UNIVERSITY OF COPENHAGEN &
UNIVERSITY OF NAIROBI &
UNIVERSITY OF ROSKILDE

Report

Conflict potential over water resources, Bathi River, Kiambu County, Kenya.

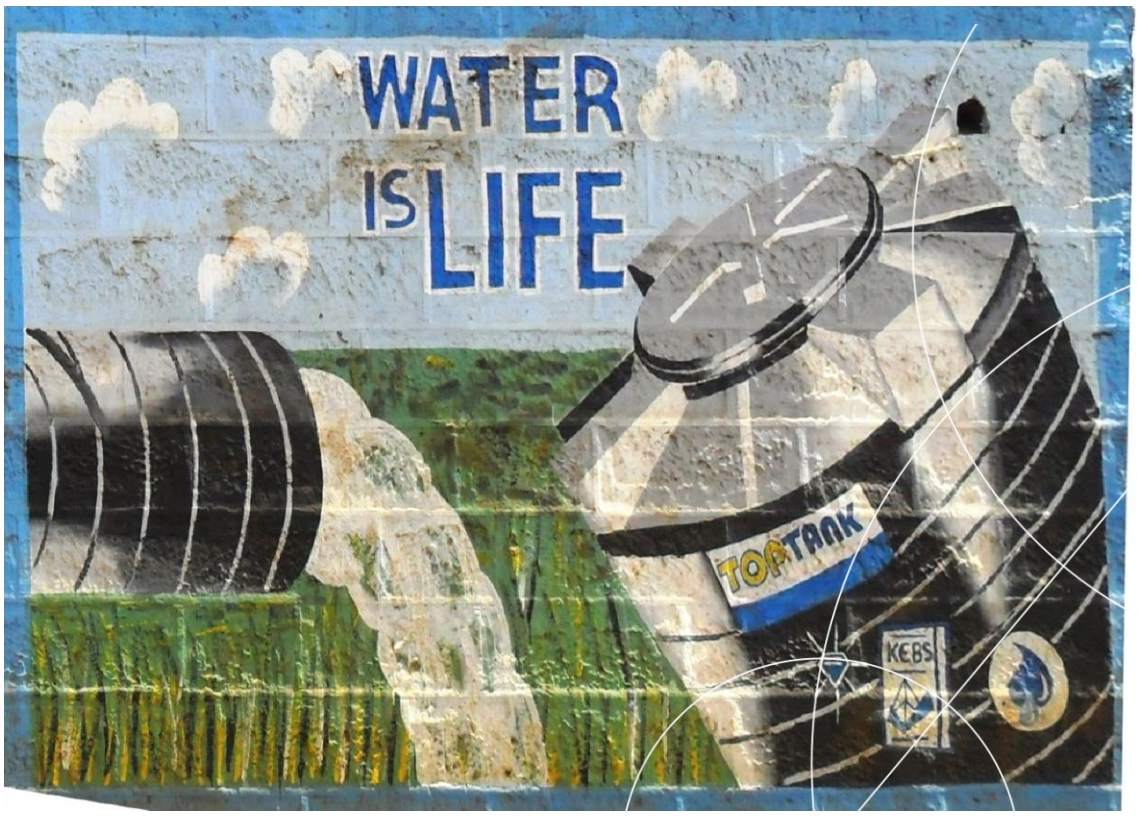
Physicochemical state of the river and social effects of the water management

SLUSE Joint course

INTERDISCIPLINARY LAND USE AND NATURAL RESOURCE MANAGEMENT (ILUNRM) 2015

Christian R. Bryn **ldb134**
Christina N. Kompf **cxb899**
Ann-Christin Struwe-Voscul **wqr772**
Sebastian F. Zastruzny **qnb322**

Supervision:
Dr. Martin Skydstrup
Dr. Ebbe Prag



Submission date: 01st of April 2015

Keywords: Bathi River, Kimende, Kenya, Irrigation, Water scarcity, Conflict, Management

Abstract

Water is one of the most substantial resources for life. It is under threat by different effects, which include, but are not limited to: Anthropogenic pollution, deforestation, higher demand and climate change. Communities affected by changing water patterns are exposed to higher stresses, which may lead to increased conflict potential. The township of Kimende, south of the Aberdare Ranges in Kenya has high precipitation and is not yet prone to water scarcity. The Bathi River, which springs north of the township, supports many adjacent farmers and is a tributary feeding the Athi-Galana River.

The willingness of investment is restricted to water abstraction, like. e.g. pumps, but is not expanded to conservation, as e.g. by higher efficient irrigation techniques; this may lead to a situation where water scarcity becomes a hindering factor for economic growth. Illegal activities such as farming close to the stream and construction of dams without permits provide potential local conflicts between farmers. Forested areas between Kimende and Kagwe prevent from regional conflicts, since discharge increases significantly after the forest.

Local farmers report uniformly reduced discharge during the last years. Quality changes are mostly perceived as increased sediment load in the stream. The awareness of the connection between personal practises and environmental impacts increases with education.

Attempts to manage the water resources fail with the improper implementation and enforcement of laws and the poor acceptance of trainings and education by farmers. Key challenges lie in the communication between authorities and farmers to sensitize for individual impacts on the water resources.

Preface

This report was written as a part of the examination for the course ILRUNM – SLUSE on the Faculty of Science at the University of Copenhagen. The report is directed towards master students within the natural and social sciences and anyone with an interest in the water situation at the Bathi River. The group would like to thank Martin Skrydstrup and Ebbe Prag for their help with ideas and inputs.

This report was handed in at the 01st of April 2015 by:

_____	_____
Christan Rekve Bryn	Christina Natalie Kompf
_____	_____
Ann-Christin Struwe-Voscul	Sebastian Fabian Zastruzny

Acknowledgements

In preparation of this assignment we had the help of many persons, without's assistance we would not have been able to write this report. We would like to use the opportunity to mention these respected persons.

First and foremost we would like to thank our counterparts Hashim Said Mohamed and Andrew Mbithi Muhama for the productive work and the fun we had during our stay in Kimende.

We like to thank our supervisors Dr. Martin Skrydstrup from the University of Copenhagen and Dr. Ebbe Prag from the University of Roskilde for the guidance before and during and after the fieldwork. Further we want to thank Prof. Dr. Mungai from the University of Nairobi for the interesting and amusing day in the field.

Our deepest gratitude belongs to the KENVO Staff, especially Ann Wanjiku and Joel Mwaniki, who organized many meetings, without we would not have been able to collect any data.

Moreover we owe special thanks to the farmers, who have been willing to allow us on their properties and took time to answer our questions and form therefore the basis of this research. The institutions, namely the Ministry of Agriculture, Livestock and Fisheries in Kimende, the Athi Water Service and the Bathi WRUA helped us a lot with their interviews. In addition the Village Chief of Kimende, John K. Thuo was of great help in identifying the challenges Kimende faces.

At latest we show high gratitude in our host families, who were the primary reason we were able to stay and work in the area and made our stay to a great experience.

Index

Abstract I

Preface III

Acknowledgements V

Index VII

List of Figures IX

List of Tables XI

List of Boxes XI

1 Introduction 1

1.1 Kimende and the Bathi River. 5

2 Methods 9

2.1 Natural Science Methods 9

2.1.1 Sample Strategy 9

2.1.2 Chemical Tests 9

2.1.3 Discharge Measurements 10

2.1.4 Potential Measuring Errors 10

2.2 Social Methods 11

2.2.1 Questionnaires 11

2.2.2 Semi-structured Interviews 12

2.2.3 Guided Field Observation 13

2.3 Statistical Analysis 13

2.3.1 SPSS 13

3 Results 15

3.1 State of the Stream 15

3.1.1 Discharge 15

3.1.2 Quality 17

3.2 Local Perception 18
3.2.1 Quality and Quantity of the Bathi River 19
3.2.2 Education and Awareness of Impacts 22
3.2.3 Water Regulation 23
3.3 Water Regulations in Kenya 24
3.3.1 The Perspective of Authorities and Organisations on the Regulations: 26
3.3.2 The Perspective of the Farmers on the Regulations 26
4 Discussion 29
5 Conclusion 33
6 References 34
Appendix i

List of Figures

Figure 1: Population of Kenya (in millions), predicted after 2010. (UN, 2013) 1

Figure 2: Change in climate vs risk of conflict in Kenya. (Hsiang, Burke and Miguel 2013) *after* (Theisen 2012) 1

Figure 3: Climate trend Kiambu. (CIAT 2010) 2

Figure 4: Impacts of climatic and social changes on freshwater systems. (IPCC 2014) 3

Figure 5: Climate diagram of Kimende. (climate-data.org n.d.) 5

Figure 6: Map of the working area. Frame shows the distance of 1km. (OpenStreetMap contributors n.d.) & (Central Bureu of Statistics (CBS) 2014) 6

Figure 7: Land use in the observed area. Frame shows the distance of 1km. (OpenStreetMap contributors n.d.) & (FAO 2012) 7

Figure 8: Locations of the water samples. Frame shows the distance of 1km. (OpenStreetMap contributors n.d.) 16

Figure 9: Discharge at 18 locations (see. Fig. 8). The continuous black line represents discharge measurements at different points along Bathi River. A divide between an upper and lower region is shown with a vertical, dotted line between site 8 and 9. The tributaries are described as T1, T2 and T3, intersecting Bathi at different stages. Measurements at the tributaries are all obtained just before an intersection. 16

Figure 10: Nitrate (top), Nitrite (center) and Ammonia (bottom) concentrations for the Bathi River. The tributaries are marked T2a, T2b and T3. Guideline concentrations are given from WHO and the ministry of environmental and natural resources in Kenya. 17

Figure 11: Phosphate concentrations (top), pH (center) and EC (bottom) for Bathi River and the tributaries T2a, T2b and T3. WHO-and the national guideline values are visualized in the figure. 18

Figure 12: Location of the conducted questionnaires. Frame shows the distance of 1km. (OpenStreetMap contributors n.d.) 19

Figure 13: Sources of irrigation water. 19

Figure 14: *left*: Quality changed over time (n=26); *right* affected by the quality change (n=12). 20

Figure 15: *left*: Quanity changed over time (n=26); *right* affected by the quantity change (n=25). 21

Figure 16: Reasons for lower quality given by farmers (n=8). 21

Figure 17: Reasons for lower quantity given by farmers (n=16). 21

Figure 18: Highest received education (n=26). 22

Figure 19: Distribution of answers shown according to the highest received education (left) and received training by the MoA (right). The size of the circle corresponds to the frequency of cumulated responds to the questions mentioned in the text. (For background data see App. 8) 23

Figure 20: Awareness about different regulations. *left*: Irrigation practices; *center*: amount of water; *right*: use of fertilizers. 23

Figure 21: Institutional Structure of water management given by Water Act 2014. 25

List of Tables

Table 1: Effects of water scarcity. *after* (Hendrix und Salehyan 2012) 3

Table 2: Statistics of the Lari subcounty in 2009. (MoA representative, interview, 06.03.2015) 5

Table 3: Relevant threshold concentrations for the observed area, given by the WHO and the Ministry of Environment, Water and Natural Resources (MoEWNR), Kenya. (MENR 2006, WHO 2011) 8

Table 4: Recorded chemical parameters in the field. 9

Table 5: Interviewed people or institutions. 12

Table 6: Official Regulations regarding water use and management. 25

Table 7: Guidelines/regional regulations. 26

List of Boxes

Box 1: Research questions and investigating subquestions. 5

Box 2: Profile of local guide and interpreter. 11

Box 3: Portraits of different institutions interviewed. 13

1 Introduction

Kenya is strongly dependent on its natural resources, since 80% of the economy is based on agriculture (UNEP 2009). The main tributaries to the freshwater balance of Kenya are the high mountainous, forested areas of its highland called the water towers, like e.g. Aberdare Range, which is crucial for the water supply of the adjacent lowlands and also Nairobi (Liniger, et al. 2005, UNEP 2009, MENR 2012).

The natural resources of Kenya are under pressure by an increasing population (Fig. 1), limiting the available space and resources per capita (UNEP 2009, MENR 2012).

Effects of climate change due to increased temperatures and changed rainfall patterns have impacts on the land use, the water resources and ecosystems (GoK 2010, MENR 2013). Especially in the agriculturally orientated rural Africa these changes have huge influences on the livelihood strategies, by altering accustomed harvest patterns and strategies (Reardon and Taylor 1996). One example is, that increased temperature is indirectly correlated, as Theisen 2012 showed for Kenya, with the conflict potential (Fig. 2). These climatic anomalies may not have direct influences, but it is widely accepted by the research community, that they induce social stress to societies, as they alter water availability (O'Loughlin, Linke and Witmer 2014).

Models from CIAT (2010) predict, that the average annual temperature in Kiambu will increase until 2050 by 2,3 °C and the precipitaion increases from 1120 mm to 1280 mm. (Fig. 3) Rainfall patterns get more extreme, with wetter month getting wetter and drier months getting drier. (CIAT 2010)

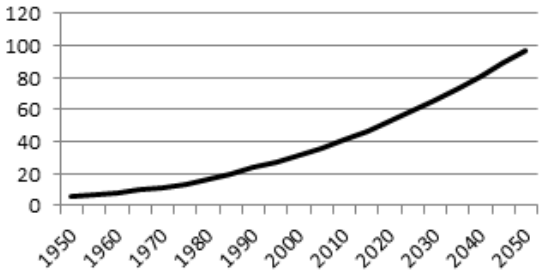


Figure 1: Population of Kenya (in millions), predicted after 2010. (UN, 2013)

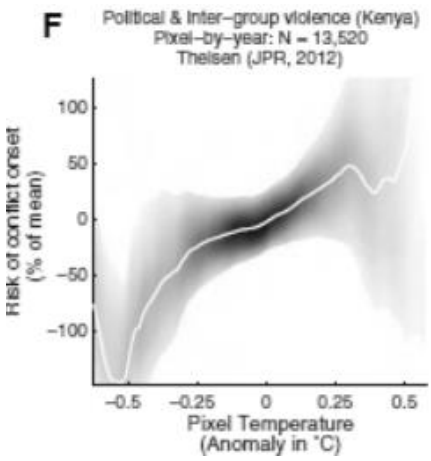


Figure 2: Change in climate vs risk of conflict in Kenya. (Hsiang, Burke and Miguel 2013) *after* (Theisen 2012)

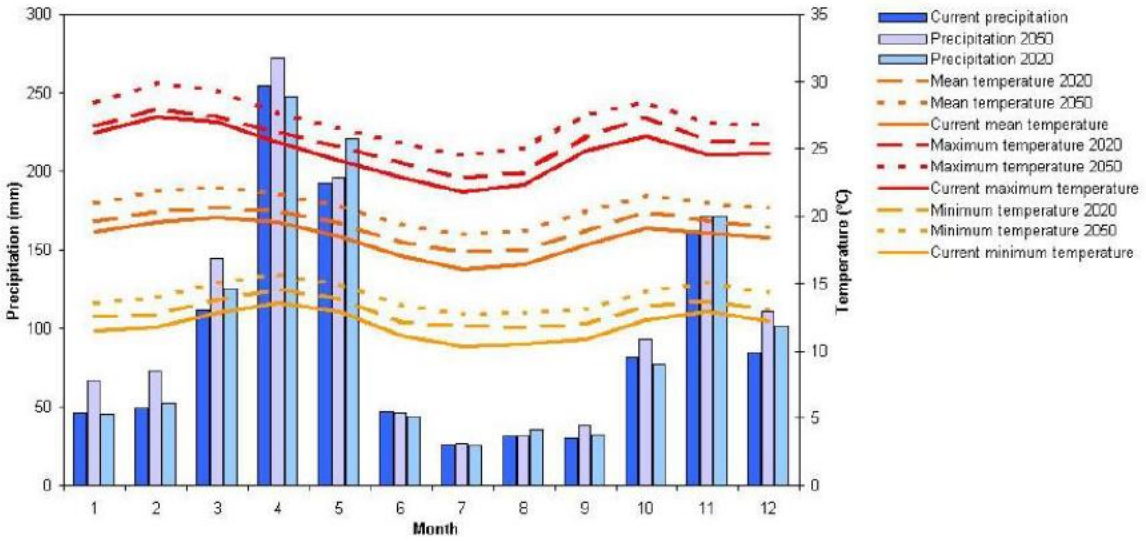


Figure 3: Climate trend Kiambu. (CIAT 2010)

Occurring acts of deforestation in Kenya (Transparency International 2011) and in particular in the Kijabe and Keirita forest (KENVO 2008) may add to the potential water shortage, as it is assumed, that forests contribute immensely to the water production and the continuous output of water throughout the seasons (Ong and Swallow 2003, Legesse, Vallet-Coulomb and Gasse 2003, Calder 1998, Hamilton, et al. 2008). However the contribution of forest to the water balance is not yet fully clarified by the scientific community. Presenting theories regarding this topic is beyond the scope of this project but is given in Ong and Swallow 2003.

Due to lacking investment simple irrigation practices (e.g. furrow and sprinkler irrigation) are used which are proven to have low water use efficiency. (Al-Jamal, Ball and Sammis 2001, Hansona, et al. 1997) High prices for timber lead to the plantation of trees along the riverine (Business daily Africa n.d.), draining large areas due to their higher water demand compared to crops (Tang, Folmer and Xue 2013). This is especially true for eucalyptus, which has high yields for timber, but a very high demand for water (Davidson and Reid 1989, Myers, et al. 1998).

The lack of controls and regulations in the past lead to uncontrolled land use change resulting in degradation of the environment, overexploitation of the resources and ineffective management of water (UN-Water Africa 2003). The government authorities are often not able to deal with the changed situation (WWAP 2015), but play an important role in identifying and managing disputes (O'Loughlin, Linke and Witmer 2014).

