Dangerous soil erosion!?

A study on soil erosion in the Voi River catchment, South-East Kenya

A.J.K. Kort
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November 2006

Westerveld Conservation Trust

Universiteit Twente
de ondernemende universiteit

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Report about soil erosion in the Voi River catchment, Kenya for the Bachelor-thesis of Civil Engineering (& Management) and the minor Sustainable Development in a North-South Perspective, "As the world turns" of TDG, University of Twente, The Netherlands. Internship carried out at Westerveld Conservation Trust (Dutch-Kenyan NGO) in Voi, Kenya from 11th of July till 11th of November 2006.

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The pessimist sees difficulties in every opportunity
The optimist sees opportunities in every difficulty

(Winston Churchill)

You see things and you say: “Why?”
But I dream of things that have never been there and I say: “Why not?”

(author unknown)

He who has begun has half done.
Dare to be wise, begin

(Horace)

Summary

This report is about water erosion in a part of the Voi River catchment, Taita-Taveta District, Coast Province, Kenya. Population pressure in this area is resulting in unsustainable fuel wood collection, overgrazing, inappropriate land use techniques, and deforestation. Furthermore climate changes are likely to cause more droughts. The area is under present conditions semi-arid and therefore vulnerable to erosion. These facts result in the following problem definition: in the Voi River catchment erosion is too high because of decreasing vegetation cover. The objective of this research is to give soil conservation recommendations based upon an erosion hazard assessment and socio-economic analysis.

The method used for collecting data is Rapid Rural Appraisal (RRA). RRA is used widely in developing countries for pre-project exploratory work. It has been used because it gives fast accurate social and technical data by triangulation of interviews, secondary data and observations. Also it takes local conditions into account what is very important for giving good conservation recommendations. During fieldwork the area has been mapped and divided in different sub-areas. The sub-areas are: Voi town & Mwakingali Hills, Sagala Hills, Voi River, Plains, Sisal estate and Taita Hills.

Erosion hazard has been determined by erosion intensity and erosivity. To determine erosion intensity drainage density and drainage texture are used. For erosivity slope, soil characteristics under wet conditions, and difference between recommended and present land use. For the whole research area a rainfall aggressiveness rate has been determined with weather data of Voi. Rainfall aggressiveness was highest in April and was quite high, taken the aridity of the area into account. Erosion intensity was highest at the foothills of Mwakingali Hills, Sagala Hills, and Small Taita Hills. Gullying in these areas was severe. The hill-areas had very steep slopes and were susceptible to erosion. Erosion risk was highest in the foothills. Erosion risk was high north of the Small Taita Hills and south of Voi River. Results of the erosion hazard assessment, conducted with the indicators mentioned above except of rainfall aggressiveness, are that especially the foothills are vulnerable to erosion. In the Small Taita Hills erosion risk was especially severe.

The theory of Poiesz, in combination with interviews and observations, has been used to analyze the behaviour of people in taking conservation measures. It became clear that the environment was forcing people to take conservation measures. Awareness of erosion as a problem was high throughout the research area. The motivation of people however to take measures was moderate as experienced by Westerveld Conservation Trust (WCT) and observations made clear. Only in the Small Taita Hills people were motivated. The capacities of people were differing for each sub-area. In general local people were taking already quite some measures, but most of the time they were inadequate or badly constructed. Maintenance of simple techniques is over the whole research area very well, but maintenance of more advanced techniques, as terraces, was moderate to bad. Community or NGO projects were also maintained badly. The overall conclusion was that erosion prevention practiced in the Taita Hills by local farmers is quite high, but most of the time still inadequate, on the Sisal estate soil prevention is good, and for Plains and Voi River it is moderate to low and inadequate, because most people are not actively preventing erosion.

