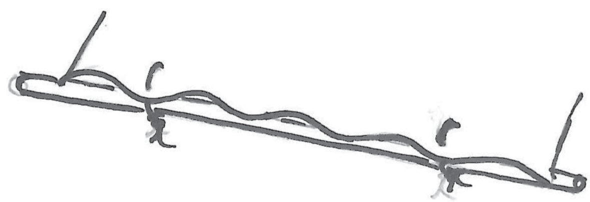


2. Find four poles with a v shape at the end, approximately 1,3 meter and of a sturdy thickness.
3. Place the blue drum or oil drum at a good location. This will serve as support while constructing.
4. Place the iron sheet on top of the drum, measuring where the poles will be set into the ground.
5. Dig a hole at about 10 cm, sticking the poles in with the v shape pointing upwards. Do not fill the holes yet.
6. By using the iron sheet as measuring tool, place the crossover beams into each v shaped pole, checking that the iron sheet will rest upon it. Fasten with wire.

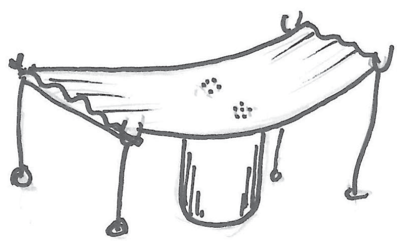


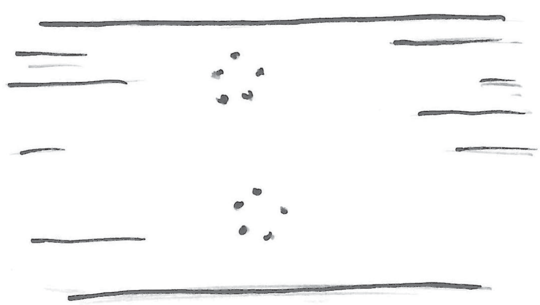


7. While the iron sheet is resting on both pole frames and the drum, check that there is a slope on both sides towards the middle. Adjust the hole depth if needed.
8. Fill the holes with gravel and sand, and pack it tightly to make the pole frames sturdy.
9. Punch a hole in the iron sheet at each side of the cross over pole to tie it down with wire



10. If there is no hole in the drum, make an adequately big one with a saw or a knife.
11. Punch a number of holes at the lowest part of the iron sheet, and make sure the water will run into the reservoir. The small holes will work as a filter for larger objects. A filter made out of cloth may be fitted over the holes in the drum to filter out smaller objects.
12. Now check that everything is working properly by pouring a cup of water from both sides of the iron sheet.





11.7 Rainwater harvesting test unit

Constructing the rainwater harvesting test unit became one of the primary objectives during the second field trip to the village. The construction itself took one day with the work of two persons; one masonry and one assistant. In selecting materials, the focus was in finding local cheap and reliable components, where most were located in Katangi or Kyua. Proposed construction drawings may be found in the appendix on page 188.

General construction steps:

1. Four poles of treated timber poles were connected by 2x4” timber. The height of the poles is aimed at keeping the gutter interface at a sensible height of 170 cm.
2. The top part consists of two triangles creating an angular roof.
3. Three 2x2 rafters were nailed onto the triangles on which 3 iron sheets were mounted.
4. Four holes were dug in the ground into which the entire unit was lifted. Subsequently, concrete was filled in the holes creating a solid foundation.
5. A 3 000 liter tank was then placed under the framework. The tank was lowered one foot into the ground to fit.
6. Gutters are installed, with a jerry can drop outlet fitted at the end. Two pieces of gutter is used to direct the water into the tank. Pipes may also be used for this purpose. (this part is not seen at the picture, as a drum and a rope were used for educational purposes)

Bill of materials - Test unit

Description	***Details***	***Q***	***Feet***		***Price***	***Total Ksh***	***NOK***
Timber pole	Ø 9cm	4	24		67	1 600	111
Frame timber	2x4"	4	30,6		40	1 224	85
Back beam	2x4"	3	4,5		40	180	12
Angle beam	2x4"	3	28,7		40	1 146	79
Support beams	2x4"	8	23,8		40	950	66
Rafters	2x2"	3	22,1		25	551	38
Iron sheets	3m x 3ft	3			700	2 100	145
Nail, timber	1kg	1			190	190	13
Roofing nails	1kg	1			190	190	13
Foundation	Cement	1			730	730	51
Tank	3 000 liter	1			24 500	24 500	1 697
Tap	Steel	1			580	580	40
Tap pipe	Steel	1			300	300	21
Gutter	Galv. iron	2			500	1 000	69
Installaiton wire	Ø2mm				100	100	7
Jerry cans	5 liter	1			100	300	21
Transport					2 000	2 000	139
Masonry	1d	1			750	750	52
Sum						38 391	2 659

Figure 58 Working together to finish the test unit

Part 5 - Assessments

12 Future projects

The rainwater harvesting system for personal use was identified as the main point of improvement in Ngumbulu, and was the most appropriate focus area. However, the water issue is complex and needs solutions and improvement on a number of areas to mend the villagers distress. The following chapters identify some of these areas and gives suggestions on how to proceed with them.

12.1 Smaller dams

As shown in the technology chapter, rainwater harvesting is more than just run-off from roofs. There is also run-off from land, hills and valleys. In semi-arid areas this run off is often not utilized, as seasonal rivers and streams carries away the water instantly. This is one of the big problems with desertification, since there are no roots or plants to stop water from escaping.

In Ngumbulu there has been a few projects with dam building by the community where 20-30 people dig a large hole at the end of a stream. This has proven to be successful as the dams keep their water far into the dry season. It is encouraged to continue with this dam building so the landscape run-off is kept in the area. However a large dam requires a large area, numerous workers, management and money. In addition, some still have to walk far to benefit from this water.

An option may be smaller dams. Smaller dams dug by 3 or 4 families in a suitable area close to their homes may give moisture to the fields, water for the animals and contribute to raising the water table. During the field studies locals were consulted about this, and many were willing to team up with their neighbors to construct them, some even had suggestions on locations. It seemed that all villages, except for Kathangathini, would be suitable for dams. Kathangathini is a very flat area and none of the inhabitants thought it to be possible to benefit from dams here. However, more investigation is needed before this area is excluded.

In general there are two suitable types of dams for this purpose: charco dams and hillside dams.

To read more about these kind of dams the booklet "water from small dams" by Erik Nissen-Petersen is highly recommended.

Figure 59 Personal dam Ngumbulu

Charco dams (Milambo)

These dams are built in a way that tries to reduce evaporation losses by deepening the water reservoirs and minimizing their surface area. Trees and scrubs are grown on the windy site of the charco dams to function as windbreaks that also reduce evaporation.

The soil should, preferably, be deep clay, silt or Black Cotton soil. Coarse textured sandy soils should be avoided as these are highly permeable and water will drain through them. If seepage is high in charco dams, they can be plastered with clayey soil and compacted using compactors made of tree trunks.

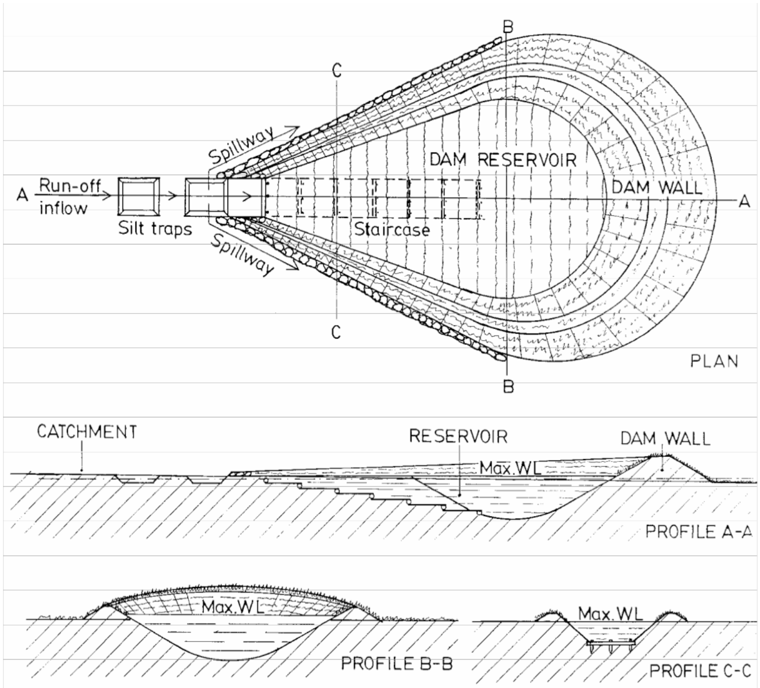


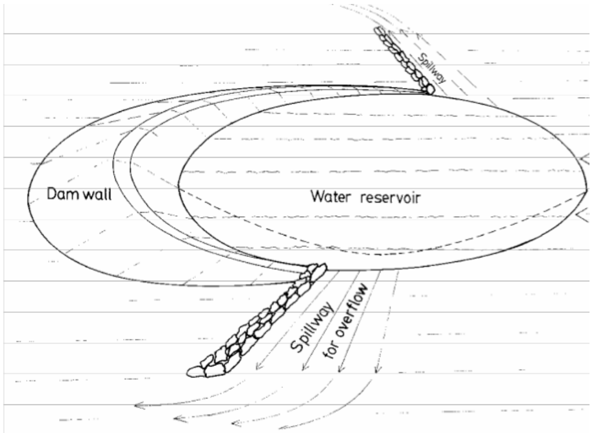
Figure 60 Charco dam illustrations. Source:Erik Nissen-Petersen, Water from small dams

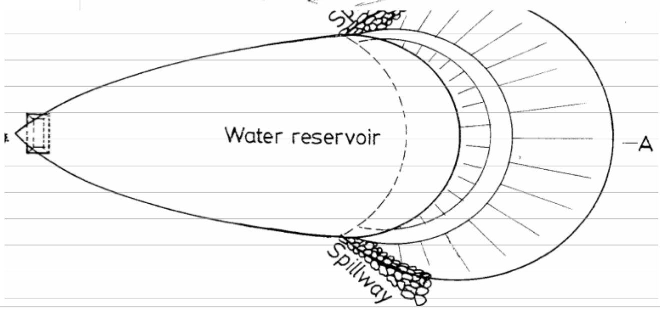
Hillside dams

Small earth dams with curved walls built on hillsides and sloping land are the simplest and cheapest earth dams to locate, design, construct and maintain.

The design of hillside dams consists of a semi-circular dam wall, shaped like a new moon. The curved dam wall is made of compacted earth, which must be higher at the middle than at both ends to prevent any water spilling over the middle of the dam wall. The gradient (slope) of the sides of the dam wall should be 2:1, which is 2 m of width for every 1 m of height.

Naturally, the best soil type for constructing a water reservoir should have a high content of clay. However, soil types other than the clayey type can also be used, although some seepage may occur downstream.





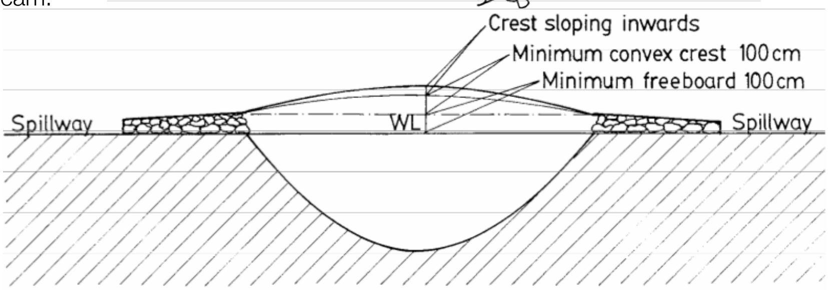


Figure 61 Hillside dam illustrations. Source:Erik Nissen-Petersen, Water from small dams

Figure 62 Hillside dam Kitui county, Kenya

12.2 Water trolley

Transporting water from river holes and other water sources is one of the most strenuous exercises the villagers must endure. Usually only four jerry cans may be carried by the donkeys meaning that they must take the trip every single day to have enough water for domestic use. And the ones without a donkey must carry manually.

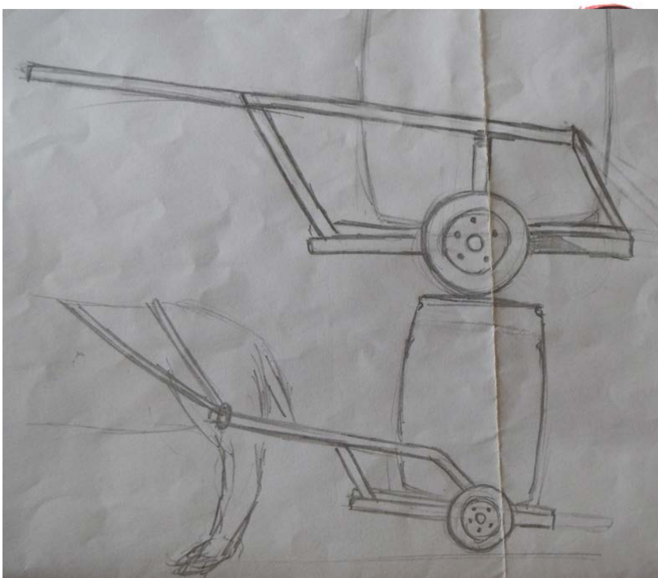
During the field trip some trolleys or carts were seen both in general and in Ngumbulu. Some were wood and steel framed with car wheels, and some were somewhat smaller with railings and smaller wheels. The carts were expensive, very heavy to pull and not suitable for terrestrial landscapes.

The idea was to manufacture smaller, lighter trolleys that may be pulled both manually, by donkey or even by bicycle. The trolley should be able to carry a blue plastic drum full with water up the hilly roads in Ngumbulu. By using a sulky-like frame and wheels from the now common tuk-tuks this could be a possible tool of relief for the villagers. Of course it needs to be very robust and not too expensive.

When presented with the idea, and a sketch of the imagined trolley, absolutely all villagers said this seemed like a good idea. They said they would be able to get 3-4 days of water supply in one trip, and imagined the positive impact this would have on their daily lives.

When asked about what they would pay for such a thing it seemed as 5-6 000 Ksh was a fair price, of course depending on the robustness and final capacity.

This could be a prospect for a future project for the development center, and the newly opened (may 2014) weld shop in Ngumbulu could play a vital role in this. A product development process must be done on this before realization, of course, with close attention to the villagers needs. This may be a possible Engineers Without Borders master thesis in the future.