Climate change may also play a role in the form of changing rain patterns, leading to flood and drought situations (UNEP 2009, MENR 2012, Mustapha 2009, Twesigye, et al. 2011, Hunink, et al.

2012, Liniger, et al. 2005). Effects of the climate change related drivers and non-climatic changes on societies at different levels are listed in the fifth assessment of the intergovernmental Panel on Climate Change (IPCC 2014). Figure 4 shows these impacts with regard to freshwater resources.

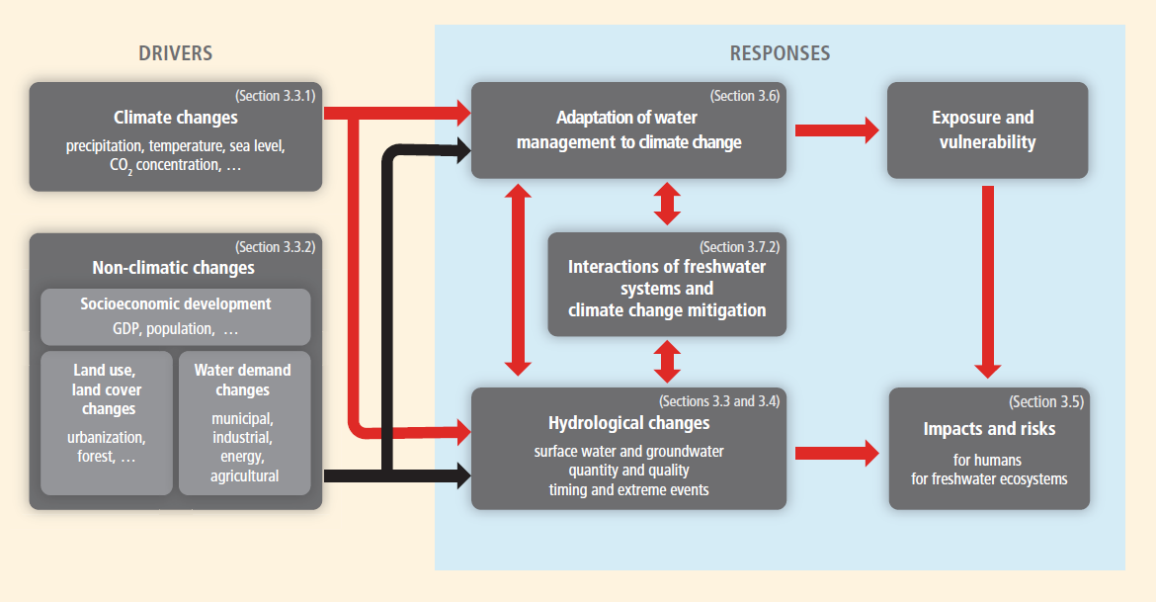


Figure 4: Impacts of climatic and social changes on freshwater systems. (IPCC 2014)

The UN grants the basic human right to safe drinking water; it is often challenged by different interests, leading to overexploitation or pollution of water resources (WWAP 2015). Problems regarding resources can be intensified by i.a. the lack of sufficient water management, if the existing livelihood strategies cannot be maintained (WWAP 2015). This change in water availability and quality has socio-economic effects on the farming communities relying on the water resources (Tab. 1) (Were, Dick and Singh 2014, Gichuki 1999, Hendrix and Salehyan 2012), this is especially true for countries in which the response capacity is low (O'Brien, et al. 2007). The practices of farmers living upstream may have direct or indirect influences on the water availability and quality further downstream and may result in conflicts (Jack 2009, Adams, Watson and Mutiso 1997, Gichuki 1999, Groll, et al. 2015, Burt, et al. 1997).

Table 1: Effects of water scarcity. *after* (Hendrix und Salehyan 2012)

1. Rainfall derivations may lead to conflict among consumers of water.
2. Excess (floods and shortages) can lead to price disputes.
3. Livelihoods come under stress, which may lead to migration.
4. State intervention in markets to revenue patronage opportunities.
5. Negative macroeconomic effects.

Case studies towards this topic are crucial for the Bathi River and essential since the Bathi River is subject to major issues regarding its water situation (Bathi WRUA 2012) and forms part of the water supply for Nairobi (Biotope Consultancy Services 2011). The high density of agriculture and the abstraction of water for irrigation put pressure on the water resources. Use of fertilizers and pesticides contribute to the pollution of the surface water. Awareness of problems is a key factor in resolving these problems with the contribution of local communities. The extent of appreciation of the local people is not investigated until now.

In recent years the government of Kenya (GoK) has imposed diverse regulations governing the use of water to the best possible way. For that purpose, various aspects of the integrated water resource management approach are implemented by the Water Act (2014).

However, the UN World Water Development Report 2015 and the African Water Vision 2015 claim that a mismanagement of the water resources in Africa occur due to lack of information of the population, implementation and controls of laws and transparency. Furthermore, informal rules might be more accessible for the local farmers.

This lack in governing and controlling may now or in the future lead to an over-abstraction of the water (WWAP 2015).

After evaluating the secondary literature a problem statement and subsequent research questions (Box. 1) were formulated:

The water situation in Kimende is under pressure of increased water abstraction and land use change, which is perceived by local farmers but is not yet in a severe state, so that changes of water use are not yet taking place, the conflict between imposed law and informal practices adds to conflict between farmers.

1. **How is the quantitative and qualitative state of the river water in two areas up- and downstream? Do inter and intraspatial changes between these locations occur?**
    a. **How is the water quality? How does the quality differ spatially?**
    b. **How is the spatial development of the discharge at different stages?**
2. **What is the common perception of the water situation and how does this (perception) influence the social system on different levels? How is the expectation for the future?**
    a. **How do the inhabitants of the communities on these locations percept the water situation (quality and quantity)? Did they (the people) noticed changes within the past years or decades?**
    b. **How is the farmer`s awareness regarding their impacts on the Bathi River from individual consumption?**
    c. **What consequences are apparent for the individual and for the social relations on different scales?**
3. **What are the official and informal regulations regarding water management in the Bathi River area?**
    a. **Which water management practises and regulations for surface water are in place within the catchment area?**
    b. **How is the upstream downstream relation regulated? If existing: How does compensation takes place?**
    c. **Which regulations are followed by the locals? Are there verbal agreements?**

Box 1: Research questions and investigating subquestions.

1.1 Kimende and the Bathi River.

The Kimende Twp is located in the upper Lari sub county (Tab. 2) which is part of Kiambu County (Fig. 6). It is adjacent to the Kikuyu Escarpment Forest, which is part of the southern Aberdare Range and covers 37,600 ha (KENVO 2008). The climate is classified as warm temperate, summer dry with warm summers (Koeppen-Geiger Csb) (Kottek, et al. 2006) with an average annual temperature of 14,2 °C, the annual precipitation is at 1395 mm (Fig. 5).

Due to its high altitude (2405 m a.s.l.) the temperatures are generally lower than in the low areas of Kenya and the precipitation is higher. (App. 5 & 6 for distribution maps)

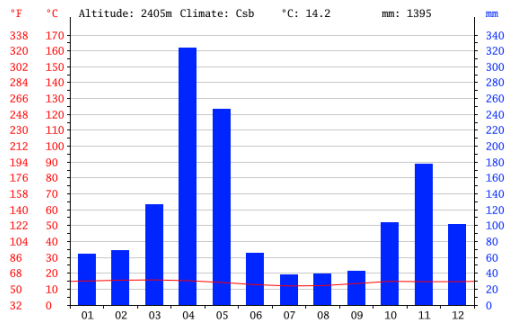


Figure 5: Climate diagram of Kimende. (climate-data.org n.d.)

Table 2: Statistics of the Lari subcounty in 2009. (MoA representative, interview, 06.03.2015)

Area	464,1 km^2
Arable Land	396,4 km^2
Forest Land	17,6 km^2
Population	137,961
No of farms	20000
Staff MoA : Farmers	1:2500
Average farm size	1,8 ha
% Poverty Level	31,7%

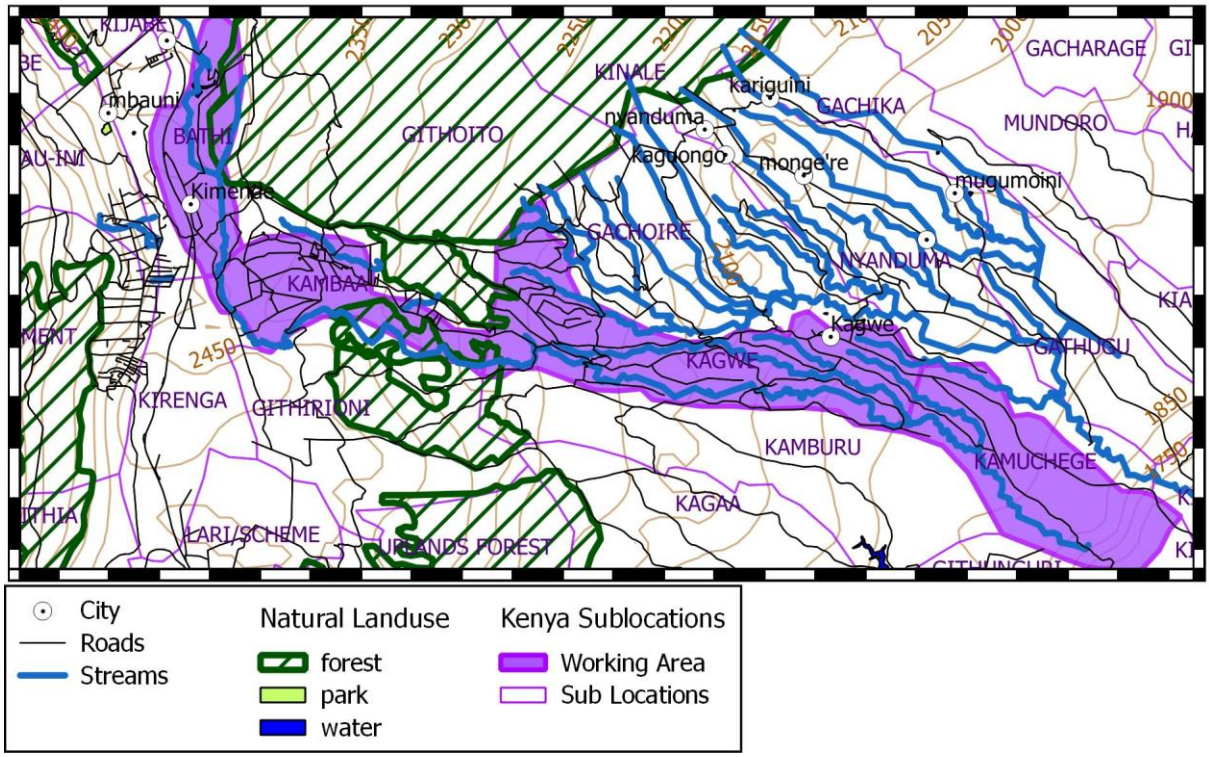
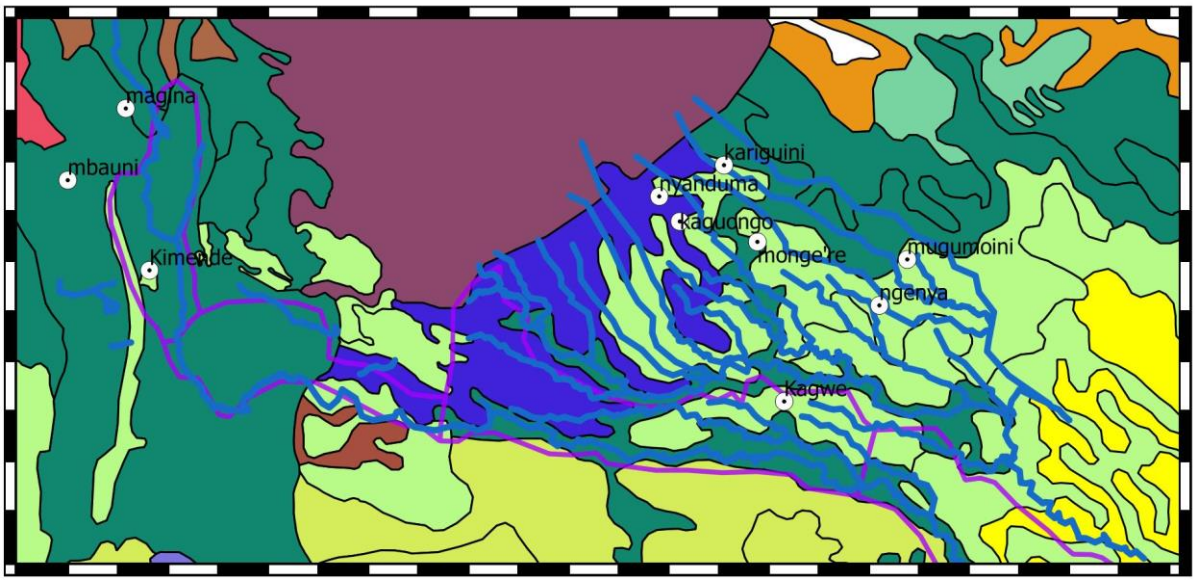


Figure 6: Map of the working area. Frame shows the distance of 1 km. (OpenStreetMap contributors n.d.) & (Central Bureu of Statistics (CBS) 2014)

The area is drained by the Bathi River, which has it source north of the town Kijabe between the Kijabe and Keirita Forest in central Kenya. It has a total length of 42 km until it enters the Athi-Galana River 8 km southeast of Githunguri. Along its route it passes different landtypes, which are mainly dominated by farming (Fig. 7). The upper area along the Kimende Twp is dominated by small scale subsistence farming with the main crops being maize, cabbage and Sukuma. The lower area, south of the Kagwe Twp is dominated by large scale tea plantations. The irrigation practices in the area change from simple can- and sprinkler-irrigation in the north to rain fed and furrow irrigation in the south.

In 1985 the Bathi River dam, north of Kimende, was constructed to supply the area with tap water (AWS representative, interview, 09.03.2015). It is managed by the Athi Water Service (AWS).



City
Kenya Sublocations
Working Area
Streams
Landcover
Irrigated Herbaceous Crop, Medium Fields
Irrigated Herbaceous Crop, Medium Fields Open general woody with herbaceous
Rainfed Herbaceous Crop, Large to Medium Fields Closed to very open herbaceous with sparse trees and shrubs
Rainfed Herbaceous Crop, Medium Fields - Wheat Closed to very open herbaceous with sparse shrubs
Rainfed Herbaceous Crop, Medium Fields Closed to very open herbaceous with sparse trees and shrubs
Rainfed Herbaceous Crop, Medium Fields Open general woody with herbaceous
Rainfed Herbaceous Crop, Medium Fields Rainfed Herbaceous Crop, Isolated Small Fields
Rainfed Herbaceous Crop, Small Fields
Rainfed Herbaceous Crop, Small Fields Closed to very open herbaceous
Rainfed Herbaceous Crop, Small Fields Closed to very open herbaceous with sparse trees and shrubs
Rainfed Herbaceous Crop, Small Fields Open general woody with herbaceous
Rainfed Herbaceous Crop, Small Fields Very open shrubs with closed to open herbaceous and sparse trees

Figure 7: Land use in the observed area. Frame shows the distance of 1 km. (OpenStreetMap contributors n.d.) & (FAO 2012)

The World Health Organization (WHO) describes the importance of clean drinking water as:

> ***"Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection"*** (WHO 2011)**.**

The WHO gives worldwide guidelines for appearance, taste, odour and drinking-water quality, and threshold concentrations for the different chemical compounds. Relevant for the researched area is also the national guidelines, given by the Kenyan Government. It is noteworthy, that the national guideline value is much lower than the one given by WHO. In accordance with the conducted field work and the quality measurements carried out the threshold concentrations for nitrate, nitrite, ammonia and phosphate, and also the optimum pH are of relevance (Tab. 3).

Table 3: Relevant threshold concentrations for the observed area, given by the WHO and the Ministry of Environment, Water and Natural Resources (MoEWNR), Kenya. (MENR 2006, WHO 2011)

Chemical compound	Drinking Water	Sources of Domestic Water
	WHO 2011	*MENR 2006*
NO_3^-	50 (mg/l)	10
NO_2^-	3 (mg/l)	3
NH_4^+	1,5/35 (Odour/Taste) (mg/l)	0,5
PO_4^{3-}	-	-
pH	6,5 – 8,5	6,5-8,5

There is not given any guidelines for phosphate concentrations. Phosphate is usually linked to algae blooms and bacterial growth in water, in which some algae and bacteria can be harmful to humans, a guideline value is thus to diffuse.

The WHO argues that natural levels of ammonia in surface waters and groundwater usually are below 0.2 mg/l (WHO 2011). Just odour and taste threshold concentrations are given for ammonia (WHO 2011). Toxic levels of phosphate are given for 200 mg/kg body weight (WHO 2011).

It is stated that pH usually has no direct impact on consumers, but pH control is important to ensure water clarification and disinfection, as well as for corrosion of pipes. Optimum pH is given. (WHO 2011)

The legal framework is given by the "The environmental management and co-ordination (water quality) regulations (2006)" from the Ministry of Environment, Water and Natural Resources (MoEWNR) in Kenya. There are given quality standards for sources of domestic water, for irrigation water and for effluent discharge into sewers among others. For irrigation use there are no guideline values for the relevant ions, only for pH, which is given the same guideline value as for domestic water use.