There are many soil conservation measures needed. In the whole area farmers have to be taught appropriate farming techniques, such as replanting of trees, use of mulch and so on. Along roads gutters have to be installed, so that gullying is prevented. Furthermore in most sub-areas vegetation cover has to be restored and gullies to be reclaimed. At the foothills waterways are recommended to prevent gullying. Trenches are recommended on the plains and foothills to increase water infiltration and plant cover. In the Small Taita Hills ladder terraces are recommended on agricultural plots. Social consequences of recommendations have to be taken into account. People must have opportunities to get fuel wood and pasture. Therefore it is needed to teach them sustainable fuel wood collection and the animal-land ratio has to be made sustainable. The latter however is very difficult to obtain.

Concluding, erosion in the research area is especially severe at the foothills. It is damaging roads, houses, plots and nature. Erosion risk of the foothills is high and local soil erosion prevention is not adequate enough, except of Sisal estate. Soil conservation measures are therefore needed fast.

It is recommended to do research at soil loss in the rainy season to compare results with other studies of erosion in East-Africa and with results of soil loss models as Universal Soil Loss Equation (USLE) to get more insight in specific local conditions and the severity of erosion in the area. Also measurements on soil loss for the research area and for trenches are recommended, so that conservation measures can be designed and the effectiveness of trenches could be determined. More data on local weather of the sub-areas is needed, because it is differing much and determines greatly soil conservation that is possible. It is strongly recommended to implement soil conservation combined with water storage measures and to make a catchment wide plan, so that areas downstream are not neglected. Before implementing projects it is wise to determine who will benefit of the project and how to give the locals ownership over the project. Gender and the powerless have to be taken into account to make the project sustainable. Before the soil conservation recommendations are implemented, it is necessary to make more detailed plans for the implementation per sub-area.

Samenvatting

Dit rapport gaat over watererosie in een deel van het stroomgebied van de Voi River, Taita-Taveta District, Coast Province, Kenya. Bevolkingsgroei veroorzaakt onduurzaam brandhout sprokkelen, overbegrazing, slechte landgebruiktechnieken en ontbossing. Daarbij zorgen klimaatveranderingen waarschijnlijk voor meer droogte. Het gebied is semi-aride en daardoor gevoelig voor erosie. Deze feiten resulteren in de volgende probleemdefinitie: in het stroomgebied van de Voi River zijn de gevolgen van erosie zeer erg door afname van de vegetatiebedekking. Het doel van deze studie is om aanbevelingen te geven voor grondconservatie gebaseerd op een erosierisicoanalyse en een socio-economische analyse.

Als methode voor het verzamelen van data is Rural Rapid Appraisal (RRA) gebruikt. RRA wordt veel gebruikt in ontwikkelingslanden voor vooronderzoeken. RRA is gebruikt omdat het snel kwalitatief goede sociale en technische data geeft, door triangulatie van interviews, literatuur en observaties. Ook houdt deze methode rekening met lokale omstandigheden, wat zeer belangrijke is voor goede aanbevelingen. Het gebied is in kaart gebracht en verdeeld in verschillende subgebieden, namelijk: Voi town & Mwakingali Hills, Sagala Hills, Voi River, Plains, Sisal estate and Taita Hills.

Erosierisico is bepaald met erosie-intensiteit en erosiegevoeligheid. Voor het bepalen van erosie-intensiteit zijn drainage dichtheid en drainage textuur gebruikt. Erosiegevoeligheid is bepaald met helling, grondkenmerken onder natte omstandigheden, en verschil tussen huidig en aanbevolen landgebruik. Voor het gehele stroomgebied is de regenvalagressiviteit berekend met weersdata van Voi. Regenvalagressiviteit was het hoogste voor april en op zichzelf vrij hoog, rekening gehouden met de ariditeit. Erosie-intensiteit was het hoogste voor gebieden onderaan de bergketens. Gully-erosie was erg in het gebied. De berggebieden hadden steile hellingen en waren gevoelig voor erosie. Het erosierisico was het ergste onderaan berghellingen. Het erosierisico was vooral hoog noordelijk van de Small Taita Hills en zuidelijk van de Voi Rivier. De resultaten van de erosierisicoanalyse, waarvoor de bovengenoemde indicatoren uitgezonderd regenvalagressiviteit zijn gebruikt, was dat het erosierisico vooral hoog was aan de voet van berghellingen en in het bijzonder in de Small Taita Hills.