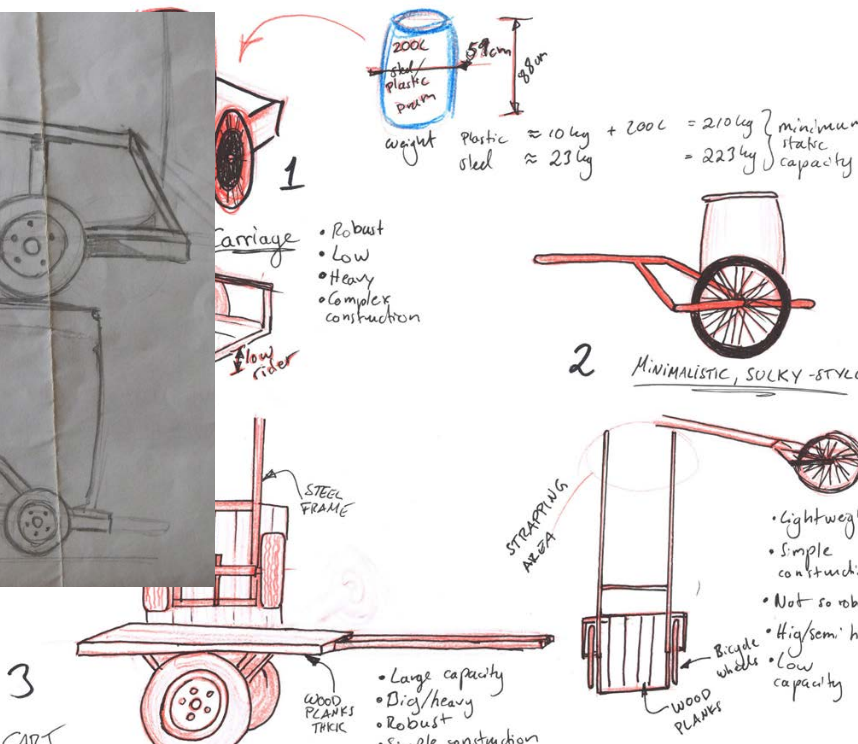


Figure 63 Sketches, water trolley

12.3 Rainwater harvesting center

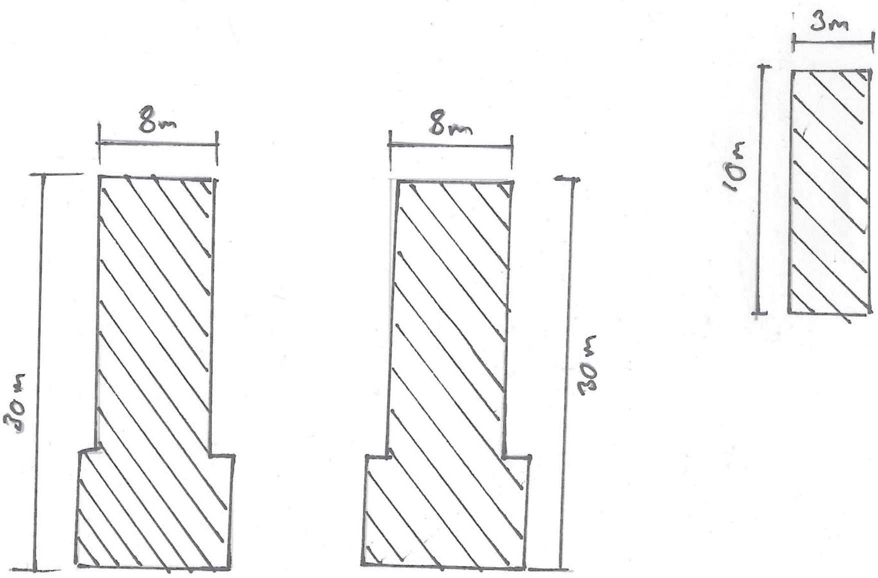
The development center itself has initiated in some great projects and is in the front line for, amongst others, agricultural knowledge in the area. They substantiate their community awareness efforts by performing the initiatives themselves showing that they actually work. This may also be done with the rainwater harvesting.

The center has a vast collection surface on their buildings with iron sheet roofs, which can in a broader sense than today be of service to the community. For now, one 10 000 liter plastic tank is connected to gutters on one side of one of the buildings, but imagine if all roof area was utilized. More tanks could be connected and run-off water may be sold to the community.

The roof area of the center is approximately 500 m^2 which may potentially (in the March- May rains) supply almost 160 000 liters of water (500 m^2 x 0.387 m x 0.8) and could be of substantial help for the nearby villagers. The water could either be saved for the drought period (which requires a large amount of storage tanks) or resold immediately. Either way, it could be a great project to initiate in for both Purpose for Life foundation and Aid in Action as the community would both get extra supply and also directly see the rainwater harvesting efforts of the center.

If the initiative is successful an even greater catchment area may be constructed using the model of the rainwater harvesting test unit.

The model may also be used at the shops in Ngumbulu as they have suitable roofs for this. It might be challenging with security and management, but is worth an investigation.



13 Conclusion

The water situation in Ngumbulu is complex, and a complicated problem often require a complicated solution. The reality in Ngumbulu is that no stand-alone, quick fix is sufficient. The illustration below shows the crucial focal points now and in the near future to make the water problem less prominent.

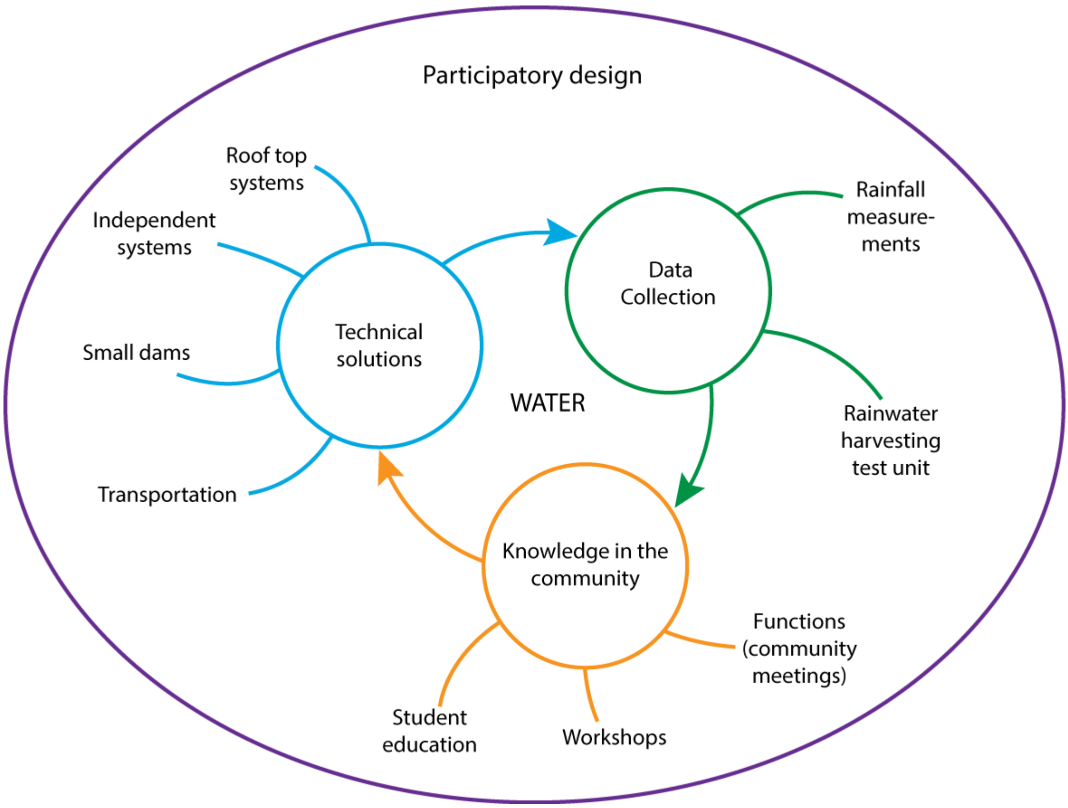


Figure 64 Conclusion illustration

The illustration does not include the already present water sources, but boreholes, community dams and natural water catchment, as well as management and other non-tangible aspects are all important parts of the puzzle.

14 Reflections and lessons learned

This chapter is dedicated to more subjective reflections and “the developer” steps into a more informal “I”-role.

To be operating outside the conventional workspace of a mechanical engineer provided me with challenges far beyond my training and previous experiences. If you told me that I would at one point find myself driving a motorcycle in the African bush with two ladies, two chickens and a bag of papayas after interviewing a bunch of villagers, I would probably laugh and get back to reading my finite element analysis book.

The process

Initially I was aware that developing products in an African village would be somewhat different from Norway, however I was not prepared for how vast the contrasts would be. As a mechanical engineer, my mind quickly went to technical solutions, even before going to Ngumbulu the first time. Luckily I realized how little I knew about the conditions I was to do product development in, and decided to go on a field trip as soon as possible. 3-4 weeks into the project I found myself on a plane to Kenya ready to do some investigations.

Arriving in the village gave me several important wake up calls and laid most of my presumptions to rest. My lack of experience with this kind of development struck me quite hard as I realized that the project was (and had to be) much more real than I had expected. People in nearby villages knew about my arrival, and everywhere I went people looked to me for imminent effects in the community. I remember one of the staff at the local development center asked me after two days: “So, do you have a solution to the water problem yet?” Which meant one of my primary tasks as a foreigner was to manage extremely high expectations and at the same time try to inspire and make my stay a positive experience for the people. This was something I as a mechanical engineer has never encountered before.

Back in Norway I started evaluating my experiences and all the data I had collected. My initial realization was that I don’t have a clue of how to do this the right way. The water problem in the village is huge and it was my task trying to fix it. It was a heavy burden, which in fact threw me off for a while, but thinking about the villagers, and my chance of actually doing something good for them urged me to attack the challenges. First off was to gain knowledge about how to perform proper development in these conditions, and learning about the aid culture, successes and failures. This was more work than I expected, and the more literature that was read on the matter, the more it became evident that ***how*** things are done greatly supersedes the importance of ***what*** is being done. Therefore the product development itself became a piece of the puzzle more than the puzzle itself. This was reflected in the project work, as the concept development phase was cut down in favor of understanding the situation.

In a sense, the project work became a process of maturation and understanding what is really important while preforming development in marginalized communities. After all, the project would be touching lives, and if performed incorrectly the consequences could be negative. This is perhaps the greatest lesson learned from the process, that there are living humans involved, which is seldom the case in imaginary projects at the university.

This gave me a new direction for the master thesis, where the theory of participatory design, the focus on education and other “software” matters became more prominent. Having gone through the process of learning from other projects failure, getting valuable tips from experienced aid workers and reading aid theory left me more ready for the task at hand and felt as if the future of the project was brighter.

Going into the field for a second time I had understood how important participatory design is to ensure a sustainable long-term project. This is why I tried, in everything I did in the village, not to be the prime leader and direct what was going on, but subtly instruct the members of the center of how things could, not should, be done. Sometimes this was frustrating and was not always achieved, but it was necessary to create a feeling of inclusiveness. The big problem was that the length of the field trip, and also the length of an entire of a master project is not enough to sufficiently achieve participatory design. However, by focusing on making thing simple and small-scale, and by putting all efforts into making the development center feel that this is their project too, hopefully some seeds were sown and the project will be ongoing even without my immediate presence. Only time will tell.

Uncertainties

Now that the master thesis is completed there are several uncertainties about the project, the proposed solutions and the process itself. Did I get to the root of the problem? It is very hard to know whether the primary needs of the villagers were met because of my limited time actually spent with them. Even if everybody were positive to rainwater harvesting and the solutions proposed, it may be a mere act of politeness from the locals, as many tribes find negativity an insult.

When you work with a problem and a technique for a long time, you may unintentionally become subjective in your views, and tend to favor your own solutions. In this project I have tried to be critical to both the specifics and generalities of rainwater harvesting, however, since I really believe this is a good solution, maybe I have fallen into the trap? Maybe there are other areas that are more important than this, and is the initiative really providing enough to the community? I think so, but there is always that possibility of being completely wrong.

Another uncertainty is the level of commitment from the Ngumbulu Development Center. During the field trips we developed a good understanding of each other’s views, and by letting them be the primary initiators hopefully they feel the project is worth proceeding with. I believe I came in at the perfect time in the process, as some rainwater harvesting systems already have been provided. I came in, focusing on the most economically challenged, which also seemed to be a point the center wanted to address more. By creating a project both generating some income to the center, focusing on the locals and on increased knowledge, hopefully the NDC see the positive impact they may make in the society. However, by trying to create a holistic project where several aspects have been considered, maybe the initiative is too complex and comprehensive for the center to undertake. I, on the other hand, have great faith in the manager and the staff, and believe they will further evolve the project to the benefit of the community.

Miscellaneous

One of the goals of this project was to create a solution that was not reliant on external funding or materials. This was difficult on a personal level because when you see the conditions some people live in; you want to give them what they need on the spot. However the statement “gifts breeds dependence, investment creates development” pulled me back from the urge. It is, in my opinion, crucial to base development on this statement, however difficult. The limited economy of the locals is also challenging for the development itself, because the need for cheap material but also the effect a poorly developed product might have on the families. If you encourage someone to invest in a product you have to be sure it fits their needs otherwise you may put them in a very difficult economical position.

To perform this project alone was a great challenge and sometimes a very lonely affair. It is easy to get stuck in your own head and even though there are students and professors around, they do not have the same understanding of the preconditions as you have. Therefore I would recommend for anyone who is taking on similar tasks not to travel alone in this development jungle. In a project almost entirely based on interpretations of users needs and social factors it would be a great strength to have four eyes and two heads assessing new knowledge.

To do mechanical work in rural Kenya seemed to me, before this project, as a fairly easy task as the technical level is rather low. There are limited materials and no high tech machinery available, so I expected it to be quite simple. On the contrary, these factors showed to be what is making mechanical work in Africa a rather complicated matter. It occurred to me that even if the technology itself may be difficult in Norway, you have all resources, all materials and all tools available to make it. In Africa, even to bend a sheet of metal proved to be a challenging task, and the limited access often put a stopper to presumably great ideas. There are also other limiting factors like rough conditions, lack of spare parts and lack of maintenance in Africa, which is not to the same extent present in Norway. A lot of creativity and hard thinking went into making the solutions as cheap and durable as possible, using the available materials.

In Africa, time is relative. The culture allows for great flexibility and people often show up hours behind “schedule”, which may cause headaches for people trying to manage projects or initiatives. However my experience was that by embracing this rather than to be upset, left a more dynamic management process. Expect people to be late, and plan thereafter.