2 Methods

Two areas along the river were chosen as locations of up- and downstream, where natural and social scientific research was conducted. The upstream area is located at Kimende, the downstream area is south of the Kagwe Twp. All data points were localized and recorded with a Garmin GPS eTrex® 10.

2.1 Natural Science Methods

2.1.1 Sample Strategy

Spatiality, accessibility and key localities formed the basis for the water sampling strategy. Samples were conducted at some distance apart, but due to time limitation only on an average of 1,5 km, despite the advantage of higher resolution with higher sample frequency.

The spatiality was not set and also depended upon the easiest access point to the river. Sampling was conducted at key locations such as where tributaries join the river, after dams or other constructions/obstacles of importance.

Analysis of water quality as well as discharge measurements were conducted at each selected sampling site. Water quality analyses were conducted upstream from quantity measurements in order to limit human impact leading to inaccuracy.

2.1.2 Chemical Tests

To evaluate the inorganic chemical state of the water several parameters were taken on site (Tab. 4). The analysis was done according to the instruction manuals. Additionally, the organoleptic properties were recorded, consisting of the odour, the turbidity and colour. The direct (5 m), near (20 m) and far (100 m) environment of the sample site was recorded.

Table 4: Recorded chemical parameters in the field.

Parameter	Proxy	Method	Reference
pH	Acidity of water	pH test kit	-
Electric Conductivity (EC)	Total amount of ions	EC-meter	CD 611 WP[1]
Nitrate (NO_3^-)	Leaching of fertilizer	QUANTOFIX®Nitrate/Nitrite	91313[2]
Nitrite (NO_2^-)	Metabolite of nitrate	QUANTOFIX®Nitrate/Nitrite	91313[2]
Ammonium (NH_4^+)	Pollution by cattle / fert.	QUANTOFIX® Ammonium	91315[2]
Phosphate (PO_4^{3-})	Leaching of fertilizer	QUANTOFIX®Phosphate	91320[2]

[1]see (Milwaukee-Instruments 2011) Instruction manual for detail.

[2]see (Macherey-Nagel 2015) Instruction manual for detail.

2.1.3 Discharge Measurements

In order to obtain the volume discharged in a stream per unit of time physical measurements around the stream were conducted. For this the area of the stream profile *A* was recorded with a wading rod and tape measurement (Turnipseed and Sauer 2010). Afterwards the water velocity was estimated by timing the used time *t* over a known travel distance *x* (Rantz 1982). To validate the time it was done three times. The discharge *Q* is then calculated according to:

$$\boldsymbol{Q = A \cdot \frac{x}{t}} \qquad \textbf{(1)}$$

2.1.4 Potential Measuring Errors

The different types of measurements conducted for natural science can be prone to errors. With regard to the discharge measurements; the point of measurement, sampling frequency, human error and tool reliability induce a possibility of error in data sampling. Measurements at locations with easy access, river uniformity in depth and width, little vegetation cover and other obstructions are preferable in order to create a good base for a measuring site. Frequency of measurements in width, depth and velocity is important if a reach is asymmetrical. This is as the river bed topography and width can differ, as well as the water velocity at different points due to friction differences. Subjective perceptions and judgements can be sources of error; reflection and supervision is therefore of great importance. Errors, as to where the floating object is released into the stream, other human errors, location and tool reliability are possible, and awareness of the possible error inducers is important.

Measurements of the chemical state of the river are subjected to many of the same error sources as for the discharge measurements. Human subjectivity is of great importance as the chemical compounds, as well as the pH are colour based tests. As the perception differs between individuals, multiple subjective opinions are important in order to obtain reliable data. For the different test strips the instruction manuals inform about error preventions such as; keeping the container cool and dry (storage not over 30+ ^{o}C), keeping it closed, protect from rain and if correctly stored use until use-by-date (Macherey-Nagel 2015). For pH the colour may be more transparent if it is more diluted by a higher amount of water. The measuring probe should not be more than half full when two drops of coloured fluid is added (as instruction explains).

With regard to water quantity and quality chances are high, that points of interests are missed, as a transect walk along the whole stream and the joining tributaries was not conducted due to time constraints. Sources such as dams, river diversions or large water uptake may be present before the

discharge measurement. Sources that reduce the water quality for a point of measurement may also be present upstream without the conductor's awareness.

2.2 Social Methods

2.2.1 Questionnaires

A survey performed through the use of questionnaires offers useful information about a variety of characteristics linked to the investigated areas (Babbie 2001). Due to low time frame a survey conducted through questionnaires was chosen to yield higher number of data and an amount of 30 questionnaires was targeted. The standardized questionnaires provide answers that can be quantified and used through statistical analysis concerning the farmer's use of fertilizers and irrigation systems, their perception on water quality and quantity of Bathi River, their awareness of impacts on the river from individual consumption and furthermore their knowledge about water regulations planned and enforced in the investigated area.

2.2.1.1 Sample strategy

The survey was conducted in collaboration with the local guide and interpreter Ann Wanjiku (Box 2), who helped the group during the interviewing of farmers. Only respondents who own plots close to the river and who would be able to use the river for irrigation purposes were interviewed. During the survey performed in the upstream area around Kimende, the respondents were chosen according to the broad network of the local guide, which allowed a fast progress and meetings with well-informed people with regard to the topics asked in the questionnaire. The personal relation between the local guide and the interviewees contributed to a relaxed atmosphere during the survey, resulting in trustfully answers, but also leading to biased answers due to similar perspectives on the topic.

Profile of Ann Wanjiku

local guide and interpreter

45 years old, has lived all of her life in Kimende. Besides being a community leader, she is also a member of Kenvo and works as a volunteer. She spreads out information about Kenvos plans and motives in the area to environmental workers. Kenvo selected her for this work, due to her position as a community leader with a good network and trust among the locals.

Box 2: Profile of local guide and interpreter.

However, this sample strategy in the upstream area may have been characterized by the 'snowball effect', where one respondent identifies and refers to other relevant informants within her or his network, who could potentially be of interest for the survey. In this way, a chain of respondents is created, diminishing the notion of random sampling (Atkinson and Flint 2004), whereby the risk of biased answers increases. However, narrowing the number of respondents down to two or three in

the different investigated sub-areas within the village, limited the appearance of an escalating snowball effect.

During the survey conducted in the downstream area, another sample strategy was used due to a lack of personal contacts of the local guide and leading to a minimized snowball effect and risk of biased data. The sample strategy was a more randomized selection of respondents, based on farmers or workers on farms working close to the stream, where measurements were taken for the natural science part. The aim was still narrowing down the group of respondents to only include people being depended on the river, whereby people not fulfilling these criteria were abandoned. Due to common spoken language 'Kikuyu' between the local guide and the informants, her presence might have influenced the ability to gain the respondents trust and enhanced their willingness to participate in the investigation. However the local language may also have been a limiting factor for the investigation, since important information may have been lost.

2.2.2 Semi-structured Interviews

Semi-structured interviews are essential in order to obtain deeper knowledge about the issue investigated and thereby contribute to the ability of getting a broader and more detailed discussion about the issue. In this project they were used to obtain in-depth knowledge regarding the informants' perception of the water quality and quantity in the river, awareness of up- and downstream relations and knowledge about existing water regulations concerning the use of river water.

The interviewed people and representative institutions are listed in Table 5 and portrayed in Box 3.

Table 5: Interviewed people or institutions.

Farmer upstream doing subsistence farming	Athi Water Services
Farmer upstream growing cash crops	Chief of Kimende
Farmer downstream	Ministry of Agriculture, Livestock and Fisheries
WRUA Chairman	KENVO

The interviews were carried out on the basis of prepared interview guides. During the interviews the questions were adapted and the order adjusted since semi-structured interviews are open for changes, which allow the respondent to answer the question and explain themselves in a flexible way (Casley, et al. 1988). Open-ended questions might lead to unexpected, yet relevant, issues brought up by the respondent, which might be further explained by follow up-questions (Mikkelsen 1995).

Portraits			
KENVO Kijabe Environmental Volunteers is an organisation based on members from the local communities around Keirita Forest. KENVO mainly works on the conservation of the forest and other natural resources in the Lari sub-county in order to enhance biodiversity and livelihoods of the locals. They host workshops, seminars, exchange programs and have initiated environmental friendly income generating activities e. g. tree nurseries and ecotourism. (http://www.kenvokenya.com/)	**WRUA** Water resource users associations consist of water users, owners of riparian land and other stakeholders who voluntarily participate in conserving and managing activities of a common water source in a particular region. A WRUA can be officially registered under the WRMA (Water Resources Management Authority). For this study, the chairman of the Bathi WRUA was interviewed. (http://www.wrma.or.ke/helpdesk/knowledgebase.php?article=1)	**MoA** The main mission of the Ministry of Agriculture, Livestock and Fisheries is ensuring socio-economic development through management, protection and conservation of natural resources. One of their goals is to help building "a secure and wealthy nation anchored by an innovative, commercially oriented and competitive agricultural sector". They are responsible in implementing and monitoring agricultural legislations and regulations. (http://www.kilimo.go.ke/index.html).	**AWS** Athi Water Service is a Water Service Board under the MoEWNR. Its mission is to provide water and sewage systems in a sufficient and sustainable way. They plan and develop National Public Water Works for the majority of water supplies. It was created under the Water Act 2002. The Athi Water Service located north of Kimende, regulates the Bathi River Dam by extracting water for the water treatment plan that supply treated tap water to Kimende and other villages (interview, AWS). **(**http://awsboard.go.ke/**)**

Box 3: Portraits of different institutions interviewed.

2.2.3 Guided Field Observation

During the fieldwork, many walks guided by farmers took place. These guided walks have provided valuable knowledge and a deeper understanding regarding farming and irrigation practices in fields located adjacent to the Bathi River. The walks around the fields of the farmers were either done before or after the questionnaire/interview. Furthermore, the natural landscape and agricultural practices in the two investigated areas were observed, which has provided a greater understanding of the relation between the state and development of the Bathi River. The observatory method is important for triangulation of the gained information regarding water use, irrigation techniques and regulations.

2.3 Statistical Analysis

2.3.1 SPSS

For statistical analysis and interpretation of the data obtained through the survey, SPSS Statistics software program has been used. Each question from the questionnaire functions as a variable and the specific variables of interest for the further analysis were picked out. These variables were labelled (shortly described) and typed into the software together with the associated responses. All responses occur as numbers, which enables statistical analysis of the data. For open-ended

questions, where the farmers were able to provide individual answers, the responses had to be divided into fixed categories. SPSS was mainly used for descriptive statistics in order illustrate occurring trends, through the use of tables, pie- and bar charts. Pie- and bar charts are statistical graphs used to illustrate trends in the distribution of data, and each section (slice or column) represents the quantity, either expressed through percentage or number of responses.

Cross tabulation can be used as a method for statistical analysis of quantitative data obtained through a survey. The method makes it possible to analyse the relationship between variables, by comparing two or more variables with each other. Cross tabulations enables one to discover new perspectives that are not immediately apparent in the survey responses (Snap Surveys 2010).

3 Results

3.1 State of the Stream

3.1.1 Discharge

Discharge and quality measurements were conducted to evaluate the physical-chemical state of the stream. The measurements provide a solid base to evaluate if the requirements by the WHO are met within the area and how much water is available for use. Potential points of abstractions (i.a. dams and diversions) can be located. If not available the river system can be mapped.

Discharge measurements were obtained at 18 different locations, 14 measured along the Bathi River and 4 in tributaries joining the river (Fig. 8). The available maps in the southern part proved to be of little detail. Tributaries, river joints and systems had to be mapped additionally, but where not the purpose of the research. Obtained discharge data is shown in Figure 9.

Measurements show a heterogeneous discharge distribution along Bathi River. The upper region shows a relatively low discharge compared to those obtained in the lower region.

In the upper region there is a large difference in discharge between site 1 and 2. These sites are separated by a dam, the discharge in this locations fluctuates depending on how much water is released from the dam (AWS representative, interview, 09.03.2015). Visualized in the graph; the forest, dividing the upper- and lower region, has a huge impact on the discharge, as the discharge increases from 11,7 to 754 l/s. The discharge in the lower region increases again from site 13 after a large decrease from site 9 to 12.

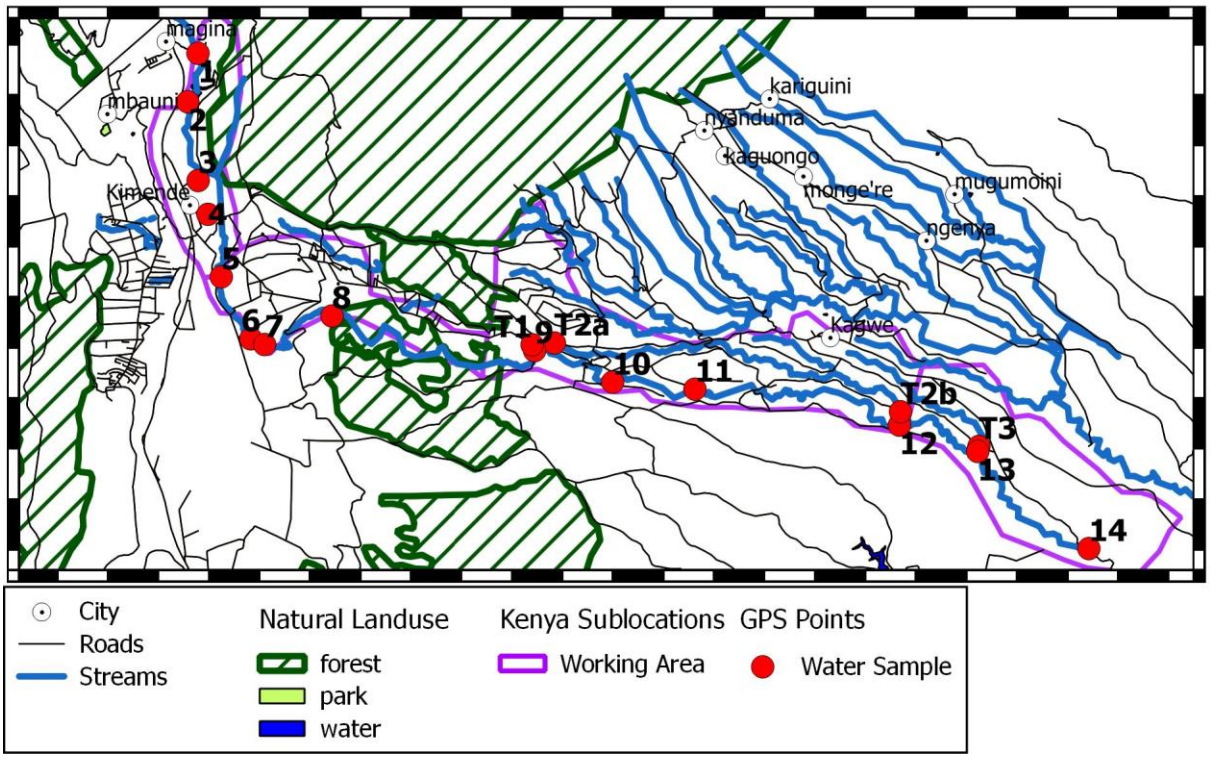


Figure 8: Locations of the water samples. Frame shows the distance of 1 km. (OpenStreetMap contributors n.d.)

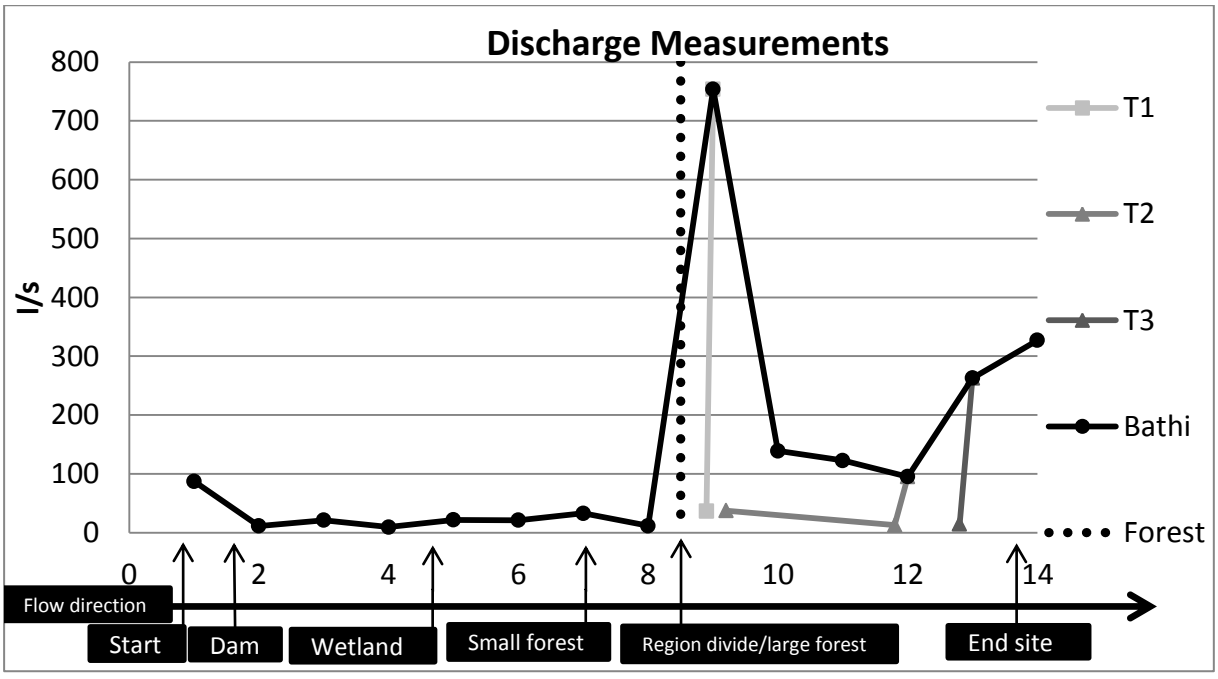


Figure 9: Discharge at 18 locations (see. Fig. 8). The continuous black line represents discharge measurements at different points along Bathi River. A divide between an upper and lower region is shown with a vertical, dotted line between site 8 and 9. The tributaries are described as T1, T2 and T3, intersecting Bathi at different stages. Measurements at the tributaries are all obtained just before an intersection.