De theorie van Poiesz, in combinatie met interviews en observaties, is gebruikt om het gedrag van mensen aangaande grondconservatie te analyseren. De studie maakte duidelijk dat omgevingsfactoren boeren dwongen om maatregelen te nemen. In het onderzoeksgebied is het bewustzijn van het erosie probleem groot. De motivatie van mensen om maatregelen te nemen daarentegen is matig, zoals ervaringen van Westerveld Conservation Trust (WCT) en observaties uitwezen. Alleen in de Small Taita Hills waren boeren gemotiveerd. De capaciteiten van mensen verschilden per deelgebied. In het algemeen namen lokale mensen al redelijk veel erosiewerende maatregelen, maar meestal waren ze van slechte kwaliteit. Eenvoudige technieken werden in het onderzoeksgebied goed onderhouden, maar meer gecompliceerde technieken, zoals terrassen, werden matig tot slecht onderhouden. Gemeenschapsprojecten en projecten van NGO’s werden ook slecht onderhouden. De algehele conclusie was dat erosiepreventie door boeren in de Taita Hills vrij hoog is, maar niet goed genoeg, op de Sisal estate goed is, en voor de deelgebieden Plains en Voi River matig tot slecht en van slechte kwaliteit, omdat de meeste mensen niet daadkrachtig erosie proberen te voorkomen.

Er zijn veel erosiewerende maatregelen nodig. In het hele gebied moeten aan boeren juist landbouwmethoden worden geleerd, aangaande het herplanten van bomen, gebruik van plantenresten etc. Naast wegen moeten afvoergoten voor water worden gemaakt, zodat gullies worden voorkomen. Verder moet de vegetatiebedekking in de meeste deelgebieden worden hersteld en gullies gestopt. Onderaan bergen wordt het aanbevolen om waterwegen te maken om gullies te voorkomen. Trenches worden aanbevolen op de vlaktes en onderaan berghellingen, zodat infiltratie van water en plantbedekking toenemen. Het wordt aanbevolen om in de Small Taita Hills trapterrassen aan te leggen op landbouwgronden. Met de sociale gevolgen van deze aanbevelingen moet rekening worden gehouden. Mensen moeten alternatieven krijgen voor houtwinning en het weiden van vee. Daarom zouden mensen moeten leren om op een duurzame manier hout te winnen en vee te weiden. Dit laatste is echter zeer moeilijk.

Gesteld kan worden dat erosie in het onderzoeksgebied vooral erg is aan de voet van bergen. Erosie beschadigt wegen, huizen, akkers en natuur. Erosierisico voor de voet van de bergen is groot en erosiepreventie is niet goed genoeg, behalve voor het deelgebied Sisal estate. Grondconservatie is daarom direct nodig.

Ook moeten metingen aan grondverlies worden verricht in het onderzoeksgebied, zodat grondverlies in deze regio kan worden vergeleken met studies in andere regio’s in Oost-Afrika en modelresultaten van Universal Soil Loss Equation (USLE). Op deze manier wordt meer inzicht in de grote van het probleem verkregen. Ook moeten grondverliesmetingen worden gedaan bij trenches, zodat conservatiemaatregelen kunnen worden ontworpen en de effectiviteit van trenches kan worden bepaald. Ook is er meer data nodig aangaande lokale weersomstandigheden, omdat dit heel erg verschilt per locatie en in grote mate bepaald welke maatregelen mogelijk zijn. Het wordt ten zeerste aanbevolen om grondconservatie toe te passen in combinatie met wateropslag en hiervoor een stroomgebied breed plan voor te maken, zodat gebieden benedenstrooms niet worden vergeten. Het is verstandig, voordat projecten worden geïmplementeerd, om te bepalen wie er profijt hebben van het project en op welke manier lokale mensen eigenaar kunnen worden van het project. Er moet rekening gehouden worden met man-vrouw-verhoudingen en machtlozen wil men een project duurzaam maken. Voordat de grondconservatie aanbevelingen worden geïmplementeerd is het van belang dat eerst gedetailleerde plannen worden gemaakt voor de implementatie per subgebied.