One great mistake (that I know of so far)

I did one great mistake, in this project, which was to not stay in the village for longer than 4 weeks in total. In my opinion fieldwork should constitute for at least one third of the projects duration, preferably much more to ensure more local participation and anchoring in the community. However there should be more facilitation from the university and Engineers Without Borders NTNU to ensure students are ready this and for such a project in general.

Looking back at the goals

Before the project was started i had some primary goals:

1. Create a project that is in correlation with the literature of designing and developing in marginalized communities as well as taking into close consideration the actual needs of the public.
2. Develop sustainable rainwater harvesting solutions for the people of Ngumbulu to increase their access to water

Arguably, both goals have been achieved, however it is uncertain to what extent. There are a vast amount of factors that may challenge the outcome and the long-term effects of this project, which will only be revealed in time. But by putting strict focus on the goals throughout the project, the chance of success increases, and hopefully these and my own personal goals have been achieved.


NGUMBULU
INGENIØRER
UTEN
GRENSER

15 Toolkit

This toolkit is meant to serve as guidance for others performing similar projects (students, locals or NGO's), and is based on lessons the developer learned through the project and through the field trips.

15.1 Structure the work

When initiating in a project, especially during field-work, always set up a timeline to keep track of progress and to keep people informed. Use large papers, section into days or weeks (depending on the length of the project) and hang them a place where as many people as possible can see them. Use post its, or small pieces of paper, to write down tasks and set them on the day or week you hope to achieve them. Shift the tasks around as the project runs and constantly discuss this with the involved people. This way everybody has a general knowledge of what and when tasks are to be done.

Tips: Never assume that people automatically know what the next step is, so make sure its clear for everyone.

15.2 Evaluations

After every major step of the development process make sure to evaluate the results. Without a proper evaluation it is impossible to now the impact of the solutions and to determine the next step in the process.

Step-vise go through the different phases of the project and discuss what went well, what went according to plan and what may have been done differently. Do this in a holistic view, where impacts in all aspects of the project are evaluated. Write down the positive and negative effects of the solutions so that they may be maximized or minimized in the future.

WEEK 1
Wed
Th
Discussing program
Discussed test unit
Constructed Demonstration unit
Tested the unit
Went through all the concepts
Identified Pro's & Con's
Identified what to investigate
Selected the best concepts

15.3 Workshops

Workshops are an arena for people to gather and may serve a number of purposes depending on the needs and the stage of a project. Workshops are used to either try out ideas, gain new knowledge or to inform and educate each other.

Depending on the theme of the workshop gather a group of people that may contribute to the solution. A group of 5 - 10 people with different skills and backgrounds and of different sex is desired. A workshop may last for an hour or an entire day depending on the complexity of the problem. It is advised to keep the workshop short If possible to ensure the quality of the discussions.

On beforehand appoint a facilitator to make sure the workshop stays on topic and that it is focused on the matter at hand. The facilitator is to set the rules of the meeting and to stress that everyone is equal and has the right to express their opinion. The facilitator shall also set the goal for the session and to determine when the goal has been reached. Also have one secretary to take notes during the session.

Tips: Be sure to have plenty of fluids and grab a decent lunch to fuel the mind and body!

15.4 Identifying the problems

The first and most important step of any development process is to really understand the problem. Albert Einstein said: “If I were given one hour to save the planet, I would spend 59 minutes defining the problem and one minute resolving it.” And the best way of defining the problem is to talk to people with knowledge about it. Therefore a large part of the field studies in Ngumbulu was spend talking to inhabitants about their general problems and their issues with water. The approach was both quantitative and qualitative interviews and discussions with people in the area. The first field trip was mostly quantitative, and the second was more qualitative.

By traveling to people’s homes it seemed as the villagers felt safer and were very willing to share their opinions. During the second field trip three families in each of the surrounding villages (one that was considered very economically challenged, one less challenged, and one random) were visited to get a solid selection, and not to leave out any of the villages.

When conducting the interviews it is important to allow for discussion and loose talks. This often gave important information that did not come from the questionnaire. One of the questionnaire used in the second field trip is added for reference in the appendix on page 184.

Always be polite, smile and present your goals for the session.

Group interviews may also be a good way of identifying problems as the discussion between group members may lead to additional knowledge.

***Tip:** NGOs can sometimes unintentionally send a message of separateness by wearing branded NGO clothing and creating spatial distance between themselves and the participants.*

"Experiences from the field show that it takes some time to adjust to the language and culture barrier, but the more you discuss, the more you understand. And remember the barrier goes both ways so be patient, open and understanding."

15.5 Generating ideas

Generating ideas may be seen as a journey where you know approximately where to go, but may take many wrong turns and sometimes be completely off track before you reach your destination. First and foremost, never travel alone, so sure to have a group of people to discuss and propose solutions. Then you do some "brainstorming" where you generate as many solutions as possible. Always keep the users needs in mind and saying "No" is not allowed, never be critical in a idea generation session. If you have an idea, use drawing to make sure everyone understands. This may be unfamiliar and hard in the beginning, but it is a great tool.

After brainstorming now is the time to be critical. Set up a pro's and cons sheet and be very realistic in the approach, "is this really a good solution?". Narrow down to 2 – 3 possible solutions to take further into prototyping-phase.

Tip: Remember that a problem may have a non-technical solution.

15.6 Prototyping

Prototyping is building to think. When you build a small model, or just use some pens and rubber bands to demonstrate a principle, the brain visualizes the product in real life, and you get a better feel of the viability. You might also see what challenges you will meet in the final construction. The prototype gives the developer and the locals a common ground for further discussions and often misunderstandings are solved in the process.

Tip: A prototype may be made with simple tools and materials that are at hand. Bottles, sticks and wire are perfect tools for prototyping.

15.7 Functions (Community meetings)

Functions are a common way of gathering people in Africa to include the community in projects, rallies or education days. The difference between workshops and functions are the level of participation and structure of the event. A function is able to include a larger number of people.

A good way of reaching people in rural communities is to notify teachers of the local schools. They, in turn, give student information to hand over to their parents about time, place and topic. Another way is to hand out flyers manually, or by letting someone drive around with a loudspeaker. Always call for the function a couple of days in advance so the students who forget to tell their parents get another chance.

Functions in Ngumbulu are usually held at 9 or 10 am so people have time to perform their morning chores before coming. However, many are busy during the day, so do not expect too big of a turn up. Also it is usual for people to show up late, and be prepared to wait. Here there must be a balance between letting people realize that time is important and going with the local way of doing things. Start the function when enough people have turned up, the rest will miss the first part and maybe come sooner the next time around.

When people come, be sure to note their name and telephone number. And it never hurts to offer a small sweet or a fruit as a welcome gift.

If the function is primarily education and information, hire chairs and set them in the shadow so people may be comfortable when listening.

Africans are generally patient, but limit the function to one, one and a half hour as people have other chores to attend.

As for developers, let the locals inform you of the traditional way of performing the function and use their knowledge about how to best reach the community members with your information.

16 Thanks

To all contributors to this project I would like to express my sincere appreciation for whatever you did to help me on this journey. The project would not be what it is without the ones I have mentioned here, and the ones I have not.

THE GREAT LOCALS

Samuel Makasi and his entire family

Elizabeth Kyalo

Christopher Nduu

Francis Mumina

David Kavete

Joel Kavete

and every villager in the area!

HIGHLY IMPORTANT NTNU PEOPLE

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Detlef Blankenburg

My fellow students

OTHER ESSENTIAL PEOPLE

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My family

ORGANIZATIONS

Aid in Action

Purpose for Life Foundation

Engineers Without Borders NTNU

Spark NTNU

Norwegian Institute of Science and Technology

Trønder Energi

Magnus Kile Andersen

NTNU 2014

17 Norsk

17.1 Sammendrag

Denne rapporten viser utviklingen av et regnvannshøstingssystem for landsbyen Ngumbulu i Kenya. Rapporten er delt inn i fem deler:

Part 1 - Om

Denne delen gir en oversikt over selve prosjektet, med mål og metoder brukt i utviklingsprosessen. Fokuset ligger primært på deltakende design og på å utvikle produktet på en fornuftig og bærekraftig måte.

Part 2 - Kartlegging

Kartleggingen gir en grundig innføring i det aktuelle området som viser eksisterende vannkilder og dagens situasjon. Deretter utføres en brukeranalyse som viser deres krav og ønsker til det endelige produktet. De primære behovene er knyttet til billigere alternativer, lokale produksjonsmuligheter og kunnskap om regnvannshøsting generelt. Tilgjengelige ressurser og teknologiske aspekter av regnvann høsting blir også presentert for å få en komplett oversikt før konseptutviklingen.

Del 3 - Utviklingsprosessen

Dette er selve konseptutviklingsdelen, hvor flere aktuelle alternativer er utforsket og evaluert. Konseptene ble delt inn i to separate systemer, ett for de med tak av bølgeblikk, og en for de uten. De endelige konseptene ble deretter prototypet og testet i Ngumbulu.

Del 4 - Løsninger

De endelige løsningene er forklart og utdypet i denne delen, både funksjon, bruksmåter og retningslinjer på hvordan bringe løsningene fremover. Installasjon og produksjons manualer presenteres for bruk av både landsbyboere og det lokale utviklingssenteret.

Del 5 - Vurdering

Dette kapitlet oppsummerer de foregående kapitlene med refleksjoner og muligheter for fremtiden. Her finnes også en verktøykasse til bruk i lignende prosjekter, knyttet til selve gjennomføringen av utviklingsprosjekter i marginaliserte samfunn.

17.2 Oppgavetekst

NORGES TEKNISK-
NATURVITENSKAPELIGE UNIVERSITET
INSTITUTT FOR PRODUKTUTVIKLING
OG MATERIALER

MASTEROPPGAVE VÅR 2014
FOR
STUD.TECHN. MAGNUS KILE ANDERSEN

UTVIKLING AV REGNVANNSSYSTEM FOR LANDSBYEN NGUMBULU, KENYA
Development of a rainwater harvesting system for the village Ngumbulu, Kenya

Klimaendringer har resultert i mer ekstremvær i Kenya med store nedbørsmengder to ganger årlig. Når det først regner, kommer det enorme mengder vann, etterfølgt av flere måneder med tørke. Lettes tilgangen til vann, spesielt i rurale strøk, vil fokus og tidsbruk kunne skiftes over til viktige oppgaver som utdanning, utvikling og verdiskaping, noe kvinner og barn vil i særlig stor grad nyte godt av.

Oppgaven utføres i samarbeid med Aid in Action og Ingeniører uten grenser. Aid in Action er en frivillig hjelpeorganisasjon som ble startet av Anne Louise Hübert etter at hun besøkte en landsby i Kenya. Aid in Action har som formål å gi nødhjelp og hjelp til bærekraftig utvikling for trengende mennesker blant annet i Ngumbulu i Kenya hvor vannmangel sees på som en av hovedgrunnene til manglende utvikling.

Tidligere arbeider viser gode muligheter for utnyttelse av systemer for samling av regnvann, som et viktig tilskudd til vannforsyning. Hovedfokuset i oppgaven vil være på små-skala segmentet, dvs. hovedsakelig til personlig bruk for en eller et mindre antall familier. Målet er å utvikle konsepter for innsamling og oppbevaring av regnvann som et tilskudd. Det kan være nødvendig å forandre måten vannet fra andre kilder blir hentet og oppbevart på for å skape et helhetlig system. Konseptet skal være bærekraftig, tilpasset lokale behov med mulighet for lokal produksjon og verdiskaping. Arbeidet er en videreføring av en prosjektoppgave med samme tittel høst 2013.

Oppgaven omfatter følgende punkter:

1. Analyse og beskrivelse av dagens løsning (produkt, teknologi og marked)
2. Gjennomføring av en behovsanalyse for en brukerkravspesifikasjon
3. Utredning av eksisterende teknologier og tilgang til komponenter og materialer
4. Utarbeiding av en produktkravspesifikasjon
5. Utvikling, evaluering og presentasjon av alternative konsepter
6. Valg og videre detaljering av det mest lovende konsept
7. Bygging og testing av nødvendige funksjonsmodeller
8. Presentasjon og evaluering av resultatene, spesielt med hensyn til en eventuell realiseringsfase i Ngumbulu, Kenya

Oppgaven skal aktiv ta i bruk PU - journal.

Senest 3 uker etter oppgavestart skal et A3 ark som illustrerer arbeidet leveres inn. En mal for dette arket finnes på instituttets hjemmeside under menyen masteroppgave (http://www.ntnu.no/ipm/masteroppgave). Arket skal også oppdateres en uke før innlevering av masteroppgaven.

Arbeidet i masteroppgaven skal risikovurderes. Hovedaktiviteter som er kjent/planlagt skal risikovurderes ved oppstart og skjema skal leveres innen 3 uker etter utlevering av oppgavetekst. Alle prosjekt skal vurderes, også de som kun er teoretiske og virtuelle. Risikovurdering er en løpende dokumentasjon og skal gjøres før oppstart av enhver aktivitet som KAN være forbundet med risiko. Kopi av signert risikovurdering skal være inkludert i vedlegg ved levering av rapport

Besvarelsen skal ha med signert oppgavetekst, og redigeres mest mulig som en forskningsrapport med et sammendrag på norsk og engelsk, konklusjon, litteraturliste, innholdsfortegnelse, etc. Ved utarbeidelse av teksten skal kandidaten legge vekt på å gjøre teksten oversiktlig og velskrevet. Med henblikk på lesning av besvarelsen er det viktig at de nødvendige henvisninger for korresponderende steder i tekst, tabeller og figurer anføres på begge steder. Ved bedømmelse legges det stor vekt på at resultater er grundig bearbeidet, at de oppstilles tabellarisk og/eller grafisk på en oversiktlig måte og diskuteres utførlig.

Besvarelsen skal leveres i elektronisk format via DAIM, NTNUs system for Digital arkivering og innlevering av masteroppgaver.