3.1.2 Quality

Quality measurements are conducted at 17 locations, whereof 3 of these are conducted in tributaries.

Nitrate concentrations are oscillating throughout the course of the river. The concentration increases after the dam, until a decreasing trend from when the streams runs parallel to Kimende town, through the wetlands until the lowest value just before a small forest between site 7 and 8. An increase up to the larger forest is shown with the steep slope in the graph from site 7-8. In the lower region the concentration decreases after the forest and stays relatively low throughout the region. The nitrate concentrations measured are well above the national guideline, but below the WHO guideline concentration. (Fig. 10, top)

Nitrite concentrations are generally low and below the national guideline values. The highest concentrations are from after the dam (site 2) until after the wetlands further downstream (site 5). Concentrations are well below the national threshold. (Fig. 10, center)

Ammonia concentrations are generally low throughout the river, as well as for the tributaries. A peak is present before running parallel to Kimende town (site 4), and reaches a higher level than national guidelines, tough well below the WHO guidelines. (Fig 10, bottom)

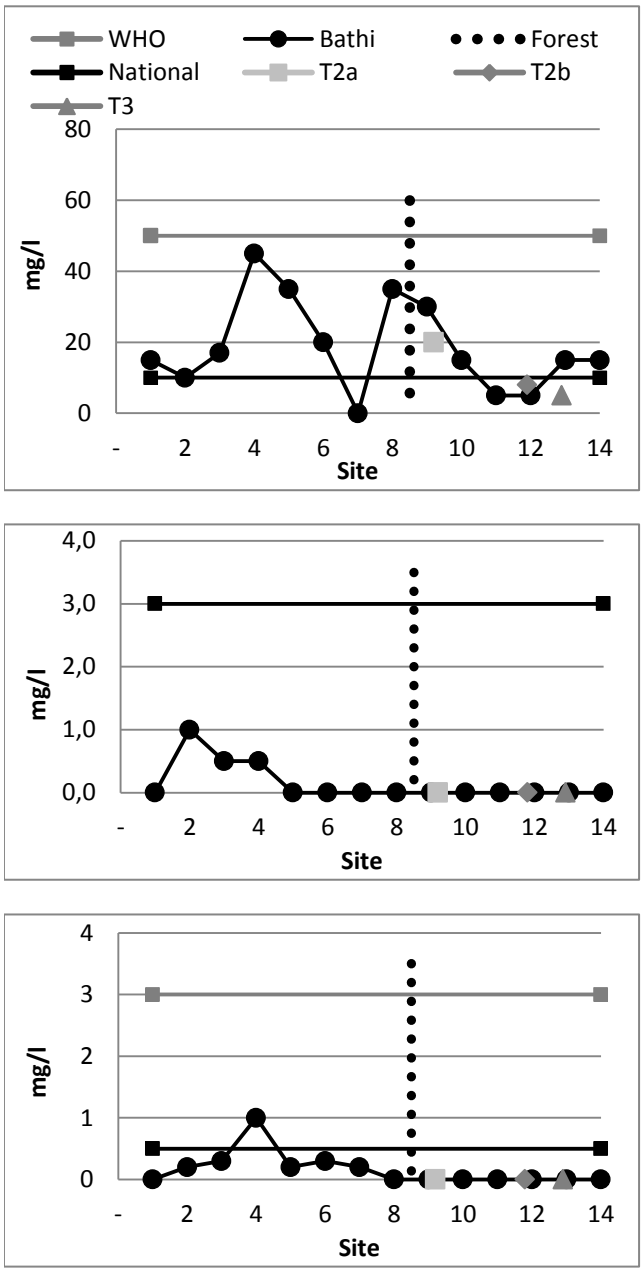


Figure 10: Nitrate (top), Nitrite (center) and Ammonia (bottom) concentrations for the Bathi River. The tributaries are marked T2a, T2b and T3. Guideline concentrations are given from WHO and the ministry of environmental and natural resources in Kenya.

Phosphate concentrations are generally low, with a peak before and after the forest (site 8 and 9), and at the last measurement site (14). No guideline values are given for Phosphate from either WHO or Kenyan government. (Fig 11, top)

Potential hydrogen (pH) varies spatially, with an average around 7,5. The lowest value is measured at point 2, the first point after the dam. The highest pH was measured at point 6, after wetlands. (Fig 11, center)

Electric conductivity has generally low values in areas with low discharge and higher values for higher discharge. (Fig 11, bottom)

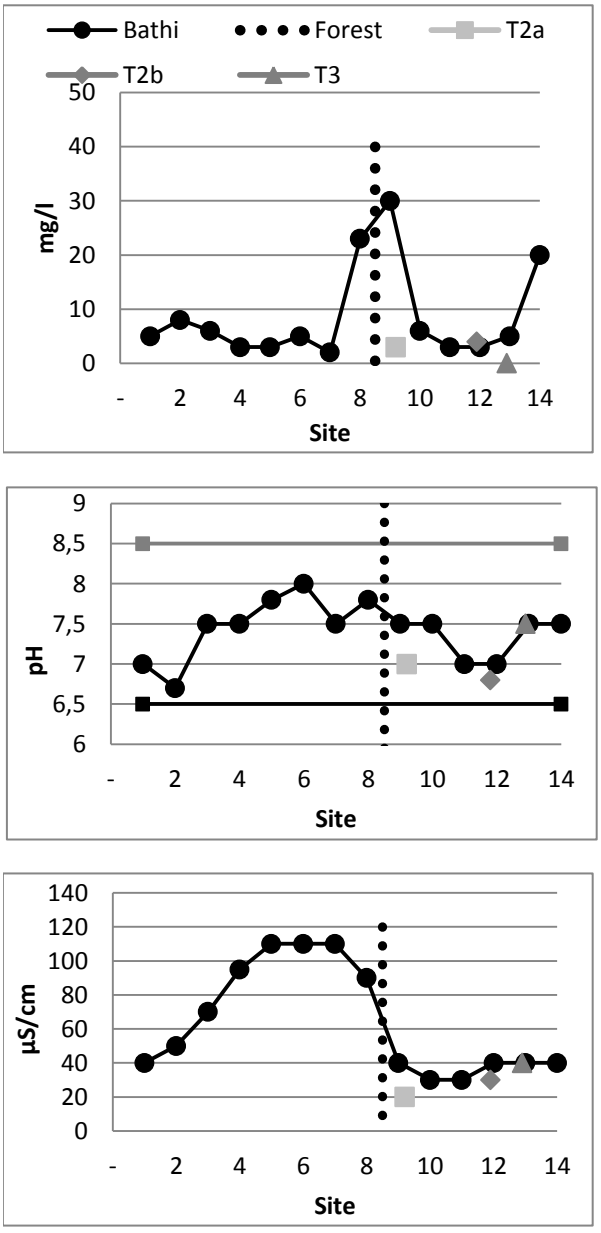


Figure 11: Phosphate concentrations (top), pH (center) and EC (bottom) for Bathi River and the tributaries T2a, T2b and T3. WHO-and the national guideline

3.2 Local Perception

The following section will provide a presentation of the common perception on water quality and quantity of the Bathi River, the local population's awareness about individual impact on the Bathi River and the awareness about water regulations. The results are drawn from the data obtained from the survey conducted in the two different areas of Kimende (upstream Bathi River) and Kagwe (Downstream Bathi River).

The aim of the survey was originally to achieve 30 responses from the questionnaires. Due to time constraints a total number of 26 respondents was gathered, whereof 15 were collected in the area around Kimende and 11 responses were obtained from locals around Kagwe (Fig. 12). The lower number of respondents might influence the validity of the result, because it might not adequately represent the whole population.

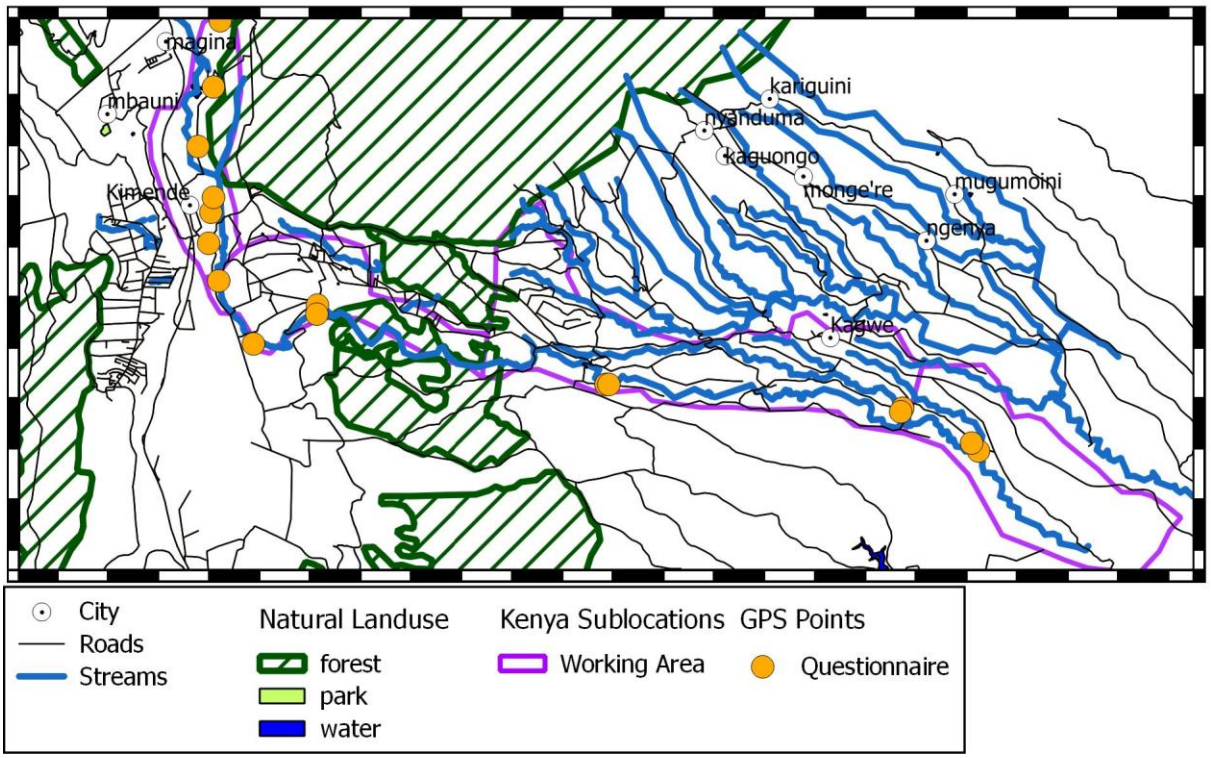


Figure 12: Location of the conducted questionnaires. Frame shows the distance of 1 km. (OpenStreetMap contributors n.d.)

The survey aimed to mainly include people whose primary source of water extracted for irrigation was water from the Bathi River. Several of the respondents relied on multiple sources of water for irrigation and the specific type of water sources used in the investigated areas is shown in Figure 13. As the figure illustrates, 22 people uses the Bathi River for irrigation, this does not exclude access to alternative water sources.

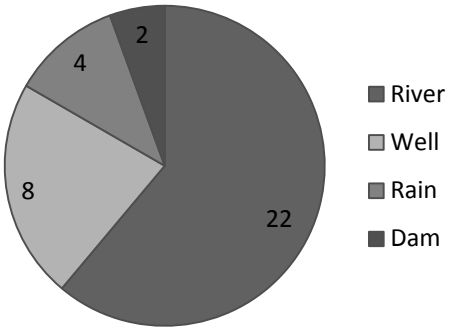


Figure 13: Sources of irrigation water.

3.2.1 Quality and Quantity of the Bathi River

In the investigation of the farmer's perception on the state of the water in Bathi River, the respondents were asked if the water quality and quantity have changed over a longer period. Those farmers claiming that either the quality and/or quantity of the river water have changed were moreover asked whether they felt affected by the changes or not. Figure 14, left demonstrates the distribution of the responses regarding quality changes and affection by quality changes, while Figure 14, right shows the results concerning farmers' perception on quantity changes and affection by quantity changes.

12 farmers claim that the quality of the water in Bathi River has changed over time. The time frame, in which the changes occurred, varies between the respondents and ranges between 2-30 years ago. Based on the answers from the respondents, the quality changes mainly refers to a decrease in water quality restricted to a higher sediment content, since it can be visible and easily noticed in the water. An eventually degradation of water quality due to chemical pollution, may not be visible from the farmers perspective. Therefore complaints about chemical state of the stream were limited to seasonal appearance of sediments. An interviewed farmer from Kimende, complained about degraded water quality due to pollution by fertilizers and pesticides, in which he claims causes health issues seen as e.g. higher incidences of cancer (Farmer upstream, interview, 05.03.2015). The survey shows that out of 12 farmers recognizing changes in quality, 7 farmers feel affected. The reasons why the farmers feel affected by changed water quality are various, e. g. the river cannot be used for domestic purposes, not used effectively, not drinkable and health issues (awareness that it needs to be boiled before drinking).

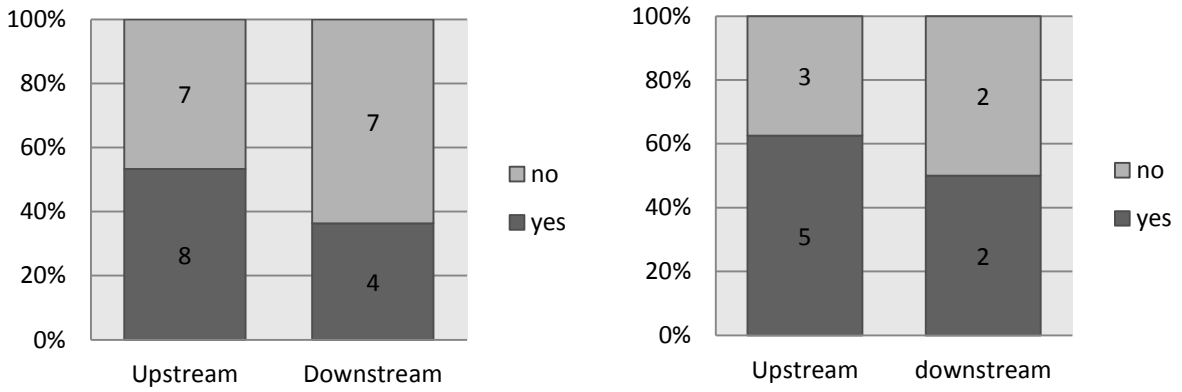


Figure 14: *left*: Quality changed over time (n=26); *right* affected by the quality change (n=12).

Compared to quality changes, more farmers have recognized changes in water quantity in Bathi River over a longer period. Only one farmer out of the 26 interviewed didn't notice any changes in quantity (Fig 15, left). As Figure 15, right illustrates, 15 farmers feel affected by the changed water quantity, the majority of those living in the upstream area.

Comparing Figure 14 and 15; the investigation and the statistical outcome show, that more farmers in the upstream area feel affected by quality and quantity changes. The majority of the farmers who feel affected by changed quantity claim that they today experience less, or simply not enough, water for irrigation. The changed water quantity is expressed through shrinkage in the size of the river and lower water level. According to most farmers, the water quantity in the river went down between 10-15 years ago, which is also confirmed by two interviewed farmers from Kimende (Farmer upstream, interview, 05.03.2015; Farmer upstream, interview, 09.03.2015).

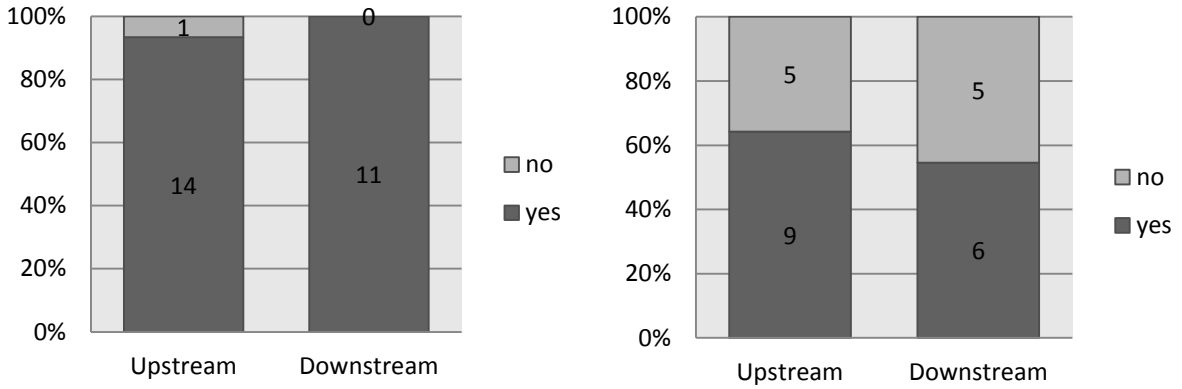


Figure 15: *left*: Quanity changed over time (n=26); *right* affected by the quantity change (n=25).