Preface

This report is a part of the Re-hydrating the Earth in Arid Lands project (REAL project). The main goal of the REAL-project is to obtain the knowledge how to re-hydrate arid and semi-arid areas. This report is a preparatory study on soil erosion in a part of the Voi River catchment. The recommendations of this report are taken into account by Wilco van Bodegraven, who has written a report on re-hydrating the Voi River catchment. Wilco has also taken into account water storage besides erosion. Hopefully this report, in combination with the report of Wilco, makes an important contribution for stopping the dangerous erosion in the Voi River catchment, by making government institutions, the population and other parties aware of the problems in this area. The report could form the base for a thorough plan countering soil erosion, so that the wellbeing of the people in the Voi River catchment could be increased.

The report is part of the Bachelor thesis of the study *Civil Engineering (& Management)* and the minor *Sustainable Development in a North-South Perspective, "As the World Turns"* of the Technology and Development Group, both of the University of Twente, The Netherlands. The internship has been carried out at Westerveld Conservation Trust (WCT), a Dutch-Kenyan Non Governmental Organization (NGO), involved with the building of sand storage dams and making of trenches for increasing water storage in arid and semi-arid lands. The internship has been done from the 11th of July till the 11th of November 2006 in Kenya. The internship has been carried out with Wilco van Bodegraven. The fieldwork in Voi took almost three months. After that the final report has been written in Nairobi.

I would like to thank several people in particular for the achievement of this report. First of all I would like to thank my supervisors, dr. ir. D.C.M. Augustijn and dr. J.S. Clancy, of the University of Twente. They gave important input and support for carrying out this research. I would like to thank them for there superb supervising. Secondly I would like to thank Westerveld Conservation Trust for the opportunity they gave for carrying out the research. Also I would like to thank the supervisors of WCT, Mrs. M.G. van Westerop and Mr. J. Mukusya. Mrs. Van Westerop gave us a lot of important information about projects WCT had done previously and what the goals and working methods of WCT are. Mr. Mukusya showed us some interesting parts of Kenya and arranged our accommodation in Voi. Also he give some important insights on farming, erosion control and development work in general, which was important information for the report.
Further thanks goes to Heijmans, Roosendaal, The Netherlands for sponsoring us with a land measuring tool for measuring slopes. Without this tool the research could not have been done. Also I want to thank Mrs. M. van Tiel of Heijmans and Mr. J. Spit of Syncera (The Netherlands) for their suggestions and recommendations on the report.
The people of Amani Guest House, the place we stayed in Voi, deserve special thanks. Especially Marianne Wangu and here family I owe a lot. They did a lot to make our stay well. Also I would like to thank the people who we met during our fieldwork and provided us with crucial information. I would like to thank them for their kindness and time.
Last but not least I would like to thank my colleague student and friend Wilco van Bodegraven with whom I carried out the fieldwork in Voi. We helped each other by giving each other recommendations. We had nice chats about several subjects of which the most interesting and striking were development work, African culture versus European culture, and Christian faith. I would like to thank Wilco a lot for all the insights and help by the research and making my stay in Kenya unforgettable.

Hopefully my efforts of wandering through the Kenyan bush with Wilco have not been a waste. It would be the best if the recommendations in this report on soil erosion will be implemented soon so that the lives of people can be improved and protected. We saw at some sights gullies which swept away houses, agricultural plots, nature, roads etcetera. This is only one of the consequences of soil erosion. Lots of other consequences I have not even mentioned yet. So it is clear that the people in Voi area need help or have something to do to counter soil erosion.