Kontaktpersoner:	Anne Louise Hübert	Aid in Action
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LIST OF FIGURES

18 Appendices

18.1 Material price sheet

What	Location	Price Ksh	Unit	Comment
Sisal stems	Ngumbulu	60	Per stem	2-3 m
Flat galvanized Iron sheets	Kitui	500	pr item	1x2 m
Iron sheet roofs	Katangi	700	pr item	1x3 m
Prefabricated iron gutters	Kitui	300	pr m	
Plastic pipe	Kitui	100	pr m	Ø2 inch
Polyethylene tarp, black	Katangi	300	pr m	
Plastic tarp, see through	Katangi	150	pr m	
Drum, plastic, 200 l	Katangi	2000		
Plastic tank, 3000 liter	Kitui	24 000		
Plastic tank, 2000 liter	Kitui	15 000		
Plastic tank, 1000 liter	Kitui	9 000		
20 l Jerry-cans	Katangi	250		
Small jerry can, 5 liter	Ngumbulu	100		
Timber	Katangi	40	pr m	2 x 4 inch
Timber	Katangi	25	pr m	2 x 2 inch
Wooden planks (fascia boards)	Kitui	200	pr m	6 x 1 inch
Treated poles	Kitui	67	pr m	approx Ø9cm
Square beams steel	Kitui	500	pr 6 m	1/2 inch
Z-bar steel	Kitui	700	pr 6 m	1x2x1 inch
V-profiles steel	Kitui	500	pr 6 m	2x2 inch
Nails, timber	Katangi	190	Pr Kg	approx 250 stk
Roofing nails	Katangi	190	Pr Kg	approx 250 stk
Steel wire	Katangi	250	pr kg	Ø 2mm
Cement	Katangi	730	50kg	

Group	Number	Type	Demand	Discussion	Extracted from	Focus
Cost	1.1	Total cost	< 10 000 Ks	Should the proposed solution be more expensive, close evaluations including the user must be performed. *The value does not take down-payment plans into account.*	*"A discussion of cost" "User demand specification"*	
Function demands	2.1	Capacity	Weekly supply of 90 liters per person.	Highly debatable as the user is generally happy about any increase in domestic water supply. Should be considered in cooperation with cost.	*"Water consumption estimates" "User demand specification"*	
	2.2	Modularity	Simple increase in storage	Modular systems where user easily can increase the capacity is desired	*"User demand specification"*	
	2.3	Water quality	Easy to keep clean and contain no hazardous materials.	Target values are WHO standards. However, a realistic approach should be made given the operation conditions. A minimum is that water is safe after boiling or similar treatment.	*"Design considerations"*	
	2.4	Covers	Reservoir to be coverable	The reservoir must be coverable to avoid contamination either by a lid, blankets or similar	*"Design considerations"*	
	2.5	Filters	Filters are to be installable on the system	This is non negotiable as filters are truly important for the water quality	*"Design considerations"*	
Environ mental demand	3.1	Location	Within the family compound, or in close proximity (100 meters).	For supervision and short distance carrying. Highly debatable if good solutions break with the demand,	*"User demand Specification" "Developer"*	
	3.2	Physical size	The system should minimize the impact on arid land.	Present installments should be utilized to minimize physical impact. No direct restrictions and may be discussed.	*"Developer"*	
Operatio nal demands	4.1	Operations	First flush to be diverted by one simple operation.	It is desirable that this is as easy as possible, and should not require a large effort from the user.	*"Fundamental needs"*	
	4.2	Multipurpose	Components to be utilized to other purposes	Would give the system an extra desirable aspect, however not a firm demand	*"Developer"*	
	4.3	Evaporation	Reservoirs should be easily coverable to avoid evaporation	Cover is either a lid, blankets or similar	*"Focus: roof catchment systems"*	

Group	Number	Type	Demand	Discussion	Extracted from	Focus
	4.4	Effort to make operative	Limited to before each rain season	Debatable, however as few as possible operations is to be needed before system is operative before each rains.		
Installation	5.1	Who	Buyer/NDC	The buyer should (with a minimum of training) be the main installer of the system to avoid cost. In special cases the NDC would be the installer, however this is not desired.	*"User demand specification"*	
	5.2	Methods	Simple methods and tooling like hammer, saw and knife only	The lack of technical knowledge requires simple methods of installation if buyer is to be self reliant on this matter.	*"Fundamental needs"*	
	5.3	Time (only applies to NDC)	Minimal	As little time as possible is desired if the NDC is to do the installation to reach a larger number of beneficiaries.	*"Developer"*	
	5.4	Where	No exclusions	The system should be installable and useable regardless of what preconditions the user/buyer has. All roofs, all compounds should be susceptible for the system. In special cases the demand may be altered.	*"Utilization of rainwater harvesting"*	
	5.5	Relocation	Possibility of retrieving and displacing the system	Displacing the system as a part of payment insurance is important. The system should be able to be retrieved; however should other arrangements be fit for the same purpose, the demand may be discussed.	*"User demand specification (NDC)"*	
	5.6	Tooling	Knife Hammer, Metal scissors, Shovel/pick	Different demands apply if installed by user or NDC. However simple tooling is important to ensure easy and proper installation.	*"Utilization of rainwater harvesting" "A matter of resources" "Fundamental needs"*	
Reliability	6.1	Durability	<10 years	The longer the component lasts, the better. Must be seen in relation to cost. Warranty is not a common demand in rural-African areas, however some indications on lifespan should be given. Rules should follow the system and demand only applies if adequately maintained. Target value, but is of course severely influenced by cost.	*"Developer"*	
	6.2	Robustness and efficiency	Keep efficiency during heavy rainstorms and tough conditions	The system components shall not break in the typical heavy winds and rainstorms that occur in Ngumbulu.	*"Environmental conditions"*	

Group	Number	Type	Demand	Discussion	Extracted from	Focus
Maintenance	7.1	Who	Buyer	There should be no need for additional support for regular maintenance. A minimum of training may be required to fulfill the demand.	*"User demand specification"*	
	7.2	Frequency	In the first days of rain season only.	Maintenance should be non-critical fixes or cleaning only during the entire lifetime. The less maintenance needed is better.	*"User demand specification"*	
Production	8.1	Methods	No welding or specialized tooling needed. Simple tools like hammer, saw and knife should be enough.	Due to lack of skilled labor, however if workarounds are seen fit, the demand is debatable.	*"Fundamental needs" "A matter of resources" "User demand specification"*	
	8.2	Availability of components	Ngumbulu> Katangi> Kitui	If imported by NDC Kitui is the farthest allowed. Katangi is preferred. For users Ngumbulu is the farthest allowed.	*"Fundamental needs" "A matter of resources"*	
	8.3	Local production	Components should to the largest degree be producible locally	Strived for, but debatable if not achievable. Indirect value creation will fulfill the demand; such as liberation of time and exertion for the villagers, thus the demand does not get top priority.	*"User demand specification"*	
Other demands	9.1	Market demand	Villagers to have good relations with the product	This demand is highly impressionable by other factors, however it is important to consider. This demand affects the affiliations to NDC as offering an unwanted product would lower their status in the society.	*"Design considerations" "Utilization or rainwater harvesting" "User demand specification (NDC)"*	
	9.2	Safety	Minimal safety hazard	The system (predominantly tanks) shall not pose a safety threat to humans in case of breaking or in any other situations.	*"Developer"*	
	9.3	Local independency	Management by NDC only	As low level of management from NDC as possible is desired to ease workload.	*"Developer"*	
	9.4	Global independency	No government support to be needed	The demand is given to avoid corruption and time-consuming appliance processes	*"Developer"*	

18.3 Concept info

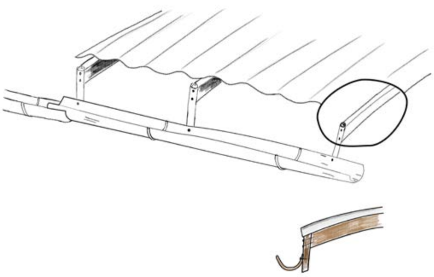
2.1 Delivery system

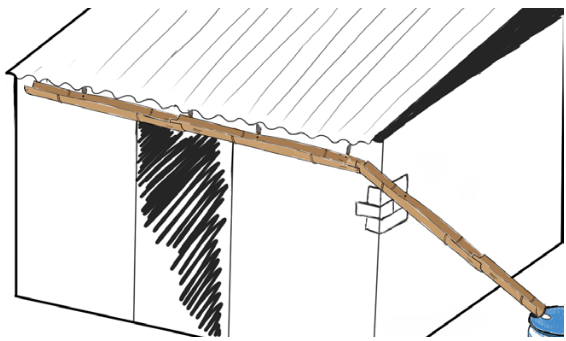
This chapter contains information and discussion on the following items:

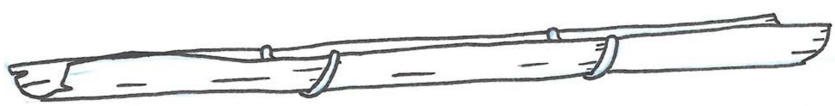
- All sisal
- Sisal Jerry-can
- Planks and tarp
- Bent iron sheet
- Flat iron sheet gutter
- Pre-made iron gutter

All Sisal

In this concept the cost is completely minimized by only using sisal stems which may either be found in the nature or bought from locals at a rate of approx. 60 Ksh per stem (2 - 2.5m). The stems are cut in half, cleaned out and overlaid. The drop outlet and downfall consists of one sisal stem in an angle, directing water towards the reservoir.



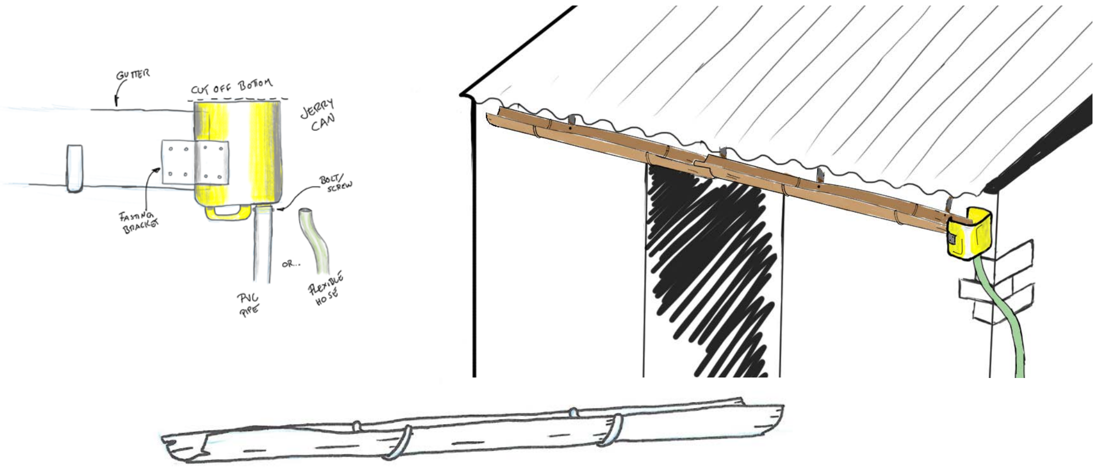




The discussion revealed that even tough the sisal seems good for gutters; it may not be possible as a drop outlet. There will be severe issues in fastening of this, as well as a long stem is required. Also the need for extra support of this render the concept difficult to make and the durability is questionable.

Sisal Jerry can

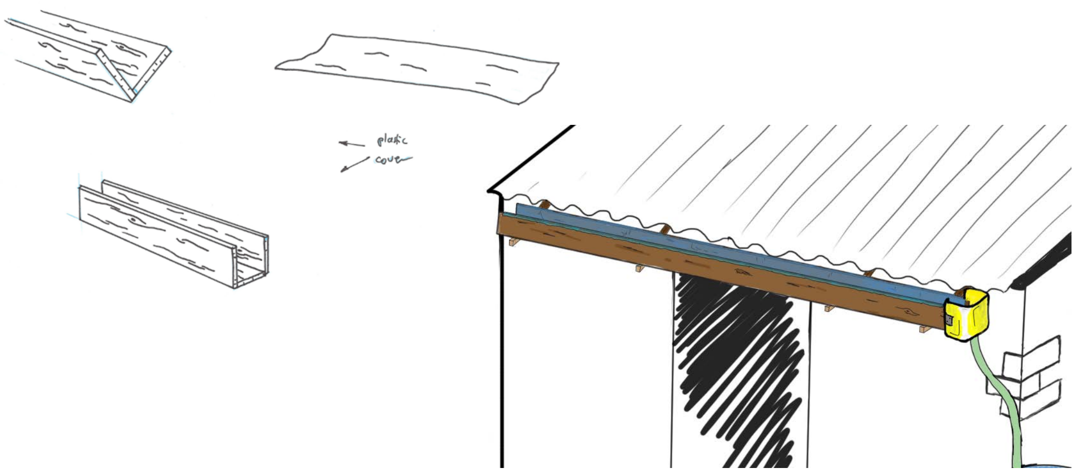
The concept uses the cheap sisal stem as gutter and a jerry can (or other small container, such as a large bottle) as drop outlet. The downfall may either be a rope, a hollow stem or a stick. This will be decided on a later stage in the development process.



The concept is more complex as the construction and fastening of the jerry can may be difficult and more parts give extra expenses. However the efficiency and availability of parts makes the concept promising.

Planks (fascia boards) and tarpaulin

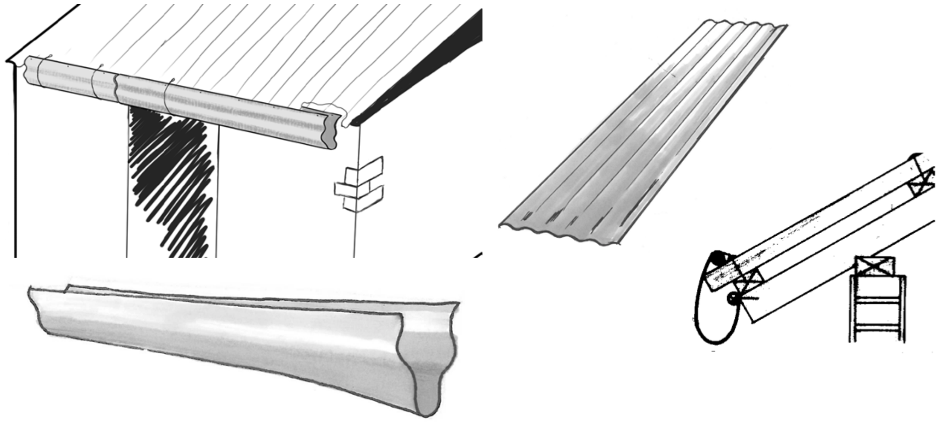
Three fascia boards are fitted together in a square shape in an attempt to make a cheap but efficient gutter. It is very hard to find straight wooden planks, so a piece of tarpaulin is laid inside the gutter to prevent water from spilling through the cracks (paste may also be used).



During the discussions it became clear that fascia boards are more expensive than the developer first anticipated and the need for extra tarp in fact makes the concept one of the most expensive. In addition nails and trained labor raises the price even further.