According to measurements of the water quality of the Bathi River and responses from farmers, the water quality does not seem to be of any remarkable issue in neither Kimende nor Kagwe. Eight farmers provided their opinions on factors that contribute to degrading water quality (Fig. 16). Human influences, e.g. contamination by clothes washing, fertilizers/pesticides and disposal of water used for domestic use, are the main reasons for lower water quality. Weather and animals causes a decrease in water quality by contributing higher sedimentation during rainy season and when animals move around in the river, causing turbulence.

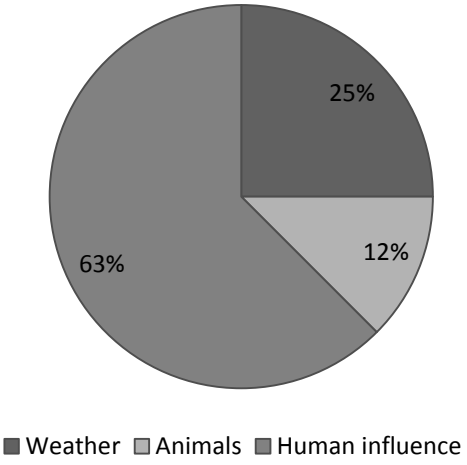


Figure 16: Reasons for lower quality given by farmers (n=8).

According to the responses from 16 farmers, various factors play a role in the decrease of water quantity. Of the different factors (Fig. 17) deforestation and the planting of eucalyptus trees appear as major contributors to water scarcity in the area. The competition for water through irrigation and the ongoing growth of the population is also perceived to influence in decreasing water resources.

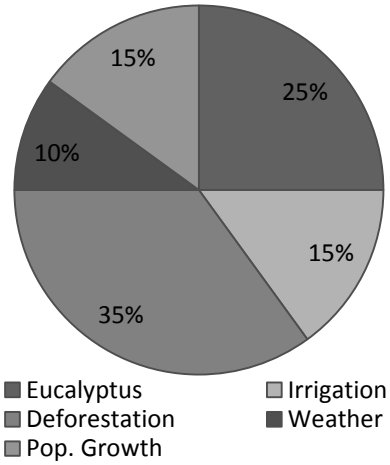


Figure 17: Reasons for lower quantity given by farmers (n=16).

3.2.2 Education and Awareness of Impacts

In the survey, 15 of the respondents had primary school as their highest received education, while 10 farmers also had finished secondary school. Only one farmer had not received any education at all. (Fig. 18)

Regarding agricultural education, 16 respondents had received agricultural training from an extensive officer represented by the MoA, while 10 farmers did not have any formal training.

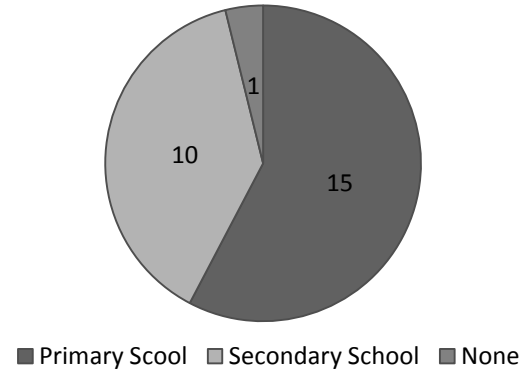


Figure 18: Highest received education (n=26).

To investigate the awareness of the farmers regarding the impact, they themselves have on the water quantity and quality of the stream, two yes/no questions were asked in the survey. The first question seeks to explore their awareness regarding the impact of irrigation on the water quantity and the other one regarding the impact of fertilizers on the water quality. The answers were then analysed related to the highest education the farmers received and if they had agricultural training.

From the farmers, which have only completed primary school, none was aware of the impact irrigation has on water quantity. On the contrary, 3 of the farmers with a degree from secondary school were aware. Concerning the use of fertilizers, only 1 of the farmers with primary school state that use of fertilizers affects the water quality, while 4 of the farmers with secondary school agreed on that.

The training by agriculutral officers shows only small effects on the awareness: In proportion more farmers showed awareness to their individual impacts on the quantity and quality of water. Trends show therefore a correlation between education of any sort and raised awareness to individual impact. The recognized trends needs to be evaluated carefully, as the sample size was limited and correlations are not necessarily strong.

In Figure 19 the size of the cycles shows the number of farmers in correlation with the education and training they received, which either were aware regarding the impacts of both, fertilizer use and irrigation, (yes/ yes), or regarding one of the two (yes/no) or regarding neither of the practices (no/ no). This was done by a cross table analyses and clearly shows that with higher education and received training the awareness of the farmer increases.

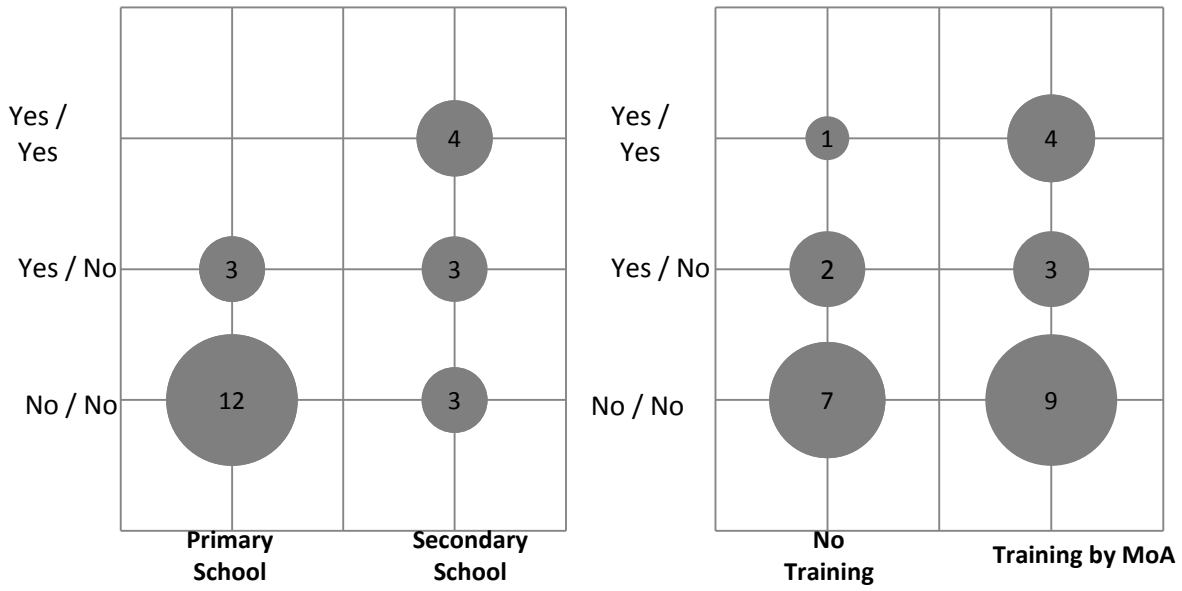


Figure 19: Distribution of answers shown according to the highest received education (left) and received training by the MoA (right). The size of the circle corresponds to the frequency of cumulated responds to the questions mentioned in the text. (For background data see App. 8)

3.2.3 Water Regulation

In the survey, the farmers were asked if they know about regulations concerning the type of irrigation practices allowed in the field, the amount of water allowed to extract from the river and about regulations concerning the amount of fertilizers and pesticides allowed to use. The results are indicated in the Figure 20.

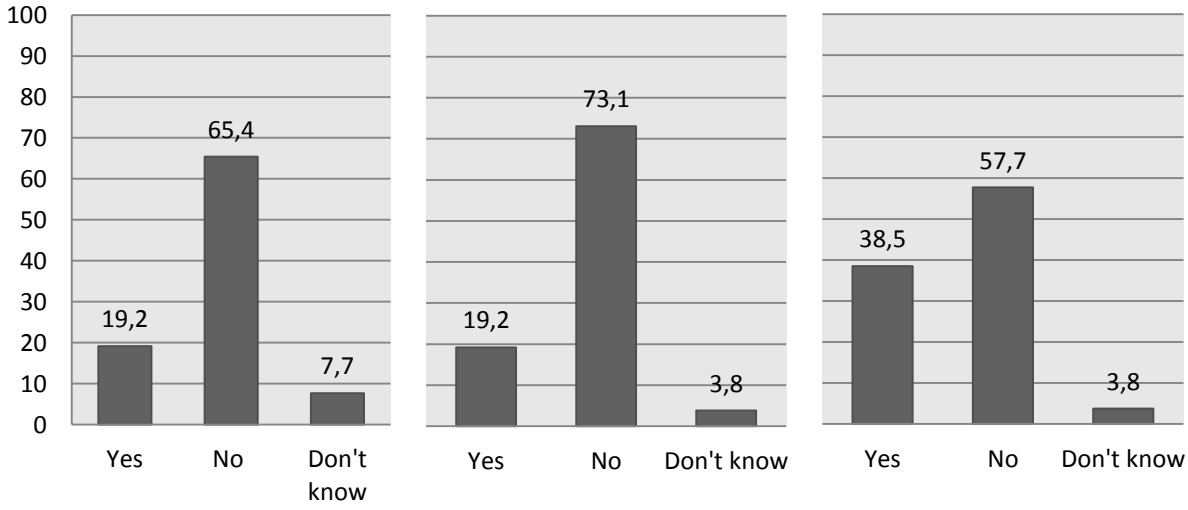


Figure 20: Awareness about different regulations. *left*: Irrigation practices; *center*: amount of water; *right*: use of fertilizers.

The survey indicates that most farmers do not know about any regulations related to water management. In regards to the type of irrigation practices allowed to apply in the fields 19,2% state that there are regulations, 65,4% state that there are no regulations, while 7,7% don't know if any regulations exists. A similar trend appears regarding regulations on the amount of water allowed to extract. 19,2% claim that regulations exists, 73,1% claim that regulations don't exist, while the remaining respondents, 3,8%, don't know of these regulations.

When it comes to regulations related to the amount of fertilizers allowed to use in the field, a higher percentage, 38,5%, claim that regulations exists (however, most refer to the instructions/guideline on the products!) and 57,7% state that no regulations exist on this field, while 3,8% don't know of any regulations.

3.3 Water Regulations in Kenya

"To provide for the management, conservation, use and control of water resources" (Water Act 2002), the Kenyan government published the "Water Act 2002". This Act defines the ownership and control of the water and distributes the responsibility in "Water resource management" and "Water supply and sewage" with different responsible authorities under the control of the MoEWNR. The "Water act 2014" (published as "Water Bill 2014") refines this distribution (Fig. 21). The important statutory provisions regarding river/stream water and agricultural practices are listed in Table 6, but besides these laws there are also guidelines and regional regulations developed by official and voluntary organisations and NGOs (Tab. 7).

There is no specific law regarding the amount and time for fertilizer and pesticide use, but in "The Environmental Management and Co-Ordination (Water Quality) Regulations, 2006" limit values for the discharge into the environment of different compounds are listed. The list contains all compounds used in fertilizers and some compounds used in pesticides and thus can be used as a benchmark. Furthermore, there are guidelines given by the authorities to (1) use the prescription on the products for a measure of the amount and (2) hand in soil samples to the responsible institution for recommendations based on the soil analysis.

Everybody in Kenya has the right of access to water (Constitution of Kenya 2010). However, a permit is needed for any kind of free abstraction from every water source, if the water is not for domestic use. This includes the use of water for irrigation, when the produced crops are not for personal consumption. Additionally, a permit is necessary for the construction of a dam and the installation of a drainage system, including furrow irrigation. These regulations restrict irrigation of agricultural fields.

The accessibility of the river/stream water is limited due to the entry restriction to private land, meaning that there is a need for permission to trespass a person's land. In the Kimende area this issue is solved by community water points along the Bathi River, available for every inhabitant.

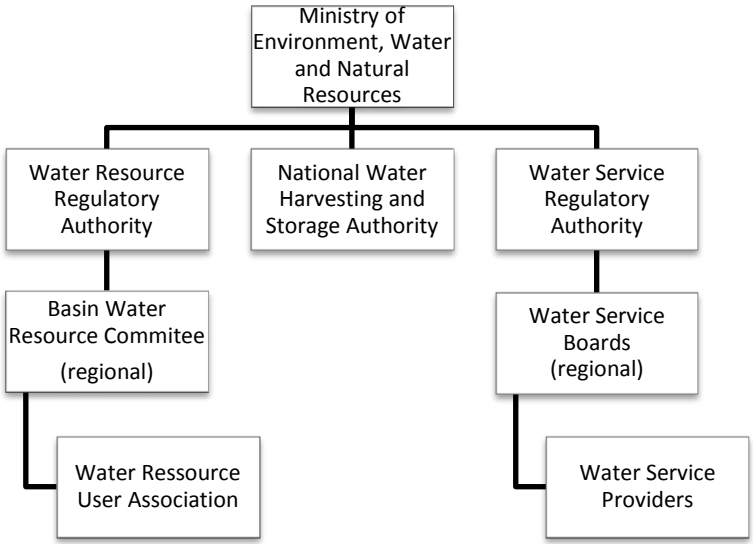


Figure 21: Institutional Structure of water management given by Water Act 2014.

Table 6: Official Regulations regarding water use and management.

Regulation regarding:	Statements:	Responsible authority	Source:
Construction of dams	A permit is needed for the construction of any kind of private dam	Water Resource Management Authority	Water Act 2014 Section 34/35
Drainage/ Furrow Irrigation	A permit is needed for the construction of a drainage system	Water Resource Management Authority	Water Act 2014 Section 34/35
Water extraction	Water extraction from any kind of water source is only allowed for domestic use, every other activity needs a permit	Water Resource Management Authority	Water Act 2014 Section 34/35
Accessibility of stream water	Everybody has right of access to water, but the entry to a person's land needs a permit	Water Resource Management Authority	Water Act 2014 Section 61 and 55
Pollution (Fertilizer/ Pesticides/ waste)	The discharge of pollution is forbidden, see limit values for effluent discharge into the environment (in Third Schedule)	National Environmental Authority + relevant authorities	Third Schedule, THE ENVIRONMENTAL MANAGEMENT AND CO-ORDINATION (WATER QUALITY) REGULATIONS, 2006
Cultivations near river/ stream	Cultivation must be minimum 6 m and maximum 30 m away from either sides of a river/stream The number depends on the the highest recorded flood lever	National Environmental Authority + relevant authorities	Section 6c, THE ENVIRONMENTAL MANAGEMENT AND CO-ORDINATION (WATER QUALITY) REGULATIONS, 2006
Irrigation close to stream/ river	A buffer zone of 50m is needed between a irrigated field and a water body	National Environmental Authority + relevant authorities	Section 21, THE ENVIRONMENTAL MANAGEMENT AND CO-ORDINATION (WATER QUALITY) REGULATIONS, 2006

Table 7: Guidelines/regional regulations.

Regulation regarding:	Statements:	Source:
Cultivation of Eucalyptus trees	Planting of eucalyptus tree must take place 30m away from stream/river	KENVO (poster) KFS[1] (KFS 2009)
Allowed water amount for extraction from river/stream	100l per day and person	WRUA/KENVO (Interview)
Accessibility of stream water	Everybody has right to access river/stream water via water community points.	Village Chief/ WRUA (Interviews)
Use of Fertilizer/ Pesticides	The prescription on the product applies. Fertilizer and pesticide should be used regarding the recommendation based on soil analysis by an official institution.	Village Chief/ Farmer Upstream (Interview) MoA/ Farmer Upstream (Interviews)

[1]Note: The KFS cites in their guide the Survey Act Cap 299 regarding the distance of 30 m between the river/stream and new planted eucalyptus trees, but the Act only lists 30 m distance for tidal river (section 111).

3.3.1 The Perspective of Authorities and Organisations on the Regulations:

The task to enforce and control the above stated regulations lays in the expertise of the village chief and his officers. The village chief of Kimende implements that, they conduct controls along the river and call every offence of the regulation to account, but many farmers do not necessarily note that they are controlled (Kimende Village Chief, interview, 06.03.2015). To assure the best enforcement there is a strong cooperation with the different voluntary organisations like KENVO and WRUA (WRUA chairman, interview, 05.03.2015; KENVO representative, interview, 05.03.2015; Kimende Village Chief, interview, 06.03.2015).

To inform farmers regarding best agricultural practices and the important regulations, trainings and information meetings are offered by authorities as well as the voluntary organisations. The announcement for these offers thereby takes place in the church, in school and on other official meetings/events (MoA representative, interview, 06.03.2015; WRUA chairman, interview, 05.03.2015).

However, there is a problem regarding the acceptance and interest from the farmers to implement new techniques and obey the law, which is due to ignorance and preference of practices, learned by the parents (WRUA chairman, interview, 05.03.2015; MoA representative, interview, 06.03.2015).

3.3.2 The Perspective of the Farmers on the Regulations

As described in Chapter 3.2, the majority of the farmers are not aware of above mentioned regulations and they never experienced any kind of enforcement or control (Farmer Upstream, interview, 09.03.15).

One of the interviewed farmers thereby mentions the lack of free and accessible training as a reason for the lack of knowledge regarding fertilizer and pesticides and for the tendency of sticking to past on knowledge (Farmer Upstream, interview, 09.03.15).

Another farmer claims ignorance and the lack of controls as the major reasons for the missing implementation of new techniques and violation of the regulations (Farmer Upstream, interview, 05.03.15).

4 Discussion

The holistic approach of the study allows to grasp the water situation in the area on a broad spectrum, stretching from the physicochemical state of the water resource, to the individual perception of the influenced persons. Limits are set due to the nature of the case study, as it only focuses on a particular setting. General assumptions must therefore be taken with great care.