Nairobi, November 2006

A.J.K. Kort

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Abbreviations and acronyms

EC	European Commission
FDA	Federal Department of Agriculture
FFW	Food For Work
GIS	Geographic Information System
INCO-DEV	International Cooperation with Developing Countries
IRC	International Research Centre
Ksh	Kenyan shilling
NGO	Non Governmental Organization
PRA	Participatory Rural Appraisal
REAL	Re-hydrating the Earth in Arid Lands
RRA	Rapid Rural Appraisal
SASOL	Sahelian Solutions
USLE	Universal Soil Loss Equation
WCT	Westerveld Conservation Trust

Swahili terms

Matatu	Public transport by minibus
Shamba	(Agricultural) plot
Sukuma wiki	Kale; kind of vegetable tastes as cabbage/spinach

Introduction

“Climate changes and population growth cause increasing pressure on the East African highlands. The results of the pressure are manifold: urban growth, intensified agriculture, decrease of forested areas, loss of biodiversity, accelerated land degradation and soil erosion. The consequences introduce great demands on land use planning.” (Pellikka et al., 2005)

This quote reflects perfectly the problems of the research area in the Voi River catchment, Coast Province, Kenya. This area is drying-out and suffers of the same problems as mentioned in the quote. Also droughts are expected to appear more often in this semi-arid part of Africa under influences of climatic changes. (Soini, 2005; Sample, 2003). Therefore the Re-hydrating the Earth in Arid Lands project (REAL project) has been started in which several NGOs and universities are working together to get the environment of semi-arid and arid areas stable and humid again in a sustainable way. The REAL project is subsidised by the European Commission (EC) and International Cooperation with Developing Countries (INCO-DEV). The participants of the project consortium are Catholic University of Leuven (Belgium), Delft University of Technology (The Netherlands), Nairobi University (Kenya), University of Dar es Salaam (Tanzania), IRC (The Netherlands), SASOL (Kenya), WCT (Kenya/The Netherlands), Protos (Belgium). (Hut et al., 2005; Westerveld & Van Westerop, 2005) The general objective of the REAL project is: to clarify the relations between local practices and theoretical approaches, by focusing on the design, management and performance of small groundwater retaining structures on a communal level in semi-arid regions in two African countries, Kenya and Tanzania, linking both the individual and the community as theory and practice, resulting in guidelines for participatory design of small water retaining structures in semi-arid regions world-wide. (Bossenbroek & Timmermans, 2003; Westerveld & Van Westerop, 2005)

WCT is involved in research into and the construction of sand storage dams and trenches. Also students from several universities have done research for WCT. Mainly research has been done on sand storage dams and trenches. The following topics for example have been investigated: criteria for the construction of sand storage dams, functioning of sand storage dams, working of trenches etcetera. The projects and research have been carried out in Kenya and Tanzania. (Bossenbroek & Timmermans, 2003; Burger et al., 2003; Hut et al., 2005; Borst & De Haas, 2006)
WCT wants to re-hydrate and improve the environment of the Voi River catchment. In the Voi River catchment WCT has built already four sand storage dams in the surroundings of Voi. Also they started with the making of trenches on a few plots along the Voi River. However, there has not been made a plan for the whole catchment area. So it is not known which actions have to be taken to re-hydrate the whole catchment. The objective of this report is to make a preliminary study for a part a of the Voi River catchment on soil erosion prevention. Prevention of soil erosion is important for re-hydrating the area, because water storage and erosion problems are interrelated. To solve the problems, it is important to take both topics into account. Soil conservation has been studied by using an erosion hazard assessment, which indicates for which areas erosion risk is high. Also research into erosion prevention by locals has been examined, using interviews and observations. Based on the technical and socio-economic data recommendations for soil conservation are given.
Wilco van Bodegraven (2006) will use the recommendations made in this report on soil erosion prevention for making an integrated report on re-hydrating the study area by taking water storage into account. Van Bodegraven (2006) has made a study about where it is needed and possible to implement water storing structures. He did research at suitable locations for small water retaining structures and did a research into local water storage activities by doing interviews. Van Bodegraven (2006) combined the research into water storage with the recommendations on soil erosion to an integrated re-hydration plan and prioritised activities needed by using a multi criteria analysis.