Bent iron sheets

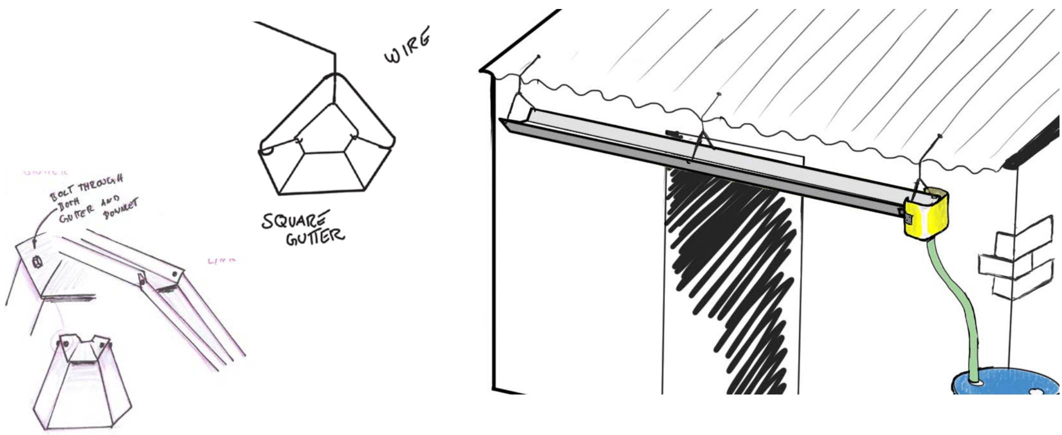
A strip of galvanized iron sheet used for roofing may serve as gutter when bent into a circular shape and fastened to the roof with wires.



This type has been seen in Ngumbulu and is known by the community. It is simple to make, durable and efficient. However it is not cheap as a rather wide part of the iron sheet must be used, and the closed fashion of the gutter makes it hard to keep clean. There is also an issue with the drop outlet, but a jerry can seems to be a solution for this.

Flat iron sheet gutter

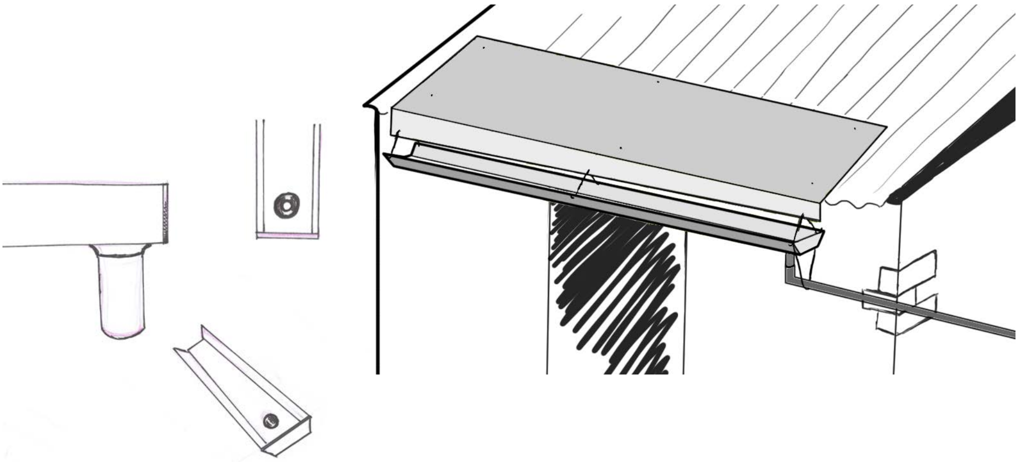
A gutter hammered into a v- or square shape from flat iron sheets may be a good opportunity for cheaper, local made gutters. Such a gutter may be very durable, efficient and is easy to clean. The downside is that it requires skills and tools to make them, which the community members may not have. The concept will also be more expensive than e.g. the sisal and possibly also the iron sheets.



The drop outlet may be either jerry can, angled iron sheet gutter or direct. After discussions the best drop outlet seemed to be the jerry can, due to lower price ant the easy installation.

Pre-made iron gutters

This option utilizes pre-made and bought galvanized iron gutters. They are available in Kitui and are seen as the best in form of durability and efficiency. However this option is by far the most expensive and leaves no possibility for local production.



In reality this is not an option for the community as there is a demand for cheaper gutters, but is included for comparison. This option usually comes with a direct drop outlet ready from vendor.

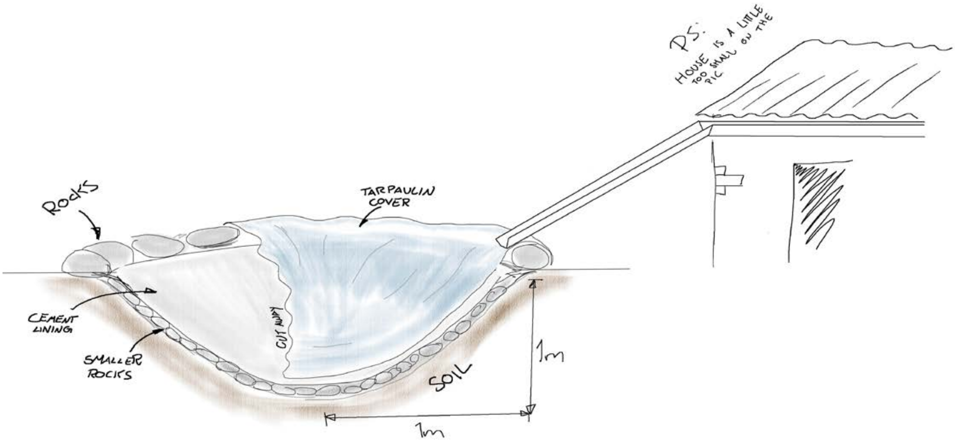
2.2 Reservoirs

This chapter contains information and discussion on the following items:

- Hole in the ground
- Jerry cans
- Blue drum
- Black tanks
- Galvanized iron tanks
- Concrete tank
- Ferro-cement tank
- Water pot
- Cement lined oil drum
- Water bag

Hole in the ground

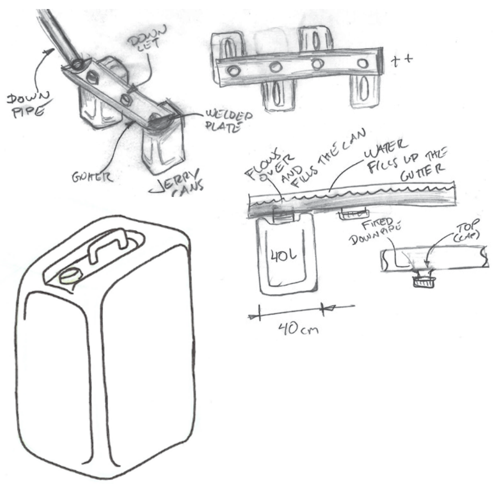
The idea was to duplicate the bigger dams, shrink it and place it closer to home. The catchment surface would then be the roof. Given that the aim is to store drinking water, a tarpaulin must be laid in the hole. The walls need to be sloped not to fall during the rain season.



The walls must perhaps be cemented or plastered with rocks to prevent erosion of the walls, which will add cost. There may also be a safety issue with retrieving water, as the walls need to be sloped. Also the large surface area gives a cover problem, and by not having a covered tank, mosquitoes may present a disease issue by breeding in the reservoir.

Jerry cans

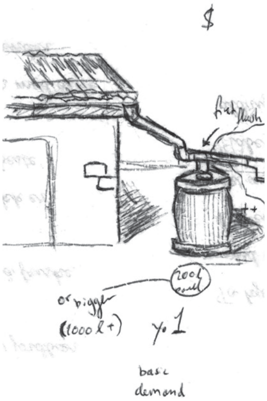
The jerry can is the most common way of collecting and transporting water in Ngumbulu where the cans are strapped to donkeys, often four at a time, or carried manually. The jerry can is robust and easy to keep clean because of small openings and caps.

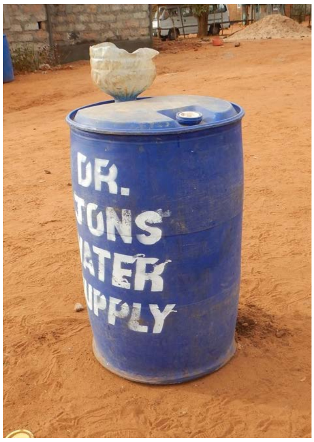


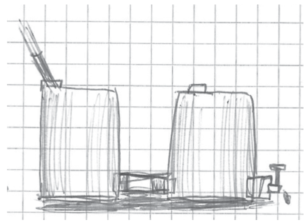
To serve as a storage reservoir for roof catchment systems one needs a large amount of jerry cans to support a family. As an example one needs approx. 50 jerry cans for 1 000 liter which may be expensive and pose an issue of placement. Also the villagers expressed a wish for larger tanks than jerry cans, which is already available in the area.

Blue drums

The blue drum is already seen in some homesteads in Ngumbulu and is a reliable and robust storage of water. The drums are made from high-density polyethylene and may contain 200 liters.



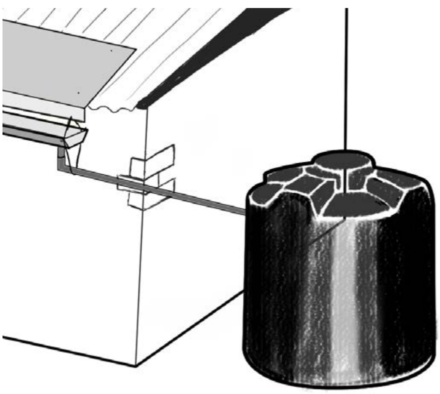




The tanks leave no possibility of local production and must be imported from Katangi. The drums are lightweight and may be used to transport water from the river when empty from rainwater. Drums have a capacity issue and are somewhat expensive per liter, but introduction cost is low and incremental increase of storage is easy.

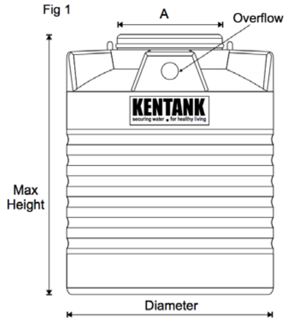
Black Tanks

This polyethylene tank has become very popular in the recent years and some of the more affluent villagers have already acquired them.



KENTANK ABOVE GROUND STATIC WATER STORAGE TANK - CCV SERIES

Fig 1



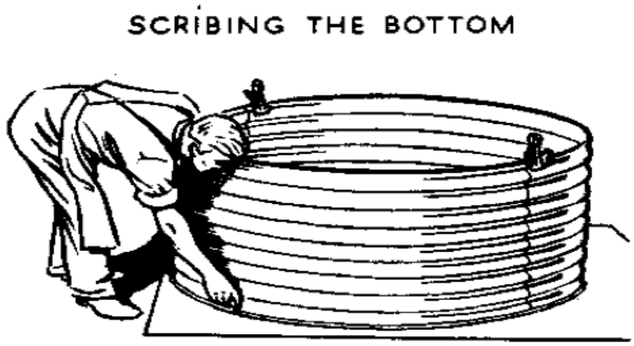
Approx. Tank Dimensions in Cms

	Tank Size	Litres	Gallons	Diameter	MAX Height	A
1	CCV 15	150	33	58	74	29.6
2	CCV 25	250	54	69	84	29.6
3	CCV 30	300	65	75	65	29.6
4	CCV 50	500	109	86	103	42.2
5	CCV 75	750	163	98	118	42.2
6	CCV 100	1000	217	107	127	42.2
7	CCV 101	1000	217	93	175	42.2
8	CCV 135	1350	293	121	138	42.2
9	CCV 150	1500	326	124	142	42.2
10	CCV 200	2000	435	135	158	42.2
11	CCV 230	2300	500	144	165	42.2
12	CCV 231	2300	500	170	125	42.2
13	CCV 250	2500	543	148	169	42.2
14	CCV 300	3000	652	156	185	42.2
15	CCV 320	3200	696	169	140	42.2
16	CCV 350	3500	761	165	187	42.2
17	CCV 400	4000	870	173	200	42.2
18	CCV 460	4600	1000	200	178	62.3
19	CCV 500	5000	1087	185	212	42.2
20	CCV 600	6000	1304	198	223	42.2
21	CCV 800	8000	1739	219	243	62.3
22	CCV 000	10000	2174	236	266	62.3
23	CCV 1600	16000	3478	290	280	62.3
24	CCV 2400	24000	5217	356	280	62.3

Black tanks must be imported and poses no possibility of local production. However, they are very robust if taken care of (30 years warranty) and are easy to clean. Tanks come in all sizes between 100 and 24 000 liters and meant to be stationary.

Galvanized iron tanks

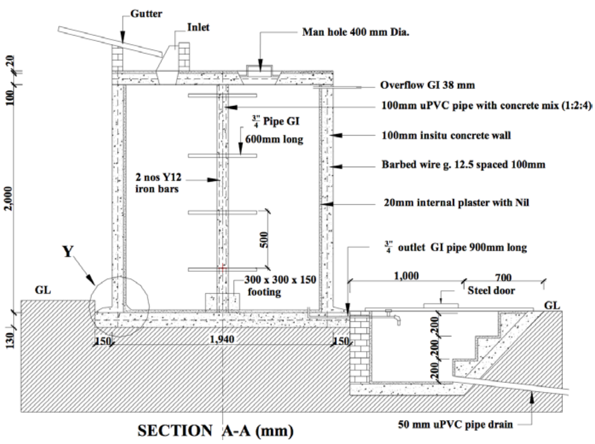
This type of tank is seen sporadically in Africa, and also in Kenya. The tank is prefabricated and is available in several sizes and shapes.



It is possible to make these on site in Ngumbulu, however skilled labor is needed. The tanks are susceptible to corrosion and several of them have been rendered unusable because of this, even in Ngumbulu.

Concrete tank

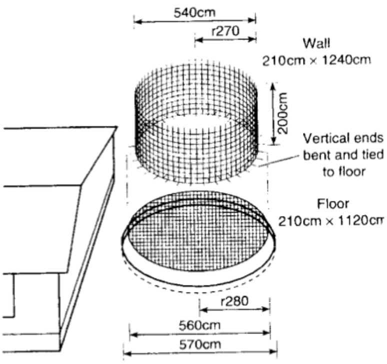
Concrete tanks are widely used as storage reservoirs in developing countries, may as a part of a roof catchment system. Tanks are built by using molds of iron sheets filled in layers with concrete mixture.