The chemical measurements prove, with regard to the measured compounds, that international threshold concentrations of the WHO are not exceeded; concentrations of these compounds are not a threat for the health of the population. However, national guidelines from the GoK are exceeded for Nitrate in most points and therefore require juridical action. Concentrations of Ammonia do not show a high risk, since it exceeds threshold concentrations only in one point, which is situated in the proximity of a paddock. In the Kagwe area ammonia is completely absent due to only low density of cattle. Nitrate and nitrite are highest north of Kimende and show decrease along the town area due to the lack of input from farmland. Wetlands south of Kimende filter the water; they further prohibit farming in the riverine. Increase takes place in the south were cropland practises increase again. After the forest nitrate decreases due to dilution and must be assumed to change on a very small scale due to the proximity to sources of input, e.g. farmland. Findings for phosphate contradict the expectation that dense vegetation filters nutrients and peaks in the forested area. Reasons remain speculative and may include change of parent material, influencing the geogenic concentrations in soil or anthropogenic effects like illegal waste dumping. Electric conductivity shows trends of correlating with the population density, therefore highest values appear in the proximity of the Kimende area, where high input of wastewater can be expected. After the forest the higher discharge leads to dilution and decreases the conductivity.

The results indicate that both areas do not have a problem with high fertilizer concentrations in the stream, though the majority of the farmers use fertilizers. Results from the questionnaires prove that the farmers use the fertilizers according to the instruction manuals.

The necessity of investment for chemical fertilizers may function as a frontier to avoid overdosing of fertilizers. The application of manure does not impose high concentrations of chemical compounds and shows often neutral nitrate balances. The fertile land of the Kimende area does not require high additional fertilization. More effective use of fertilizers might be achieved by soil sampling, as mentioned by farmers and also by the MoA. Until now there is no program or a sample strategy; the costs for analysing must therefore be paid for by the farmers and is done very rarely. The sparse

application of fertilizers leads to the dominant perception that fertilizers do not leave the shamba and have therefore no to very low impact on the environment. When describing that the chemical state of the river is adequate, it is of high importance to underline that this investigation did not include organic contamination of any kind. Observation yielded that organic pollution takes place in large scale. Pollution sources observed are: Inappropriate waste disposal in urbanized areas, grazing animals in direct proximity to streams, disposal of milk and detergents and use of potentially aggressive pesticides. Though an awareness that the river quality is not sufficient for drinking purposes, the awareness of what leads to pollution is often not addressed or acknowledged. An exception is the knowledge about the practises of washing of agricultural products in the river which is prohibited and accepted by most people (Village Chief, interview, 09.03.2015). Degraded quality of water is often not perceived by farmers since it is difficult to gain from organoleptic factors. Therefore water quality is mostly defined by the farmers as “clearness” and is only a clue on the sediment load, inducing soil erosion. The present state of the Bathi River in terms of quantity is currently sufficient enough to sustain the farming activities along it in Kimende. Until now irrigation is mostly done by can irrigation, which allows only limited water abstraction., whereby sprinkler irrigation, which uses pumps, is rare but still present in Kimende.

The individual expectations for the future differ according to the availability of alternative water sources. Already now many farmers rely on well or tapped water for domestic purposes and expect to use it for irrigation in the future too. The implementation of rainwater harvesting is an important project for the Ministry of Environment, Water and Natural Resources and some farmers (Esther Wanjiru Njugunna, conversation, 03.03.2015), as one of the key issues is identified as the seasonality of water over the year, which could be solved by appropriate storage facilities. This investment is often not available for farmers and plans for funding do not exist at the time (MoA representative, interview, 06.03.2015; Esther Wanjiru Njugunna, conversation, 03.03.2015). The size of the Bathi River is spatial stable in the Kimende area, which is controlled by the Bathi River dam in northern Kimende. The southern Keirita forest (7,5 km^2) forest in between Kambaa and Kagwe works as a high water generating area, increasing the discharge of the Bathi from 11,7 l/s to 754 l/s afterwards. Since the agriculture in the Kagwe area is fed mostly by rainwater on the slopes and only furrow irrigation in the valley line the total water abstractions are low. The local topography and the higher precipitation lead to many tributaries feeding the Bathi. These factors diminish the risk of water conflicts on a regional scale, especially between Kagwe and Kimende. Local conflicts between farmers do not exist in neither of the areas now. Conflicts rather exist towards supplied water, e.g. the sabotage of pipes that supply homes with water has been present in Kimende. The reasons are

speculated to lie in the limited areal supply of tap water due to lack of distribution capacity at the time, and economic gain from the looting of the water source (AWS representative, Interview, 09.03.2015). Regardless of the reason; water as a resource can cause conflict as it is a necessity for life and provides improved standards of living. With increasing water abstraction and climate change the conflict potential may increase not only for the Kimende region, but also for regions relying on the Aberdare water tower.

Many farmers and institutions are concerned about increasing competition for water in the future. Worries about the desiccation of the Bathi were present in a feedback round at the end of the project. By arising awareness the problems regarding competition might be overcome. Based on the survey there exists a correlation between the knowledge of coherences and educational state of a farmer; this is true for the highest obtained school and might be correct for agricultural training by the ministry, though the effect was smaller.

The planting of Eucalyptus trees, which have a significantly higher water demand, is still a common practice since it generates high income due to fast growth and it's timber is of high value (Business daily Africa n.d.; WRUA chairman, interview, 05.03.2015). If planted along the riverine this contributes to the draining. In the past (10-15 years ago) it was also planted to drain the wetlands in the floodplains, this presents a massive problem for the adjacent communities, since it is often difficult to clear the Eucalyptus with its root (local farmer, informal conversation, 02.03.2015). Many farmers rely on Eucalyptus trees as a secure source of income and keep planting them. Programs from NGO´s (e.g. the Bathi WRUA) offering two Bamboo sapling for every cut Eucalyptus are not fully adopted since a local suiting species is yet to establish (insufficient growth at the distributed species) and the market value for Bamboo is low: A ban on the cutting of bamboo was proclaimed in 1982 due to overexploitation of the indigenous species, allowing a regeneration of indigenous bamboo. Prohibition of bamboo development includes low processing technologies; lack of awareness on its potential, poor developed marketing structures, crop managements and lack of information on availability of panting materials. These variables diminish as the ban removed the bamboo potential. The current ban on exploitation of bamboo might have outlived its usefulness (Ongugo, et al. 2000). Ongugo et.al (2000) suggests a gradual easing of the ban in order to develop the bamboo sector, thus preventing the use of alternative resources such as eucalyptus.

A mayor challenge is the implementation of environmental laws and regulations. The GoK, NGOs and other institution imposed many regulations and guidelines in the past years, especially since the devolution of 2010. An issue here lies in a pluralism of laws, on the one hand official regulations may

contradict, making it difficult to obey all regulations; on the other hand informal rules may be of higher importance in the area.

A lack of transparency for- and sensitization of the farmer combined with misdemeanour of the Kenyan government in the past lead to a lost confidence into the government. The effect is that many farmers do not take action or seek advice from authorities as bureaucratic obstacles are expected. The official sites on the other hands expect self-responsibility from the farmers.

The clear discrepancy between the authorities and the farmer can further be seen in their statements regarding control of infringements. While the official sites claims that controls take place, have none of the farmers ever perceived any controlling or enforcement. Mismanagement of laws can also be seen in terms of corruption: The Athi Water Service claimed that many personal dams in the Bathi River are either illegal or permits were granted on an informal basis. This leads to a poor understatement of some farmers, who fell aggrieved and therefore do not go the bureaucratic way, furthermore it favours farmers that have income.

The consequence can be over abstraction of the water resource “where the use of resources for economic growth is under regulated and undertaken without appropriate controls” (WWAP 2015). Opposed to this inadequate information policy, authorities and some well-informed farmers claim that a missing interest and ignorance exist among the farmers. This is also reflected in the fail to ask agricultural officers for guidance, being unaware of regulations and not taking advice by NGOs, i.a. was the concept of WRUAs unknown to 92% of the farmers.

5 Conclusion

To the actual state many problems regarding the water situation of the Bathi River are identified. The key problems can be condensed to: 1) Uncontrolled individual water abstraction. This happens since the authorities fail to inform and control the farmers. 2) Unawareness due to lack of training. These trainings are offered by the MoA and NGOs but visited only sparsely. 3) Non organized community to manage water more effectively, although these communities exist, i.a. in the form of the Bathi WRUA. 4) Low need for change since alternative water sources (wells) exist and the majority of the farmers are still able to irrigate their fields as they please. Since there is no severe problem in the area at the time investigating, many farmers do not see the necessity to change behaviour towards conserving water. The last point marks the main problem arising in the near future: If incomes rise more investments can be done, which was expressed by many farmers in the wish for upgrading their irrigation systems to either increase crop production or to be able to produce acyclic to achieve higher market prices. This coupled with a potential change to water intensive cash crops may impose high stress on the water resources in Kimende. Solutions for most problems are already in place or at least prepared right now, but they lack the seriousness of authorities and discernment or acceptance of the affected farmers.

The results of this study do therefore confirm the findings of the international scientific community and worldwide institution like the UN. There is no scarcity at the moment, but if growth continues the current practises will not be sustainable and will lead to intensification of conflicts. Therefore not income, but the availability of water may be the hindering factor for future growth. Farmers already claimed that higher income would be possible for them with an acyclic production, which relies on the permanent availability of water, but is not feasible due do limitations of water with the rain patterns. Short comes of water may also lead to less higher yields. Effects of the climate change may contribute to water scarcity in the future to different extents.

For further progress and to avoid severe scarcity of useable water, it is crucial to engage communication between farmers and authorities and both sides must approach each other to tangle the challenges that lie ahead.

6 References

Adams, William, Elizabeth Watson, and Samuel Mutiso. "Water, rules and gender: Water rights in an indigenous irrigation system, Marakwet, Kenya." *Development and Change* (Wiley Online Library) 28, no. 4 (1997): 707-730.

Al-Jamal, MS, S Ball, and TW Sammis. "Comparison of sprinkler, trickle and furrow irrigation efficiencies for onion production." *Agricultural water management* (Elsevier) 46, no. 3 (2001): 253-266.

Atkinson, Rowland, and John Flint. "Snowball Sampling." *Encyclopedia of Social Science Research Methods*, 2004.

Babbie, Earl. "The practice of social research ." (Wadsworth/Thomson Learning) 2001.

Bathi WRUA. *Sub-catchment Management Plan (SCMP).* Management Plan, Kimende: Upper Athi Sub Region, 2012.

Biotope Consultancy Services. *Environmental, social and economic assessment of the fencing of the Aberdare Conservation Area, Main Report.* Nairobi: Fence Steering Committee, 2011.

Burt, Charles M, et al. "Irrigation performance measures: efficiency and uniformity." *Journal of irrigation and drainage engineering* (American Society of Civil Engineers) 123, no. 6 (1997): 423-442.

Business daily Africa. *Business daily Africa.* n.d. http://www.businessdailyafrica.com/Rising-cost-of-wood-lures-farmers-into-eucalyptus-planting-/-/1248928/1425426/-/njgnf9/-/index.html (accessed 03 20, 2015).

Calder, Ian R. *Water-resource and land-use issues.* Vol. 3. Iwmi, 1998.

Casley, Dennis J, Krishna Kumar, Banco Mundial, and others. "Collection, analysis and use of monitoring and evaluation data." In *Collection, analysis and use of monitoring and evaluation data*. Johns Hopkins University Press, 1988.

Central Bureu of Statistics (CBS). "Kenya_sublocations." *http://maps.virtualkenya.org/.* 13 03 2014. http://maps.virtualkenya.org/layers/geonode:kenya_sublocations (accessed 03 27, 2015).

CIAT. "Climate Change Adaptation and Mitigation in the Kenyan Coffee Sector." Cali: Centro Internacional de

Agriculura Internacional, January 2010.

climate-data.org. "climate-data.org." n.d. http://de.climate-data.org/ (accessed 03 20, 2015).

Constitution of Kenya. "The Constitution of Kenya." Nairobi: Goverment of Kenya, 2010.

Davidson, NJ, and JB Reid. "Response of eucalypt species to drought." *Australian Journal of Ecology* (Wiley Online Library) 14, no. 2 (1989): 139-156.

FAO. *Multipurpose Landcover Database for Kenya - AFRICOVER (GeoLayer). (Latest update: 18 Feb 2014) Accessed (27 Mar 2015).* Rome: Food and Agriculture Organization of the United Nations, 2012.

Gichuki, F, N. "Threats and opportunities for mountain area development in Kenya." *Ambio* (Springer) 28, no. 5 (1999): 430-435.

GoK. *National Climate Change Response Strategy.* Nairobi: GoK, 2010.

Groll, Michael, Chr Opp, Rashid Kulmatov, Malika Ikramova, and Inom Normatov. "Water quality, potential conflicts and solutions—an upstream--downstream analysis of the transnational Zarafshan River (Tajikistan, Uzbekistan)." *Environmental Earth Sciences* (Springer) 73, no. 2 (2015): 743-763.

Hamilton, L. S., et al. *A thematic study prepared in the framework of the Global Forest Resources Assessment 2005.* Rome: Food and Agriculture Organization of the United Antions, 2008.

Hansona, BR, LJ Schwankl, KF Schulbach, and GS Pettygrove. "A comparison of furrow, surface drip, and subsurface drip irrigation on lettuce yield and applied water." *Agricultural Water Management* (Elsevier) 33, no. 2 (1997): 139-157.

Hendrix, Cullen S, and Idean Salehyan. "Climate change, rainfall, and social conflict in Africa." *Journal of Peace Research* (SAGE Publications) 49, no. 1 (2012): 35-50.

Hsiang, Solomon M, Marshall Burke, and Edward Miguel. "Quantifying the influence of climate on human conflict." *Science* (American Association for the Advancement of Science) 341, no. 6151 (2013): 1235367.

Hunink, J.E., P. Droogers, S. Kauffman, B.M. Mwaniki, and J. Bouma. "Quantitative simulation tools to analyze up- and downstream interactions of soil and water conservation measures:

Supporting policy making in the Green Water Credits program of Kenya." *Journal of Environmental Management* 111, no. 0 (2012): 187-194.

IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth.* Edited by C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.) Field. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2014.

Jack, B Kelsey. "Upstream--downstream transactions and watershed externalities: Experimental evidence from Kenya." *Ecological economics* (Elsevier) 68, no. 6 (2009): 1813-1824.

KENVO. *KENVO - Kijabe Forest Volunteers.* 2008. http://www.kenvokenya.com/ (accessed 03 21, 2015).

Kenya Forest Service. *A Guide to On-Farm Eucalyptus Growing in Kenya.* Guideline, KFS, 2009.

Kottek, M, J Grieser, C Beck, B Rudolf, and F Bubel. "World map of the Köppen-Geiger climate classification updated." *Meteorologische Zeitschrift*, 2006: 15(3), 259-263.

Laws of Kenya. "Notice No. 120 The Environmental management and coordination (water quality) Regulations." 2006.

—. "Survey Act Revised Edition 2012, Chapter 299." 1994.

—. "Water Act. Revised Version 2012." National Council for Law Reporting with the Authority of the Attorney General, 2012.

Legesse, Dagnachew, Christine Vallet-Coulomb, and FranÃ§oise Gasse. "Hydrological response of a catchment to climate and land use changes in Tropical {Africa}: case study South Central {Ethiopia}." *Journal of Hydrology* (Elsevier BV) 275, no. 1-2 (Apr 2003): 67-85.

Liniger, Hanspeter, John Gikonyo, Boniface Kiteme, and Urs Wiesmann. "Assessing and Managing Scarce Tropical Mountain Water Resources." *Mountain Research and Development* (International Mountain Society (IMS) and United Nations University) 25, no. 2 (May 2005): 163-173.

Macherey-Nagel. *mn-net.* 2015. http://www.mn-

net.com/tabid/4928/default.aspx (accessed 03 20, 2015).

MENR. *Environmental Management and Co-Ordination (Water Quality) Regulations.* Nairobi: Goverment of Kenya, 2006.

—. *Masterplan for the Conservation and Sustainable Management of Water Catchment Areas in Kenya.* Nairobi, Kenya: Ministry of Environment and Mineral Resources, 2012.

MENR. *National Climate Change Action Plan.* Plan, Nairobi: Ministry of Environment and Mineral Resources, 2013.

Mikkelsen, Britha. *Methods for development work and research: a guide for practitioners.* Sage Publications India Pvt Ltd, 1995.

Milwaukee-Instruments. "Instrcution Manual CD600series." 2011. http://www.milwaukeeinst.com/site/db/doc/CD600.pdf (accessed 03 27, 2015).

Mustapha, Moshood K. "Influence of watershed activities on the water quality and fish assemblages of a tropical African reservoir." *Revista de Biología Tropical* 57, no. 3 (2009): 707-719.

Myers, BJ, RG Benyon, S Theiveyanathan, RS Criddle, CJ Smith, and RA Falkiner. "Response of effluent-irrigated Eucalyptus grandis and Pinus radiata to salinity and vapor pressure deficits." *Tree physiology* (Oxford University Press) 18, no. 8-9 (1998): 565-573.

O'Brien, Karen, Siri Eriksen, Lynn P Nygaard, and Ane Schjolden. "Why different interpretations of vulnerability matter in climate change discourses." *Climate policy* (Taylor \& Francis) 7, no. 1 (2007): 73-88.

O'Loughlin, John, Andrew M. Linke, and Frank D. W. Witmer. "Effects of temperature and precipitation variability on the risk of violence in sub-Saharan (Africa), 1980-2012." *Proceedings of the National Academy of Sciences* (Proceedings of the National Academy of Sciences) 111, no. 47 (Nov 2014): 16712-16717.