Furthermore, the research done in the Voi River catchment extends the scientific knowledge on the distribution of gullies in the area of Voi and the Taita Hills. The University of Helsinki (Finland) has carried out already some studies on the distribution of gullies in the Taita Hills (Sirviö et al., 2004; Sirviö & Rebeiro-Hargrave, 2004). This information can also be used for an erosion hazard assessment of the whole catchment.

In chapter 1 the research context of this research has been described, consisting of background, system analysis, problem analysis, objective, research questions, and research area. In chapter 2 the methodology is explained. In chapter 3 the theory about erosion is discussed. Chapter 4 is describing the result of the erosion hazard assessment. Chapter 5 deals with the results of research into soil erosion prevention by local people. In chapter 6 recommendations on soil conservation measures are given, based upon chapter 4 and 5. In chapter 7 conclusions and recommendations are presented. Definitions of all the important words used in this report can be found in the glossary of key terms, standing in the back of the report.

This report is meant for WCT to make a plan for re-hydrating the Voi River catchment. Also they can use this report to make government institutions, other NGOs, and chiefs aware of the problems in the Voi River catchment and to get support for acting against these problems.

1 Research context

In this chapter will be explained what the characteristics of the research area are regarding soil erosion. In the first paragraph the influences of global climate change, the history of the Voi River catchment on erosion, and the socio-economic characteristics of the research area are presented. In the system analysis, paragraph 1.2, the characteristics of the Voi River catchment will be discussed more deeply. In paragraph 1.3 the problem analysis is presented. In paragraph 1.4 objective and research questions are presented.

1.1 Location

The research area lies in the Voi River catchment in Taita-Taveta District, Coast Province, Kenya. The Voi River flows from the Taita Hills (Latitude 3º25'S, Longitude 38º20'E) to the Indian Ocean (Latitude 3º38'S, Longitude 39º52'E). The research area and the Voi River are presented in figure 1.1 and 1.2.

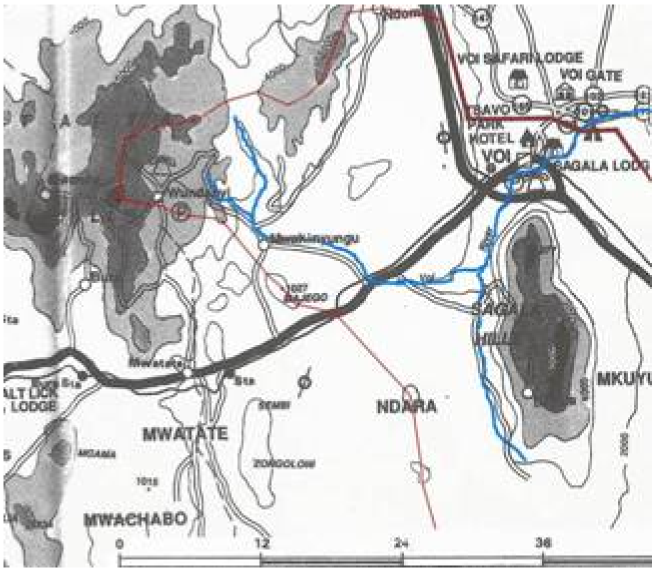


Figure 1.1 Map of Kenya and location of the research area in the Voi River catchment. (SOS Africa, 2001)

Figure 1.2 Map of Voi River catchment till the borders of Tsavo East National Park. Scale in km. (Tourists Maps (K) Ltd, n.d.)

The research is defined to a part of the Voi River catchment, because the whole catchment area was not feasible to study because of time constraints and man power. The research area is presented in figure 1.3. The research area investigated is 128 km^2 large and divided in 8 grids of 16 km². The position of the grids and their grid number is presented in figure 1.3. The red line is the estimated area of the Voi River catchment (Google earth, 2005).