Concrete tanks are relatively cheap in material and must be produced locally, but requires skilled labor and is time consuming. The durability is highly variable and depends on the accuracy in the construction process. In Ngumbulu several of them may be seen, some operational some broken and abandoned.

Ferro cement tank

Much like the concrete tank this reservoir is widely used in several countries and areas. The tanks are constructed with reinforcements and cement plastered in layers and may be built above and below the ground.

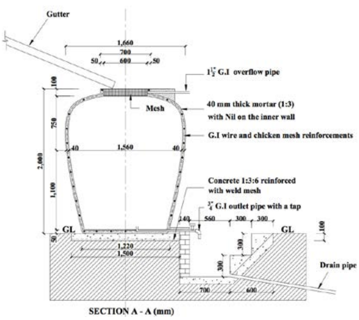


BRC mesh for floor and wall

Much like the concrete tank the ferro cement tank is cheap in material and may be produced locally. However, even more skilled labor is needed, and is even more time consuming to construct. Also this type is seen in Ngumbulu, but many have cracked and become useless.

Water pots

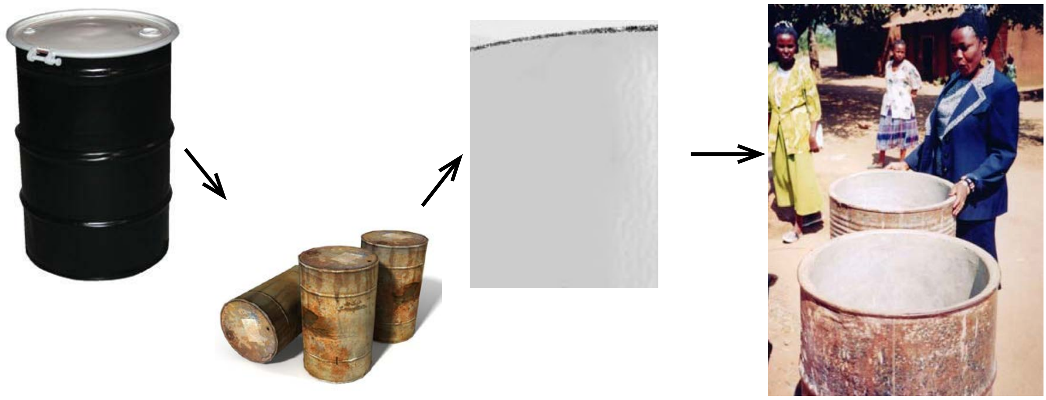
Water pots are a popular method for storing water in Asian Countries such as Thailand. The technology is similar to the ferro-cement water tanks with a cement layer on reinforcements such as barbed wire.



As with the ferro-cement tank there is the need for skilled labor, however the water pots are made smaller than the tanks and may be constructed elsewhere and transported. It is relatively cheap in materials and is relatively quick to construct.

Cement lined oil drum

Most rural homesteads can afford an oil drum to harvest rainwater from the roof. Unfortunately, the lower part of oil drums corrodes. The oil drums are then discarded as scrap metal, but by plastering the drum with cement on the inside the reservoir may be saved.



This tank is potentially very cheap and may be produced locally because of the easy construction. The durability becomes very high, and it may even be somewhat mobile. Drums can usually contain 200 liters incremental increase of storage is easy

Water bag

The modern technology of water bags are to use a vinyl fabric joined together with seam or weld to form a blather, usually square or cylinder formed. The blathers may vary in size from small liter bags to large industry blathers of several thousand liters.

The bags may be produced locally, however skills are needed in plastic welding. The bags have a durability issue in rough conditions such as Ngumbulu, and require a great ground space. A concern is what impact a punctured water bag may have on a family's domestic water situation.

Reservoir price approximation table

The hole in the ground is estimated based on the cost of cement and tarpaulin. Jerry can, drum and plastic (black tank) is taken from actual prices. Iron sheet, concrete, ferro-cement and water pot estimation is retrieved from construction manuals dating between 2000 and 2005 and is highly indicative. Cemented oil drum is based on 1000 for drum and 250 for cement which is seen to be very conservative. Water bag is highly indicative and deducted from the price of vinyl fabric in the area added to cost of taps and caps.

Price approximation table						
Type	Hole in the ground	Jerry can	Drum	Plastic	Iron sheet	
Price pr 500 liter	875	6000	5500	4500	3000	KES
Type	Concrete	Ferrocement	Water pot	Oil drum	Water bag	
Price pr 500 liter	4000	2500	3600	2500	3000	KES

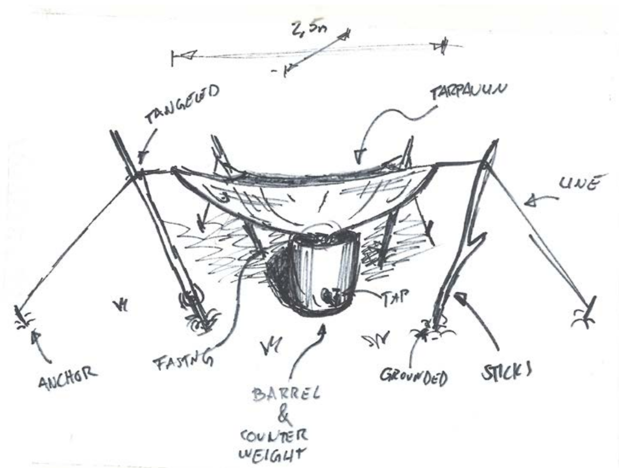
Independent system

This chapter contains information and discussion on the following items:

- Tarp and drum
- Tarp and water bag
- Laid out tarp
- Drum top catchment
- Catchment stand
- Catchment center

Tarp and drum

The tarp and drum is developed to utilize the well-known blue plastic drum as well as the flexibility of the plastic tarp. As seen in the illustrations the tarp is stretched and anchored in four poles above the plastic drum. The size of the tarp may vary, however a size of 2 by 2 meter is seen as a maximum regarding installation difficulties and stability and still keep a sufficient catchment surface. At the center of the tarp there is a hole that is fastened to one of the openings in the drum by a string. Given that half of the drum top is normally opened, the water that spills besides the string will fall into the container anyways.



To keep costs at a minimum, the poles are supposed to be found in the nature. However, they may also be bought from a timber shop at an additional price. The concept has capacity issues due to the small reservoir, but the water may be moved to other available containers such as jerry cans when full. Other issues may lie in the stability of the tarp during wind, and that the concept is to be installed before each rains which requires a lot of activity from the user.

Tarp and water bag

This is a concept developed by Norwegian engineer Henrik Bull and is somewhat similar to the tarp and drum concept. Also in this solution the tarpaulin is utilized and stretched out between four poles. The poles need not be as high as on the previous concept since the water will flow into low lying plastic water bags. A plastic tube connected at the center of the tarp is also connected to the water bags.

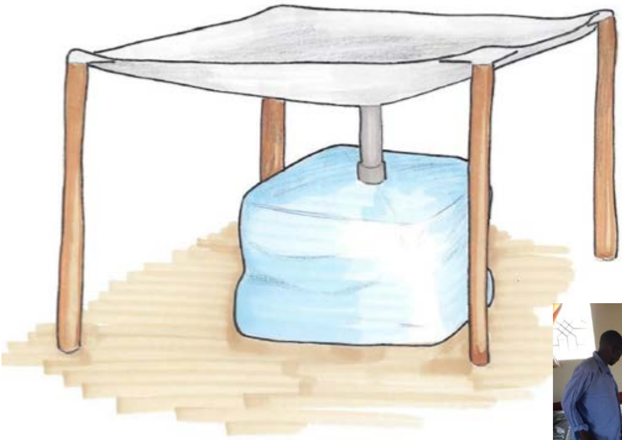
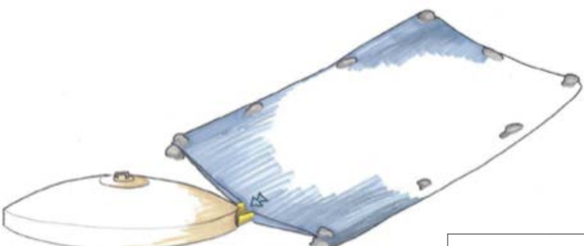


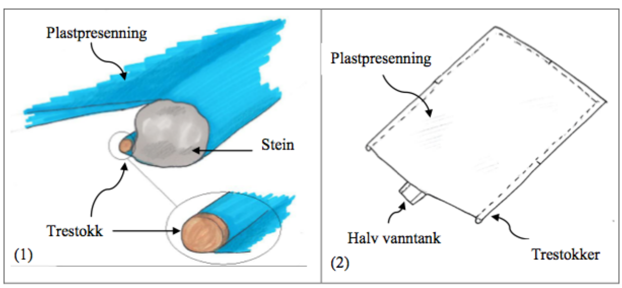
Figure 65 Illustration: Kaja Flottorp

This concept has been tested in Ngumbulu by the staff at the development center. The result were not promising with reports that the tarp was highly unstable in the strong winds and that the water bags broke fairly quickly. The plastic in the bags must be severely strengthened in order for this concept to work. Locating strong tarp for the bags have proving difficult in the area, and import may be the only solution.

Laid out tarp

This concept was developed by engineer Kaja Flottorp during a master thesis on rainwater harvesting in Kenya. The concept is to use a tarpaulin laid out on the ground to collect water and direct it towards



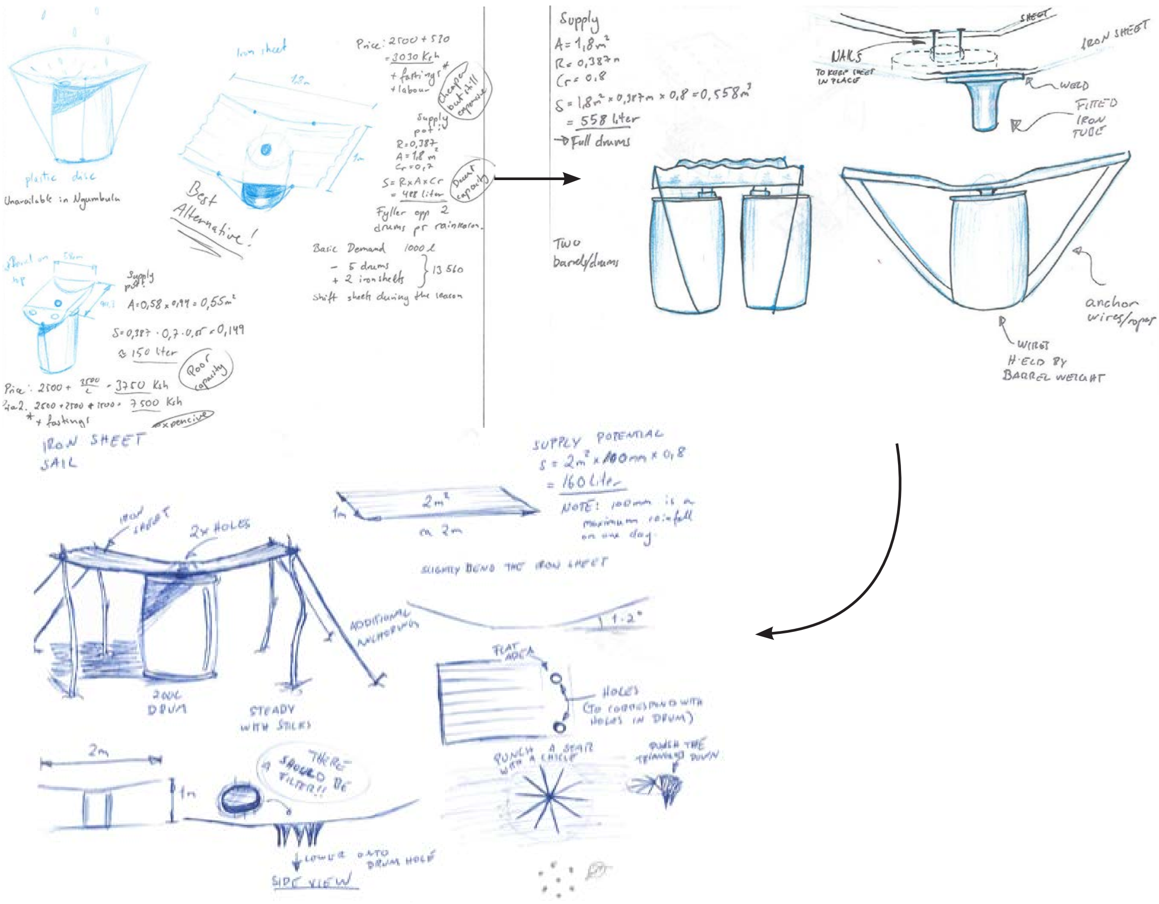


an underground concrete tank. The concept is dependent on a flat surface without vegetation angled towards the tank. After each rain the tarp is to be rolled up and stowed away waiting for the next pour.

The concrete reservoir provides a large capacity, however is a big investment and difficulties in construction quality may occur. The tarp is less subjected to winds, however the stones, rough ground and easy access by unwanted users (chickens, children) may challenge the durability of this concept.

Drum top catchment

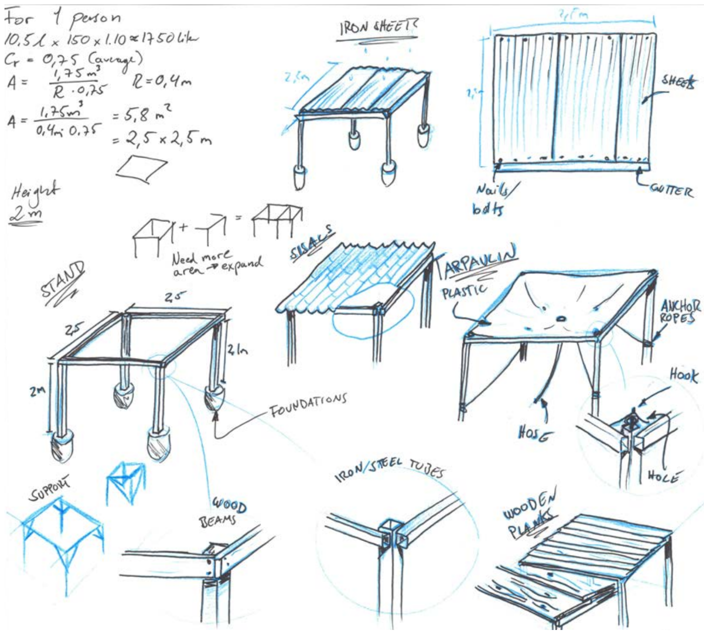
This concept uses iron sheets as catchment surface and a blue plastic drum as a reservoir. It should be noted that other reservoirs such as oil drums and small water jars (and also jerry cans) may also be used.