Ong, CK, and BM Swallow. "13 Water Productivity in Forestry and Agroforestry." *Water productivity in agriculture: limits and opportunities for improvement* (CABI) 1 (2003): 217.

Ongugo, PO, GO Sigu, JG Kariuki, AM Luvanda, and BN Kigomo. "Production-to-Consumption Systems: A Case Study of the Bamboo Sector in Kenya." *Kenya Forestry Research Institute (Not published)*, 2000.

OpenStreetMap contributors. “Open Street Map (OSM).” n.d.

Rantz, Saul E. “Measurement and computation of streamflow: Volume 1, Measurement of stage and discharge.” (USGPO) 1982.

Reardon, Thomas, and J Edward Taylor. “Agroclimatic shock, income inequality, and poverty: Evidence from Burkina Faso.” *World Development* (Elsevier) 24, no. 5 (1996): 901-914.

Snap Surveys. 2010. http://www.snapsurveys.com/blog/benefits-cross-tabulations-survey-analysis/ (accessed 03 21, 2015).

Tang, Jianjun, Henk Folmer, and Jianhong Xue. “Estimation of awareness and perception of water scarcity among farmers in the Guanzhong Plain, China, by means of a structural equation model.” *Journal of environmental management* (Elsevier) 126 (2013): 55-62.

Tang, Xuguang, et al. “How is water-use efficiency of terrestrial ecosystems distributed and changing on Earth?” *Sci. Rep.* (Nature Publishing Group) 4 (Dec 2014): 7483.

Theisen, Ole Magnus. “Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989--2004.” *Journal of Peace Research* (SAGE Publications) 49, no. 1 (2012): 81-96.

Transparency International. *Global Corruption Report: Climate Change.* London: Earthscan, 2011.

Turnipseed, D Phil, and Vernon B Sauer. *Discharge measurements at gaging stations.* US Department of the Interior, US Geological Survey, 2010.

Twesigye, Charles K, Simon M Onywere, Zachary M Getenga, Shadrach S Mwakalila, and Josephine K Nakiranda. “The impact of land use activities on vegetation cover and water quality in the Lake Victoria watershed.” *The Open Environmental Engineering Journal* 4 (2011): 66-77.

UNEP. *Kenya: Atlas of Our Changing Environment.* Nairobi, Kenya: Division of Early Warning and Assessment (DEWA) United Nations Environment Programme (UNEP), 2009.

United Nations, Department of Economic and Social Affairs. “Population Division (2013). World Population Prospects: The 2012 Revision, DVD Edition.” United Nations, Department of Economic and Social Affairs, June 2013.

UN-Water Africa. “The Africa water vision for 2025: Equitable and sustainable use of

water for socioeconomic development." *Addis Ababa, Ethiopia: Economic Commission for Africa*, 2003.

van de Loo, Elsa. "Influence of privatization of water delivery on access to the right to water in {Kenya}." *Water Policy* (IWA Publishing) 13, no. 2 (Feb 2011): 208.

Were, Kennedy, Aystein B. Dick, and Bal R. Singh. "Exploring the geophysical and socio-economic determinants of land cover changes in Eastern Mau forest reserve and Lake Nakuru drainage basin, {Kenya}." *GeoJournal* (Springer Science + Business Media) 79, no. 6 (Jan 2014): 775-790.

WHO. *Guidelines for Drinking-water Quality - 4th edition.* Geneva: World Health Organization, 2011.

WWAP. *The United Nations: World Water Development Report 2015: Water for a Sustainable World.* Paris: UNESCO, 2015.

Appendix

Contents:

App. 1.: Synopsis.....ii
App. 2.: Applied methods in the field.....xi
App. 3.: Pictures xii
App. 4.: Data matrix.....xiv
App. 5.: Rainfall patterns Kenya xvi
App. 6.: Max. temperature Kenya xvii
App. 7.: Questionnaire xviii
App. 8.: Background data to Figure 19.....xx

1 Introduction

Kenya is strongly dependent on its natural resources, since 80% of the economy is based on agriculture (UNEP 2009). The main tributary to the freshwater balance of Kenya are the high mountainous, forested areas of its highland called the water towers, like e.g. Aberdare Range, which is crucial for the water supply of the adjacent lowlands and also Nairobi (Liniger, et al. 2005, UNEP 2009, MEMR 2012).

The natural resources of Kenya are under pressure by an increasing population, limiting the available space and resources per capita (UNEP 2009, MEMR 2012). The lack of control and regulations in the past lead to overexploitation of the resources and uncontrolled land use changes resulting in degradation of the environment. Climate change may also play a role in the form of changing rain patterns, leading to flood and drought situations. (UNEP 2009, MEMR 2012, Mustapha 2009, Twesigye, et al. 2011, Hunink, et al. 2012, Liniger, et al. 2005) Especially acts of deforestation may alter the hydrology significantly (Ong and Swallow 2003, Legesse, Vallet-Coulomb and Gasse 2003, Calder 1998).

The change in water availability and quality has socio-economic effects on the communities relying on the water resources (Were, Dick and Singh 2014, Gichuki 1999). The practises of communities living upstream may have direct or indirect influences on the communities living further downstream and may result in conflicts (Jack 2009, Adams, Watson and Mutiso 1997, Gichuki 1999, Groll, et al. 2015).

The experiences from the past and the regulatory pluralism in Kenya, due to a multitude of regulations and authorities, lead to the implementation of verbal agreements or traditional forms of water management (Gichuki 1999, Liniger, et al. 2005, van de Loo 2011). A detailed description of the water governance in Kenya is given in van der Loo (2011). The implementation of local governance that is achieved due to the devolution as given by the constitution of 2010 has also effects on the water regulation. The development points towards small scale and local water management. The implementation of smallholder irrigation schemes and of water (resource) users associations (W(R)UAs) that work closely together with government authorities to manage the water distribution and to overcome the problems of the past. (Liniger, et al. 2005, Scheltema 2002, van de Loo 2011). It is also approached to avoid conflicts between upstream and downstream communities by careful resource handling and regulatory approaches, e.g. trials has been conducted in the upper Tana basin to compensate up- and downstream communities e.g. in the form of Green Water Credits (GWC) (Hunink, et al. 2009, Hunink, et al. 2012), which appliance could be relevant in the southern Aberdare area.

App. 1: Synopsis, 20.02.2015

2 Research Questions

The goal of the research is to apprehend the geophysical-socio-economic relations regarding water use in the south of the Aberdare Conservation Area (ACA).

This aims of the project is formulated as following:

Investigation of the qualitative and quantitative state of the river and its effects on the communities and the farming practises in south Aberdare Range.

This is investigation is conducted by the following research questions:

1. **How is the quantitative and qualitative state of the river water in two locations up- and downstream? Do spatial- and time changes between these locations occur?**

By focusing on an up-and downstream problem statement, measurements of water quality and quantity can be used to describe the implications of pollutant input and uneven availability of the water in the focused Galana/Athi river. The water quality and quantity can impact the health and income of household severely (Groll, et al. 2015). Especially agricultural practices that farmers upstream apply alter the water quality and quantity for the downstream community (Twesigye, et al. 2011, Muthigani 2011). The following sub-questions search to answer this:

1.1. How have annual precipitation patterns changed over time, and how have eventual changes influenced discharge rates over time?

1.2. How is the water quality? How does the quality differ spatially?

1.3. How is the spatial development of the discharge at different stages?

2. **What is the common perception of the water situation and how does this influence the relation between communities?**

To study the socio-economic effects, changes in water quantity and quality might have on the relationship between the different communities, the affected individuals' perception and awareness of environment must be understood, because these are basic requirements for human reaction (Sudarmadi, et al. 2001). Only if people observe water scarcity and pollution, they can obtain awareness of consequential problems and react (Tang, Folmer and Xue 2013). Experienced water scarcity in the lowlands resulting from intensive farming in the highlands may lead to conflicts among upstream and downstream water users. (Gichuki 1999, Liniger, et al. 2005)

App. 1: Synopsis, 20.02.2015

The following sub-questions have been formulated:

2.1. How do the inhabitants of the communities on these locations percept the water situation (quality and quantity)? Did they (the people) noticed changes within the past years or decades?

2.2. Are they aware of actual and possible problems arising from upstream practices?

2.3. What consequences do these problems have for the individuals and the communities up- and downstream?

3. What are the official regulations regarding water management in place and which regulations are actually followed in the Galana/Athi river area?

Water management practices can have a significant impact on the water state and the behaviour of the communities regarding water. Rising demand for water resources requires careful regulation and negotiation of the affected communities (Liniger, et al. 2005). Regulatory pluralism in Kenya makes it necessary to explore the influence and efficiency of available official regulations and to gain knowledge about applied verbal agreements. The following sub-questions have been formulated:

3.1. Which water management practises and regulations for surface water are in place within the catchment area?

3.2. How is the upstream downstream relation regulated? If existing: How does compensation takes place?

3.3. Which regulations are followed by the locals? Are there verbal agreements?

App. 1: Synopsis, 20.02.2015

3 Methodology

The following section provides a brief overview about the applied methods.

Qualitative methods like semi-structured interviews and participatory observation and quantitative methods like questionnaires form the basis for the social part.

Measurement and observation of parameters regarding water quantity and quality provide the natural part.

In addition to the knowledge on the topic gained through relevant literature, the following methods (both under the social and natural sciences) will contribute to the empirical material used in order to carry out the investigation.

3.1 Social Methods

3.1.1 Participatory Observation

In participatory observations, information is gained from observing individuals and the surroundings and simultaneously take part in the observed actions (Dewalt, et al. 1998).

In this study the approach is rather used as an observing walk guided by farmers to observe the agricultural fields close to the river. This is done after or while the questionnaire/interview takes place. In this way triangulation of the given information about water use, irrigation techniques and complying of regulation is done.

3.1.2 Questionnaires

A survey performed through the use of questionnaires offers useful information about general characteristics of the investigated areas (Babbie 2001). The standardized questionnaires provide answers that can be quantified and used through statistical analysis. Due to low time cost a higher amount of data can be obtained. The survey will contribute to the answering of research question two in particular. The information obtained through questionnaires will provide a general insight on the area, concerning the farmer's use of fertilizers and their perception of the water quality and quantity of the river.

Sample strategy (still uncertain!): In order to enhance the validation of the data acquired from the questionnaires, a sample size of 30 is preferred (15 from each area). The strategy used for sample selection of the people chosen for the survey, will depend on the spatial distribution of farmer's in the

App. 1: Synopsis, 20.02.2015

two investigated areas. A high population density in either the up- or downstream area will make it possible to perform systematic selection, e.g. every second farmer or applying a grid web on the areas. However, if the number of farmers is sparse in the investigated areas, it might be necessary to select and include all the existing farmers for the survey.

3.1.3 Semi-structured interviews

Semi-structured interviews are essential in order to obtain deeper knowledge about the issue investigated and thereby contribute to the ability of getting a broader and more detailed discussion about the issue. This more holistic insight of the problem would have been difficult to obtain, if only quantitative standardized data were used in the development of the project. The interviews will be carried out on the basis of a prepared interview guide. However, semi-structured interviews are open for changes, as the questions constructed are open-ended, which allow the respondent to answer the question and explain themselves in a flexible way (Casley, et al. 1988) The open-ended questions might lead to unexpected, yet relevant, issues brought up by the respondent, which might be further explained by follow up-questions (Mikkelsen 1995). The semi-structured interviews will contribute to the answering of particularly research question two and three. If possible the chiefs of the two areas as well as one farmer from up- and downstream, with fields closely situated near the river will be selected and interviewed to obtain in depth knowledge about the informants perception of the water quality and quantity in the river, awareness of up- and downstream relations and issues including their awareness about existing water regulations concerning the use of river water. Moreover, questions concerning the farmer's use of fertilizers will be addressed in order to evaluate the farmer's agricultural practices in relation to the water quality measured in the river (see natural methods below). A representative from the Water Resource Users Association (WRUA) in the region (Gatamaiyu), will act as a key informant in order to obtain specific information about the local water regulation regarding the management of the river water and whether the locals follow these regulation.

3.2 Natural Science

The spatiality of sampling is of importance. This is as the pollution concentration may not differ that much in a small scale. At selected locations measurements of river quality; nitrate, phosphate, ammonium, bacterial content and the biological oxygen demand (BOD) are to be conducted. Discharge can implicate the use of water for irrigation purposes and will give a measure of the state of quantity, and is thus included in the methodology. The actual uses of water by inhabitants are implemented into questionnaires, interviews and observations.

App. 1: Synopsis, 20.02.2015

Closer to the origin of the river in the Aberdare forest the water is expected to be purest, that is if there are no pollutants entering the stream from the forest. Sampling will therefore be done at a location where the impact of agriculture is not yet present.

Two areas along the river are chosen as locations of up- and downstream. These are preferably located at some distance apart. Three points for measurements are chosen along the reaches in the up- and downstream areas. This is to get an overall view of the state up- and downstream, and to minimize possible errors. A sketch of the sample strategy is shown in appendices 1 and 2.

Seven measurements of quality and quantity in total are to be taken along the river; three samples upstream, three samples downstream and one sample near the river source.

As the quality and quantity in the stream can slightly differ during the day, a time interval is set for measurements.

3.2.1 Overall water quality

Overall water quality is measured by turbidity, pH and electric conductivity (EC).

Turbidity is an overall measure of the water quality. It is a measure of the clarity of the sampled water as the amount of suspended particles decreases the attenuation of light. This is an objective measurement as the colouring and visibility of the water gives an estimate of the overall water quality. This is obtained by looking at the water in the stream and water samples in a see through container (EPA n.d.). pH (potential hydrogen) is measured using a pH meter. Electric conductivity is measured with an EC meter. This is an overall measure of the ionic content in the water, since ions increase the electric conductivity of water. The electric conductivity is measured in µS/cm (micro-Siemens per centimetre). Significant changes in conductivity up- and downstream can indicate one or many pollution sources entering the stream in between (EPA n.d.).

3.2.2 Biochemical oxygen demand (BOD)

BOD refers to the amount oxygen that would be consumed by microorganisms when all organic matter is oxidized in a 1 litre container (ReVelle & ReVelle, 1992).

Black or covered containers are used for water sampling in order to prevent photosynthesis. Two containers are to be filled at each location. In these two containers the concentration of dissolved oxygen (DO) is to be measured. The first bottle is analysed before incubating the other. The second sample bottle is stored for 5 days in 20 degrees before analysed. The concentration (mg/L) of BOD is calculated by differentiating the DO from the two containers (EPA, 2012).

App. 1: Synopsis, 20.02.2015

3.2.3 GPS

A global positioning system device is used to mark objects and measure areas of interest during the field work.

3.2.4 Nitrate, phosphate and ammonium

Application of manures and fertilizers to fields may cause leaching of nutrients to streams. The analytical method for nitrate, phosphate and ammonium concentrations consists of test kits which easily measures the concentration. This is done with test strips contacting the water. The colours appearing on the strips are compared to the colour scale provided in the kits (Macherey-Nageg).

3.2.5 Bacteria

A URICULT test kit is used to measure concentrations of different bacteria in the water.

Water is collected in an open container in which a culture-paddle is dipped into. The culture paddle is partially dried before inserting it into a protective vial and labelled. The sample is stored in an incubator for 16-24 hours at ideally 36±2 °C (Orion, 2013). If not incubated shortly after sampling, the sample can be stored at 2-8 °C for 24 hours (Orion, 2013). After incubation the sample is analysed by comparing the density of colonies on the paddle with the reference chart provided in the kit (manual). The type of bacteria is recognized from the colouring of the CLED (cystine lactose electrolyte deficient) medium covering the culture paddle (Orion, 2013).

3.2.6 Discharge measurements

In order to obtain the volume discharged in a stream per unit of time physical measurements around the stream need to be made. Horizontal stationing (width) is the first measurement conducted; normal tape measure from one side of the river to the other is done (Turnipseed and Sauer 2010). Stream depth is done secondly with a wading rod from a bridge, or in the water depending on the depth of the river, if so waders may have to be used. An average depth is preferred as the stream bed has a rather a half moon shaped geometry. Velocity measurement is necessary in order to get the volume of water per unit of time. If a flow meter is not available a simple measure of the time and distance can be done. An object is dropped into the stream at point *a* and the time it takes for it to reach point *b* downstream is recorded (Appendix 2). (Rantz 1982) These three measurements are added up to give the discharge in volume per unit of time.

App. 1: Synopsis, 20.02.2015

4 Collaboration with counterparts in Kenya

The fieldwork and applied methods will be conducted in collaboration with our Kenyan counterparts, which are two students from the University of Nairobi. We have been in contact via e-mail with our counterparts and have provided them with our synopsis, but we so far have not seen their ideas. We hope to be able to collaborate and adapt to each other's' ideas when we are in the field.

App. 1: Synopsis, 20.02.2015

5 Expectations

With the mentioned research questions knowledge about the following is gained: The present state of the water resources, the affected communities' perception and management regulations in place.

The working hypothesis is that due to anthropogenic effects the water quantity decreases and the water quality deteriorates. The effects become more severe along the stream due to accumulation of impacts. Communities at a lower river stage may feel grief on the upstream communities for degrading the water.

It is however unclear how the social status of the population is, maybe strong solidarity between the river people exists and the care about the environment and the community is stronger than anticipated.

Until now no data exits from the field area on the response on the devolution with regard to water resources. It may be interesting to observe if local governance improved the situation and created a framework in which the local communities have clear regulations on the usage of water for the benefit of the individual and the regional community.