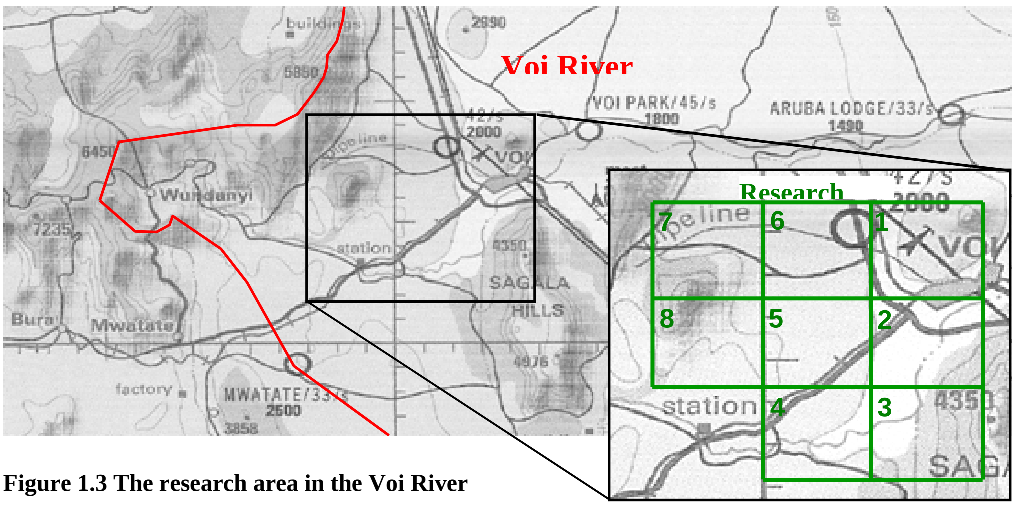


Figure 1.3 The research area in the Voi River

1.1.1 Influence of global climate on erosion

Erosion at macro scale

According to Morgan (1986) several parameters are important for erosion: “The factors which influence the rate of erosion are rainfall, runoff, wind, slope, plant cover and the presence or absence of conservation measures” (Morgan, 1986: p. 1). Erosion studied at macro level is most determined by climate, at meso level by lithology, relief and altitude and at micro level by micro-climate, lithology of soil and plant cover (Morgan, 1986: p. 7).
At macro scale climate has a lot of influence on the characteristics of erosion, because it influences rainfall and wind. Indirectly it has therefore influence on runoff and plant cover. So it determines local erosion a lot. However this of regional differences, for example in slope, can differ much.
Global studies on the relationship between erosion and climate are indicating that erosion is the most severe in areas with an effective mean annual precipitation of 300 mm. Because when precipitation increases, plant cover is increasing also. Rainfall below 300 mm is not severe enough to create maximum erosion intensity and above 300 mm plant cover increases so fast that the effect of greater rainfall is reduced. With very high levels of rainfall erosion is probably increasing again (figure 1.4). (Morgan, 1986)

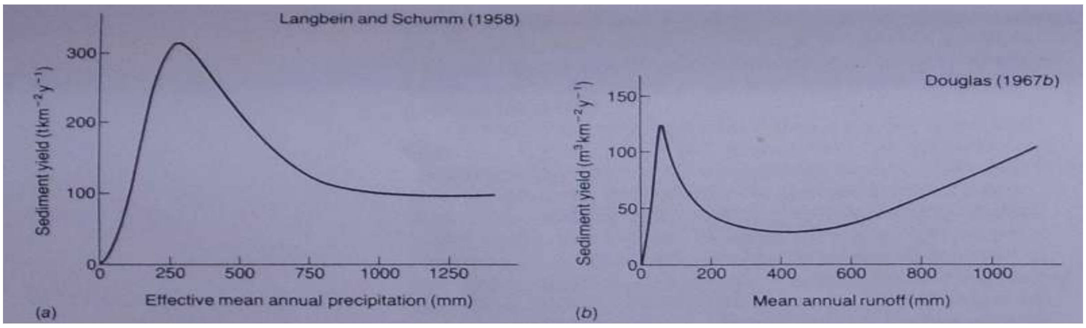


Figure 1.4 Proposed relationships between sediment yield and (a) mean annual precipitation; (b) mean annual runoff. (Morgan, 1986: p.4)