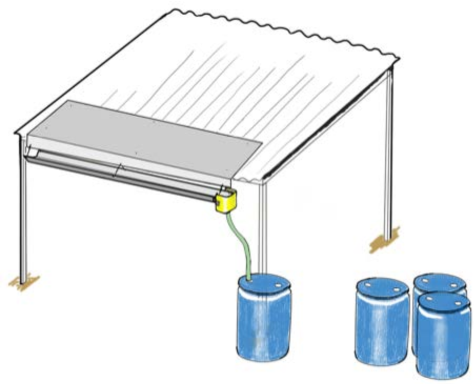


The concept has the advantage of being stable and efficient even in strong winds and is not required to be uninstalled between each rain. During the heat the iron sheet provides shadow and protection for the reservoir. Issues lies in the capacity per system as a maximum of 3m2 of catchment surface is possible and the reservoir is somewhat small.

Catchment Stand

This concept is based on larger and more permanent installation. The initial idea was to supply the stand with whatever catchment surface villagers could afford. Later discoveries showed that only the iron sheet would be suitable for the stand. Perhaps tarpaulin could be used, but is not intended for the solution.

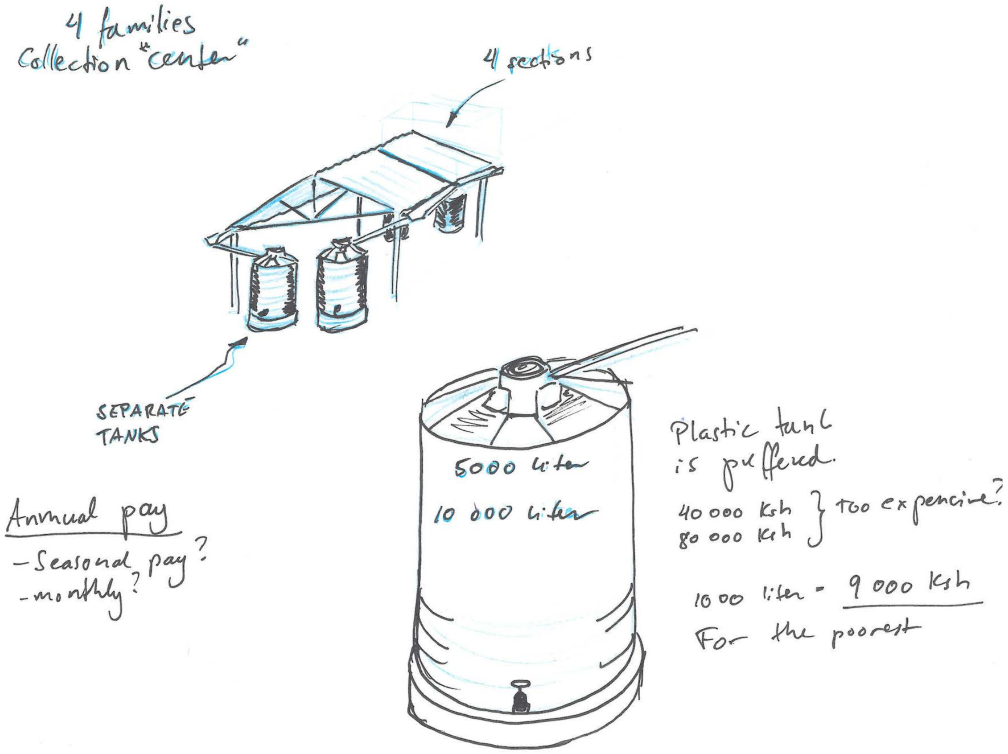




The idea is to simulate a house by constructing a framework of timber overlaid with iron sheets. In addition gutters and a reservoir is needed in the same way a for a rainwater harvesting system installed on a regular house. This implies great costs and may not be suitable for the most economically challenged in the community, however may serve as an addition for those with iron sheet roofs.

Catchment center

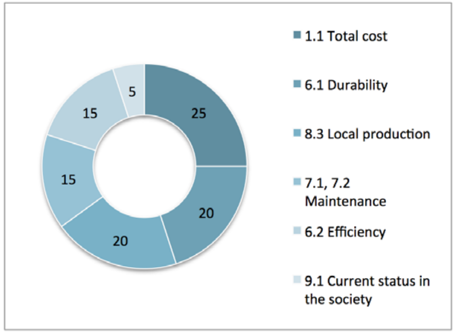
As the poorest in the community have problems finding means in which to invest in personal rainwater harvesting systems, a catchment center may be a solution. This is a construction where each family is given a portion of a catchment surface and a tank of a certain size.

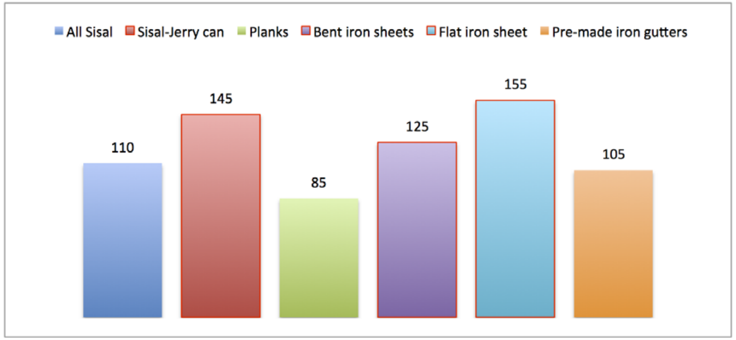


Even if such a catchment center may be cheaper in construction, several other problems follow, such as management, security and location. In other places of the world such centers have been constructed, however most of them are in densely populated area, and are large serving hundreds of people. This is not possible in Ngumbulu, as distance is part of the problem with water. Also the requirement of security and management provides an additional cost.

What	Description	Weighting (%)	All Sisal	Sisal-Jerry can	Planks	Bent iron sheets	Flat iron sheet	Pre-made iron gutters
1.1 Total cost	Total amount of money to be paied for the system. With or without downpayment	25	50	50	0	25	25	0
6.1 Durability	The total suspected lifespan of the system. All components are considered, and is indicative.	20	0	20	20	40	40	40
8.3 Local production	May components be made locally.	20	40	40	20	20	20	0
7.1, 7.2 Maintenance	How easy it is to clean and maintain.	15	15	15	15	0	30	30
6.2 Efficiency	Is water likely to spill from the gutter. Will it clog up quicly by debris.	15	0	15	30	30	30	30
9.1 Current status in the society	Popularty among the people based on prevoius experiences. Is the tank unknown, it will be neutral. Rating based on local knowledge.	5	5	5	0	10	10	5
Sum		100	110	145	85	125	155	105 of 200 max

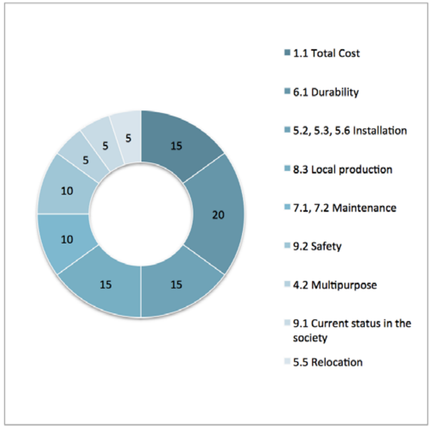
Points	
Meets the criteria	2
Neutral	1
Does not meet the criteria	0

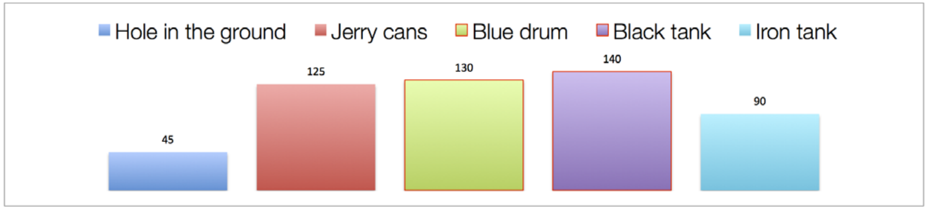


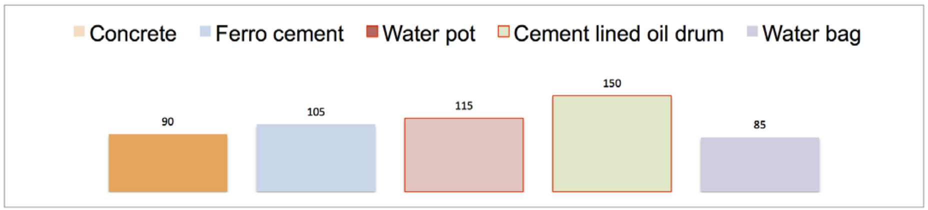


What	Description	Weighting (%)	Hole in the g	Jerry cans	Blue drum	Black tank	Iron tank	Concrete	Ferro cement	Water pot	Cement lined	Water bag
1.1 Total Cost	Total amount of money to be paied for the system. With or without downpayment The bar is set on cost per 500 liter to be able to compare the reservoirs. It is an approximation.	15	30	0	0	15	15	15	30	30	30	15
6.1 Durability	The total suspected lifespan of the system. All components are considered, and is indicative.	20	0	40	40	40	20	20	20	20	40	0
5.2, 5.3, 5.6 Installation	Time and effort it takes to install the item where it will serve as a reservoir for rainwater harvesting. Less time is preferred to serve more people quickly.	15	0	30	30	30	15	0	0	0	15	0
8.3 Local production	To what degree may the tank be made locally thus creating value to the nearby society.	15	0	0	0	0	15	30	30	30	15	30
7.1, 7.2 Maintenance	How easy it is to keep the water inside clean.	10	0	20	20	20	10	10	10	10	20	10
9.2 Safety	May the reservoir pose a threath to the environment.	10	0	10	10	10	10	10	10	10	10	10
4.2 Multipurpose	May the reservoir be used to more than a fixed point where water from the roof enters?	5	5	10	10	5	5	5	5	5	5	5
9.1 Current status in the society	Popularty among the people based on prevoius experiences. Is the tank unknown, it will be neutral. Rating based on local knowledge.	5	5	5	10	10	0	0	0	10	5	5
5.5 Relocation	To what extent may the tank be repossessed and resold if the beneficiary is not able to pay for it.	5	5	10	10	10	0	0	0	0	10	10
Sum		100	45	125	130	140	90	90	105	115	150	85 of 200 max

Points	
Meets the criteria	2
Neutral	1
Does not meet the criteria	0

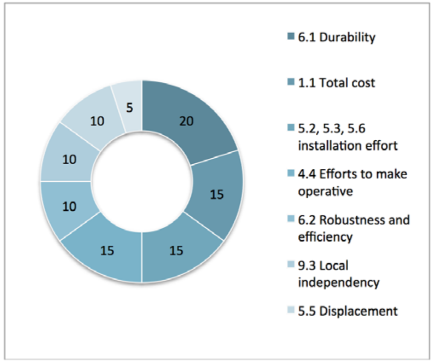


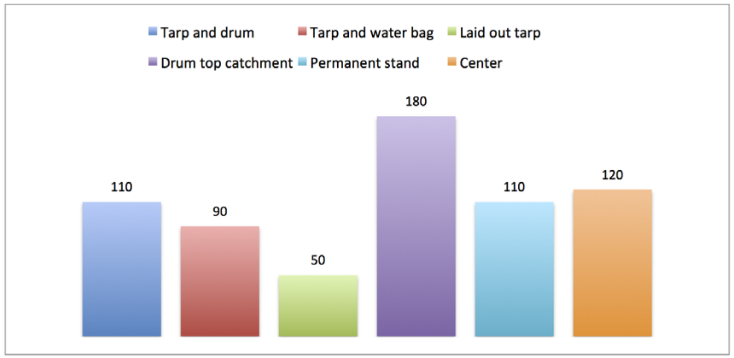




What	Description	Weighting (%)	Tarp and drum	Tarp and water bag	Laid out tarp	Drum top catchment	Permanent stand	Center
6.1 Durability	The total suspected lifespan of the system. All components are considered, and is indicative. Maintenance is also a factor here.	20	20	0	20	40	40	40
1.1 Total cost	Total amount of money to be paied for the system. With or without downpayment	15	30	30	0	30	0	15
5.2, 5.3, 5.6 installation effort	The amount of time and effort it requires from the buyer to install the system first time. Shortest amount of time is preferred.	15	15	15	0	15	0	0
4.4 Efforts to make operative	The amount of required activity required form the user to operate the system once in place. Less activity needed is positive.	15	0	0	0	30	30	15
6.2 Robustness and efficiency	Is the system suspected to keep its efficiency duting heavy winds and rainstorms, which occure in the rain season in Ngumbulu.	10	0	0	10	20	20	20
9.3 Local independency	Does the system require management from other than the buyer itself.	10	20	20	20	20	20	0
5.5 Displacement	In an event of buyer not paying for the system. How easy is it for the development center to retrieve it and sell it to someone else. This is an importent factor.	10	20	20	0	20	0	20
3.2 Physical size	How big of an impact does the system on the homestead.	5	5	5	0	5	0	10
Sum		80	110	90	50	180	110	120 of 200 max

Points	
Meets the criteria	2
Neutral	1
Does not meet the criteria	0





18.7 Revenue model iron sheet gutters

Costs		
Cost per 2 meter	125	Ksh
Time per 2 meter	10 min	
Gutters per hour	5	
Gutters per day	30	
Labr cost	350	Ksh
Cost	4100	Ksh
Income		
Margin per gutter	25	Ksh
Price pr gutter sold	150	Ksh
Income per day	4500	Ksh
Daily profit	**400**	Ksh
Days pr month	10	
Profit per month	**4000**	Ksh

18.8 Question sheets

INTERVIEW GUIDE FIELDWORK

Village family, direct questions

Wish to discover

Discover possible areas of improvement in the water situation.
Gain more knowledge about how rainwater harvesting is done in the community.
Listen to the people when proposing possible solutions for the future.

How to do the interview

The interview is set up as a mere question and answer. However it is encouraged to talk around the questions as much as possible.

Introduction

Student together with the Ngumbulu Development center (Purpose for Life) trying to find out how to help and assist in water related issues in the area.

This survey is done in good faith, and if you don't feel like you want to answer some of the questions, that is no problem.