App. 1: Synopsis, 20.02.2015

Applied Method	Upstream	Downstream
Water Discharge Measurements	8	10
Water Quality Measurements	8	9
Questionnaires	15	11
Semi Structured Interviews (farmers)	2	1
Semi Structured interviews (other)	4	-

App. 2: Applied methods in the field.

Picture A

Picture B

Picture C

Picture D

Picture E

Picture F

Picture G

Describtions:

Picture A: Eucalypus saplings at riverine.

Picture B: Deforestation in Keirita Forest.

Picture C: Typical land use upstream.

Picture D: Typical land use downstream.

Picture E: Bathi River upstream.

Picture F: Bathi River downstream.

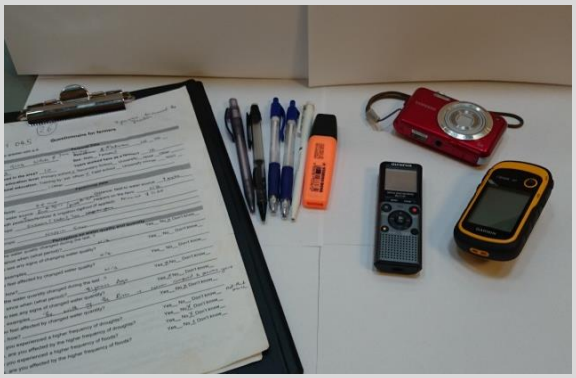
Picture G: Can irrigation practise.

App 3: Pictures illustrating mentioned circumstances in the introduction.

Picture A

Picture B

Picture C



Picture D

Picture E

Picture F *(with permission of the" forest group")*

Describtions

Picture A: Discharge measurements

Picture B: Quality measurement

Picture C: Test kit natural sciences

Picture D: Test kit social science

Picture E: Conducting a questionnaire

Picture F: Conducting an interview

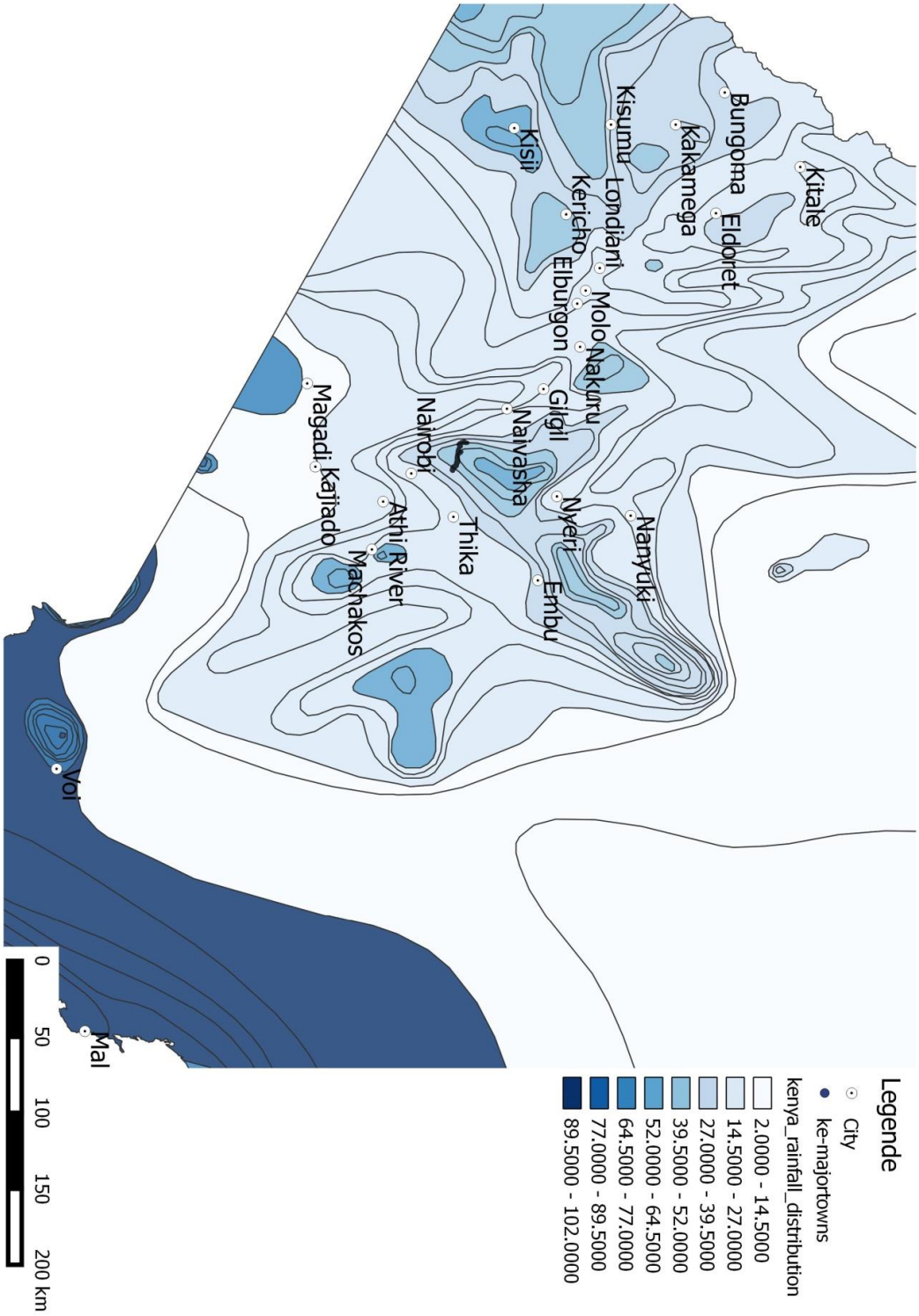
App. 3: Pictures illustrating the used methods in the field.

Researchquestions	Subquestions	Data requiered	Applied Methods	Field-equipment
How is the quantitative and qualitative state of the river water in two locations up- and downstream? Do spatial- and time changes between these locations occur?	How have annual precipitaion patterns changed over time, and how have eventual changes influenced discharge rates over time?	- secondary, quantitative data regarding precepitation - qualitative & quantitative data on discharge changes	- Literature review - Questionaires/ Interviews	Pen, Paper, Dictaphone
	How is the water quality? How does the quality differ spatially?	quantitative data: - Turbidity - Nitrate/ Nitrite - Ammonium - Phosphate - bacteria - pH	Quantitative measurment	Stick based kits Uricult kit pH-meter EC-meter GPS Measuring glass
	How is the spatial development of the discharge?	quantitative data: - discharge	Quantitative measurment	Timer Tape measure Wading rod Floating object
What is the common perception of the water situation and how does this influence the relation between communities?	How do the inhabitants of the communities on these locations percept the water situation (quality and quantity)? Did they (the people) noticed changes within the past years or decades?	Qualitative & quantitative data: - local perceptions - noted changes in water quality and quatity	Questionaires Interviews	Pen, Paper, Dictaphone
	How is their awareness of actual and possible problems arising from upstream practices?	Qualitative & quantitative data: - local awareness	Questionaires Interviews	Pen, Paper, Dictaphone
	What consequences do these problems have for the individuals and the communities up- and downstream?	Qualitative & quantitative data: - local perceptions - noted changes in water quality and quatity	Questionaires Interviews	Pen, Paper, Dictaphone

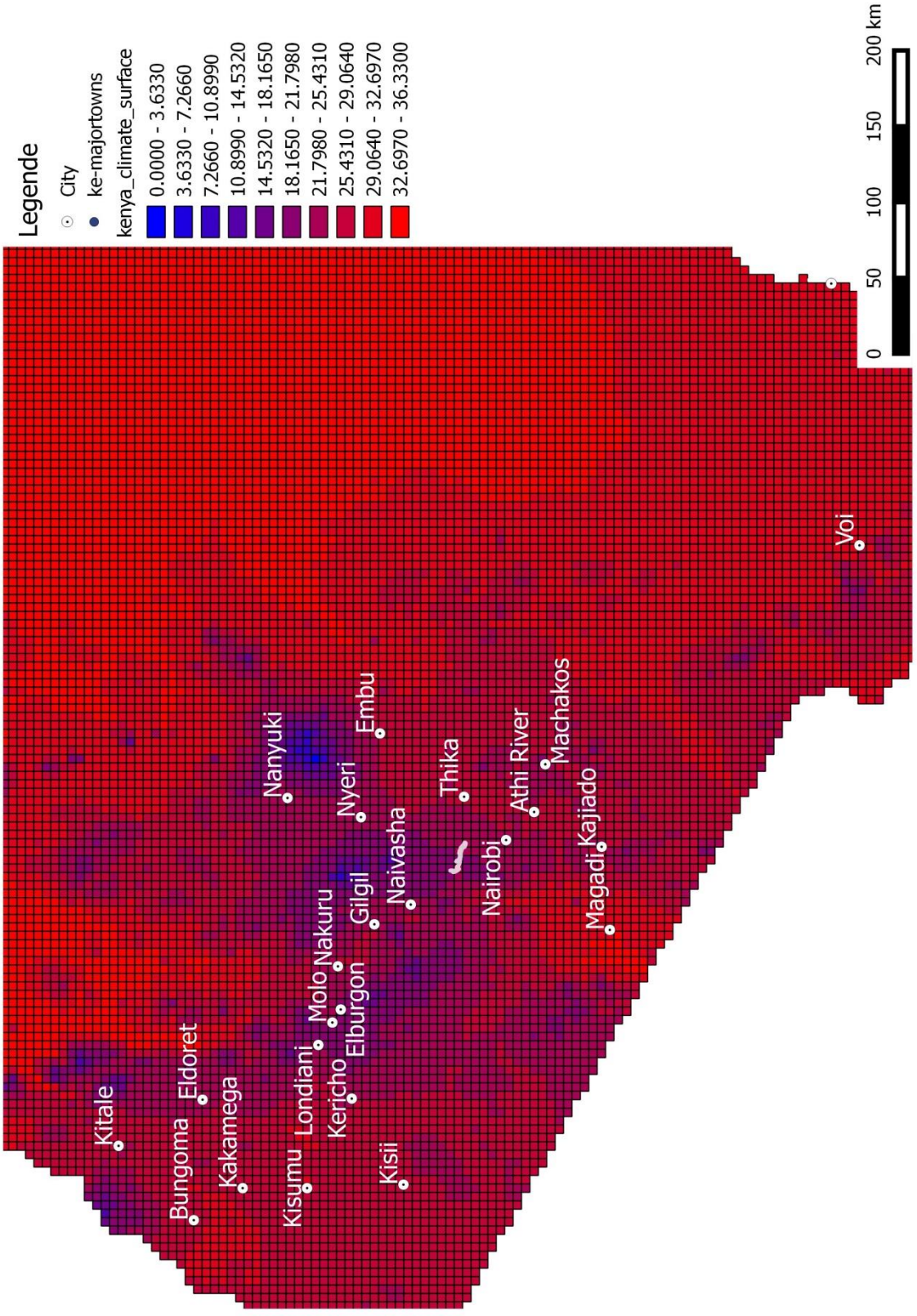
App. 4: Data Matrix

What are the official regulations regarding water management in place and which regulations are actually followed in the Galana/Athi river area?	Which water management practises and regulations for surface water are in place within the catchment area?	Secondary data: Overview of regulations Qualitative data: local Regulations	Literature review Interview with WRUA	Pen, Paper, Dictaphone
	How is the upstream downstream relation regulated? If existing: How does compensation takes place?	Secondary data: Overview of regulations Qualitative data: local Regulations	Literature review Interview with WRUA & the village chief	Pen, Paper, Dictaphone
	Which regulations are followed by the locals? Are there verbal agreements?	Qualitative & quantitative data: - local knowledge & practices	Questionaires Interviews Observations	Pen, Paper, Dictaphone

App. 4: Data Matrix



App. 5: Rainfallpatterns in Kenya.



App. 6: Max. temperature in Kenya.

Questionnaire for farmers

Mark your answer with a X.

Personal Data

Name: _____ **Residence:** _____US: __ DS: __

Age: _____ **Sex:** Male__ Female__

Years lived in the area? _____ **Years worked here as a farmer?** _____

Highest education level: Primary school__ Secondary School__ University__None __Other _____

Agricultural education: Training by: ext. officer __ Field school __ University course: ___ NGO: __

(Which: _____) Other: _____

Farm/crop data

Size of fields: _____ Distance: field to water source: _____

Type of water source: _____Helpers on the farm: _____

Crops with pesticides/fertilizer & irrigation method (if applied):

Main crops: _____

_____

Other crops: _____

Perception on water quality and quantity

Have the water *quality* changed during the last..? Yes__ No__ Don't know__

If yes, since when (what period)?_____

Do you see any signs of changing water quality? Yes__ No__ Don't know__

If yes, examples_____

Do you feel affected by changed water quality? Yes__ No__ Don't know__

If yes, how?_____

Have the water *quantity* changed during the last ..? Yes__ No__ Don't know__

If yes, since when (what period)?_____

Do you see any signs of changed water quantity? Yes__ No__ Don't know__

If yes, examples_____

Do you feel affected by changed water quantity? Yes__ No__ Don't know__

If yes, how? _____

Have you experienced a higher frequency of droughts? Yes__ No__ Don't know__

If yes, are you affected by the higher frequency of droughts? Yes__ No__ Don't know__

Have you experienced a higher frequency of floods? Yes__ No__ Don't know__

If yes; are you affected by the higher frequency of floods? Yes__ No__ Don't know__

App. 7: Questionnaire

Conflicts

Do you think anyone/anything is responsible for water scarcity? Yes__ No__ Don't know__

If yes, whom or what?_____

Do you think anyone/anything is responsible for lower quality of water? Yes__ No__ Don't know__

If yes, whom or what? _____

Do you think that your use of water for irrigation have any direct effect on the water *quantity* available for other users? Yes__ No__ Don't know__

Do you think that your use of fertilizers have any direct effect on the *quality* of the water available for other users? Yes__ No__ Don't know__

OR On a scale from 1-5, how would you rank the following statement:

Irrigation practices by upstream farmers have a direct negative effect on the water *quantity* available for other users, where

1= totally disagree___ 2= disagree___ 3= neither nor___ 4= agree___ 5= totally agree___

The use of fertilizers by upstream farmers have a direct negative effect on the *quality* of the water available for other users, where

1= totally disagree___ 2= disagree___ 3= neither nor___ 4= agree___ 5= totally agree___

Where do you dispose your used water? _____

Would you be willing to change your behavior to improve the water situation regarding:

- regarding irrigation practices? Yes__ No__ Don't know__
- regarding use of fertilizers/ pesticides? Yes__ No__ Don't know__
- regarding waste water disposal? Yes__ No__ Don't know__

Water regulations

Are there any regulations (rules) concerning:

- the type of irrigation practices applied in the field? Yes__ No__ Don't know__
- the amount of water you are allowed in the use of irrigation? Yes__ No__ Don't know__
- the amount of fertilizer/pesticides you allowed to use? Yes__ No__ Don't know__

Is there anybody informing you how to manage the water regarding the farming practices mentioned above? Yes__ No__ Don't know__

If yes, who? _____

Is there anybody controlling if you follow these regulations? Yes__ No__ Don't know__

If yes, who and how often?? _____

Would you be willing to follow guidelines concerning:

- water for irrigation? Yes__ No__ Don't know__
- concerning the amount of fertilizer/pesticide? Yes__ No__ Don't know__

Have you heard about WRUA (Water Resource Users Association)? Yes__ No__ Don't know__

If yes, what do you know about WRUA (Gatamaiyu)?

_____

_____

Do you support the activities of the local WRUAs? Yes__ No__ Don't know__

Would you like to engage in the activities of the WRUAs? Yes__ No__ Don't know__

App. 7: Questionnaire

Education

Highest edu

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	primary school	15	57,7	57,7	57,7
	secondary school	10	38,5	38,5	96,2
	none	1	3,8	3,8	100,0
	Total	26	100,0	100,0	

Highest edu * Irrigation effects quantity Crosstabulation

		Irrigation effects quantity				Total %	
		Yes	%	No	%		
Highest edu	primary school	0	0%	12	100%	12	52,2%
	secondary school	7	70%	3	30%	10	43,5%
	none	0	0%	1	100%	1	4,4%
Total		7	30,4%	16	69,6%	23	100%

Highest edu * fertilizers effects quality Crosstabulation

		fertilizers effects quality						Total %	
		Yes	%	No	%	Don't know	%		
Highest edu	primary school	1	6,7%	14	93,3%	0	0%	15	57%
	secondary school	4	40%	5	50%	1	10%	10	38,5%
	none	0	0%	1	100%	0	0%	1	3,8%
Total		5	19,2%	20	76,9%	1	3,8%	26	100%

Agricultural education

Agricultural Education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Training by officer MOA	16	61,5	61,5	61,5
	none	10	38,5	38,5	100,0
	Total	26	100,0	100,0	

Agri education * Irrigation effects quantity

		Irrigation effects quantity				Total %	
		Yes	%	No	%		
Agri edu	Training by officer MOA	5	35,7%	9	64,3%	14	60,9%
	none	2	22,2%	7	77,8%	9	39,1%
Total		7	30,4%	16	69,6%	23	100%

Agri education * fertilizers effects quality

		fertilizers effects quality						Total %	
		Yes	%	No	%	Don't know	%		
Agri edu	Training by officer MOA	4	25%	11	68,8%	1	6,25%	16	61,5%
	none	1	10%	9	90%	0	0%	10	38,5%
Total		5	19,2%	20	76,9%	1	3,8%	26	100%

App. 8: Background data to Figure 19.