Questions

GENERAL

1. What is your name?
2. Where approximately is your house located on the map
3. How many people do you feed each day?

WATER

4. How much water do you use each day (approximately)?
5. Where do you get your water, and how do you transport it and how much time do you spend collecting water each day?
6. How much money would you say you use for water during a day, or a week?
7. Do you harvest any rainwater?

If yes:

a. What method do you use?
b. Do you think it helps
c. Do you have any troubles with the rainwater harvesting?

If no:

a. Why do you not harvest?
b. Would you consider doing so if you had enough money?

- ➢ Measure all the buildings with iron sheet roofs to calculate the possible catchment surface.

If there are no iron sheet roofs:

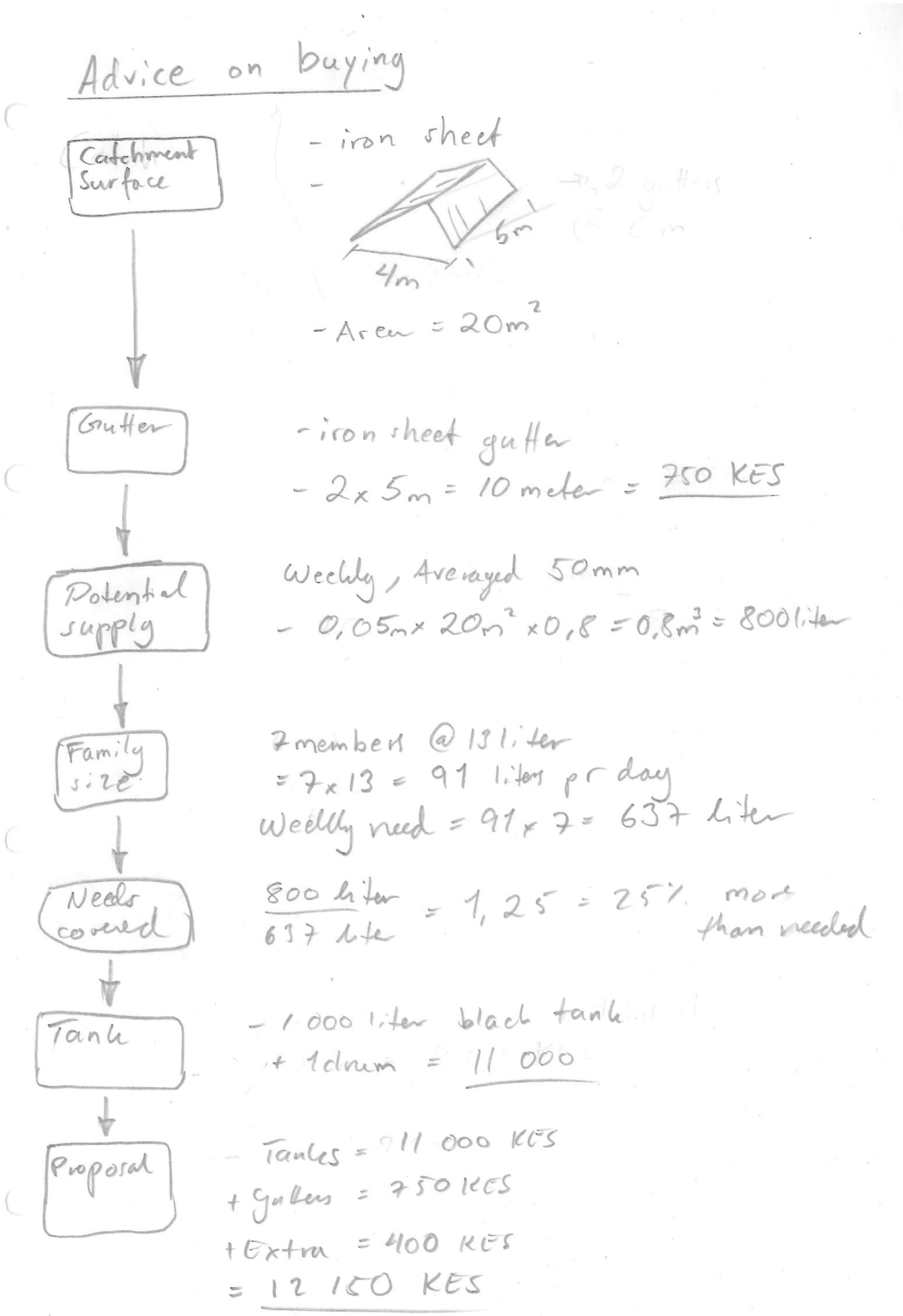
8. Do you have any ideas of how to harvest rainwater even if you have no iron sheets on your buildings?

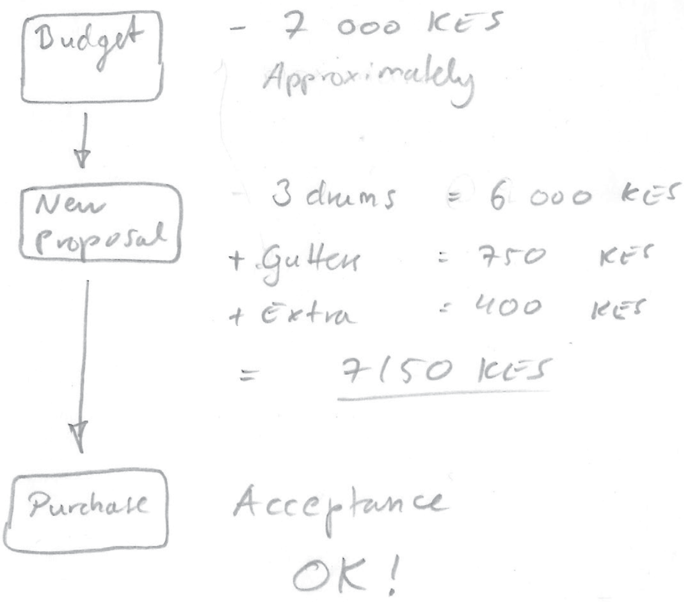
9. What types, and how many cans/tanks to store water do you have?
10. What tanks size would you be able to buy if you had the opportunity right now:
    - Drum of 200 liters – 2 500 Ksh
    - Black tanks of 1000 liter – 10 000 Ksh
    - Black tanks of 3000 liter – 25 000 Ksh

    Down payment may be possible over 5 years

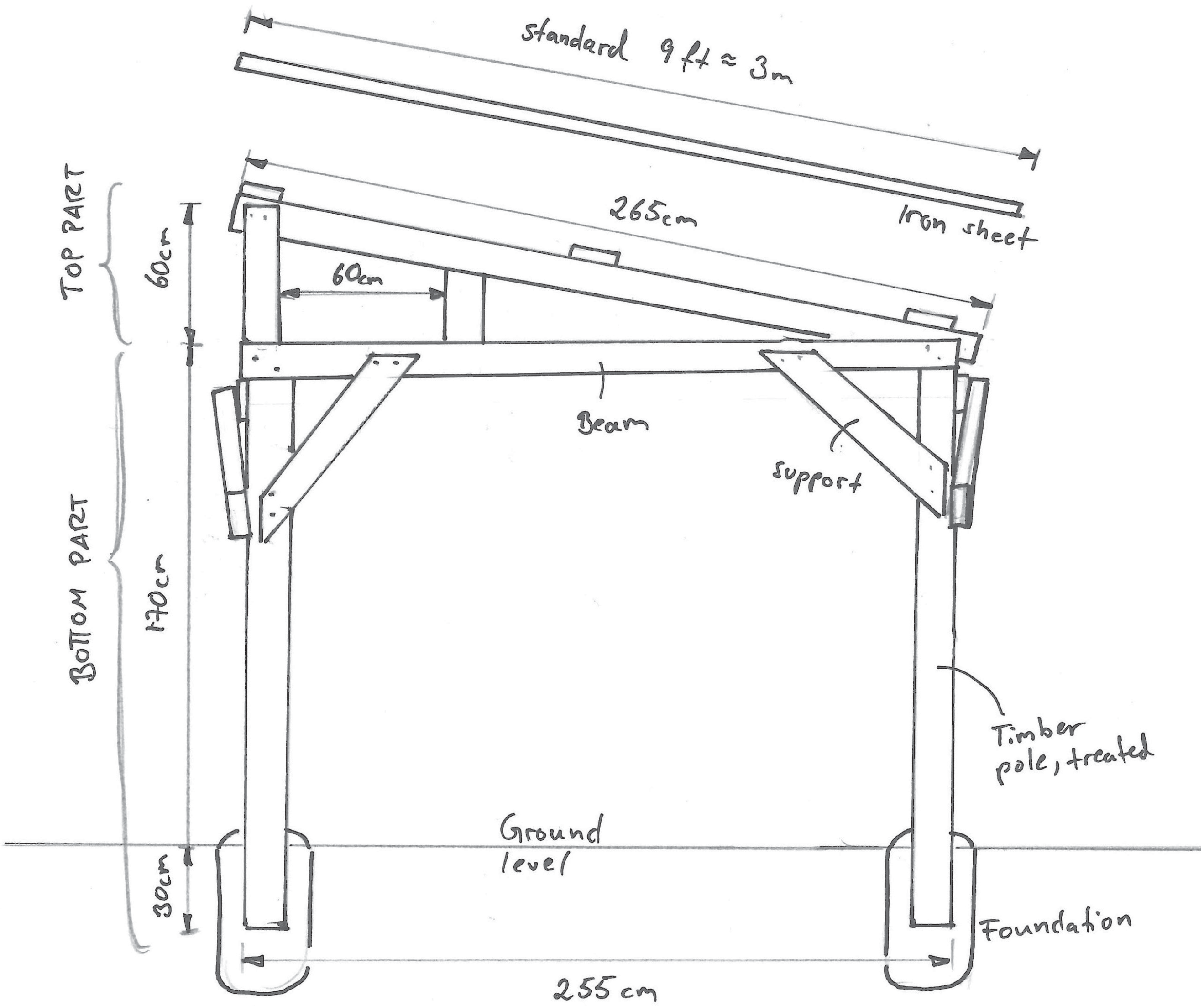
11. Do you think a small dam close to your home could be a good way to collect more water?
12. Would you be interested in digging a dam together with some of your neighbors(4 or 5 of them)?
13. If there was a way of transporting water more easily, with a small trolley/cart or similar, would you be interested in investing is such a thing?
14. How much would you be interested to pay for a small trolley/cart.

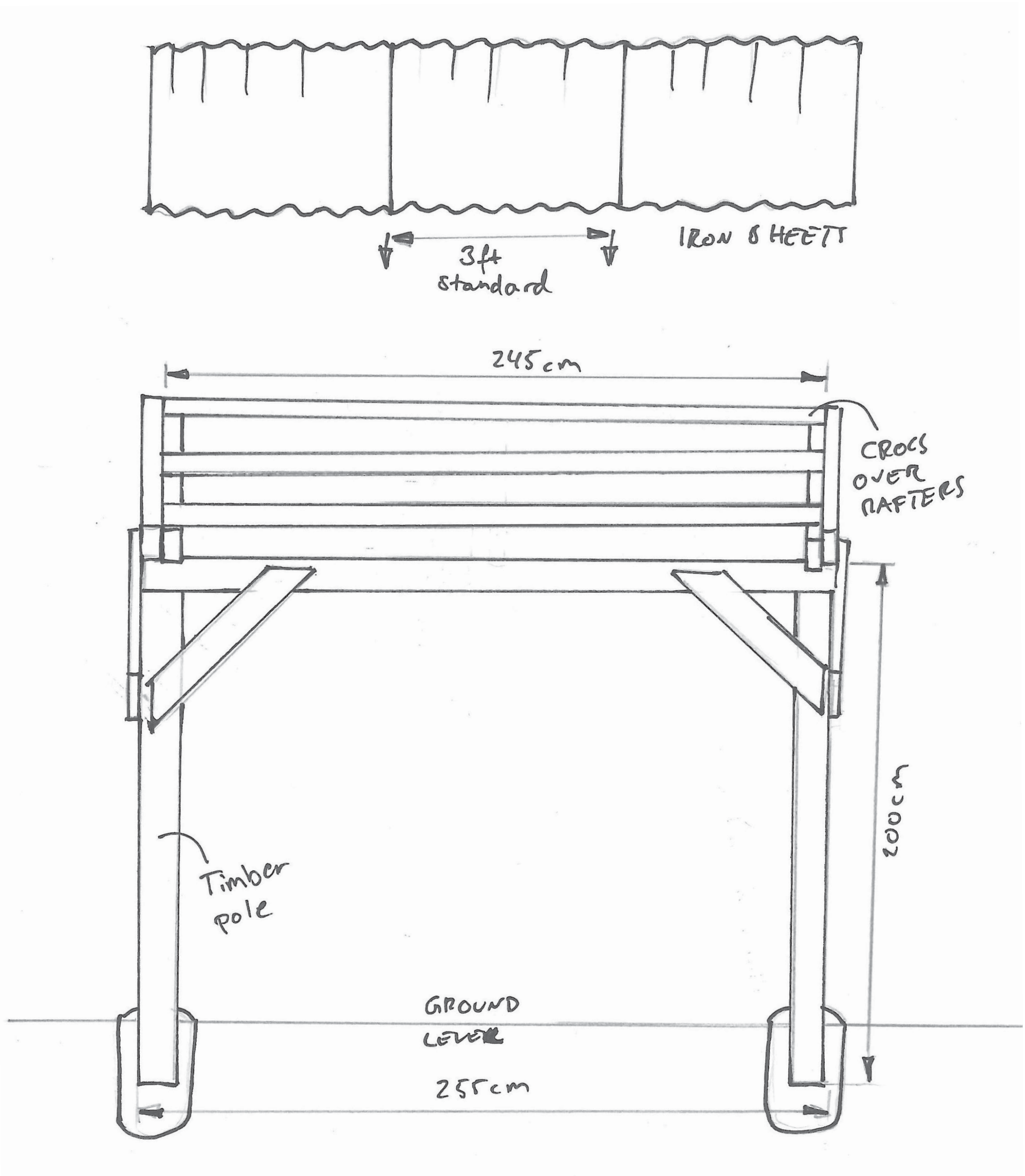
18.9 Proposal chain example




Budget
- 7 000 KES
Approximately
New Proposal
- 3 drums = 6 000 KES
+ Gutter = 750 KES
+ Extra = 400 KES
= 7150 KES
Purchase
Acceptance
OK!

18.10 Construction drawings - Test unit




IRON SHEETS
3ft
standard
245cm
CROSS
OVER
RAFTERS
200cm
Timber
pole
GROUND
LEVEL
255cm