Furthermore in climatologically arid and semi-arid zones the vulnerability to erosion is very high. “The problem of soil erosion in these areas is compounded by the need for water conservation and the ecological sensitivity of the environment, so that removals of the vegetation cover for cropping or grazing results in rapid declines in organic content of the soil, followed by soil exhaustion and the risk of desertification.” (Morgan, 1986: p. 4)
The tropics are very sensitive for vegetation removal. In West Africa for example soil loss increased after removal of vegetation on open grassland savannah, dense grassland savannah and tropical rain forest for agricultural plots on slopes ranging from 0.3º to 4º. Mean annual soil loss yields increased from 0.015, 0.02 and 0.003 kg m^{-2} under natural conditions for these grounds respectively to 0.8, 2.6, 9.0 kg m^{-2} after clearance. So vegetation altering can have big influences in the tropics. (Morgan, 1986)
In figure 1.5 is presented a map of global variations in suspended sediment yield. Figure 1.5 shows that the Voi River catchment is suffering of severe erosion with mean annual sediment yield above 250 t km^{-2}. This is not so strange if you keep in mind that a big part of the plains receive only around the 250-500mm precipitation per year and most of the catchment is situated in the semi-arid tropics and therefore suffers of the problems mentioned above (see paragraph 1.2.2 for more information). (Soini, 2005; FAO-SDRN Agrometerology Group)

Figure 1.5 Map of global variations in suspended sediment yield. (Morgan, 1986: p.5)

Climate change
Climate is changing over the whole world. The exact results of these changes are not yet known. Current researches are indicating that precipitation will change for East Africa and in particularly Kenya. By influences
of El Niño the chance on occurrence of droughts increase in Somalia and Southeast Kenya, while in Western Kenya more precipitation is expected during El Niño. The rains that occur in Kenya in the short rainy season from October to December will be more heavily. (Sample, 2003; Burgers & Oldenborgh, 1999) During El Niña, which is almost the opposite of El Niño, Western Kenya will face less rainfall. For the rest of Kenya it seems to have almost no influence. (Burgers & Oldenborgh, 1999)

Concluding
The Voi River catchment is very susceptible to erosion because of the climate zone in which the area is situated. Therefore vegetation altering can have severe influences on soil loss rates. South-Eastern Kenya has probably to deal with more periods of water scarcity in the future, because of periods with less rainfall induced by El Niño. This could have devastating consequences for vegetation through which erosion could increase. For the Voi River catchment the water problem is even bigger. Because, besides the influences of global climate change, the population is also growing and there are severe problems related to population pressure on the environment. These problems are more deeply discussed in the next paragraph.

1.1.2 History of the Voi River catchment

Large parts of forests were already cut at the beginning of the 20th century, when the *Uganda railroad* from Mombasa to Kampala was made. This because the British needed wood for the railway and *white settlers* started to cultivate large plots in the fertile Sagala and Taita Hills. Big *sisal plantations* were developed at the end of the 19th century and the beginning of the 20th century. Also in the 1920s *reforestation* programmes were started, because a lot of wood was cut for the construction of the railway, clearing of agricultural plots and timber. *Woodcut* was in those days already a problem. (Soini, 2005)
Over time, the people got bigger *herds*. The *land-animal ratio* was becoming lower and pressure on pasture increased. In 1948 the *Tsavo National Parks* were founded. This had as consequence that the already under pressure standing pasture plains were becoming smaller. More animals had to graze on fewer plots, disturbing the environment. This resulted in *overgrazing* of the area. Consequences of overgrazing were *erosion*, smaller herds and *need for more land*. (Soini, 2005) Also people living inside the park were *relocated* in the Taita Hills.

In the 1960s and 1970s lots of trees were cut to make *charcoal*. This part of Kenya was one of the biggest exporters of charcoal. Nowadays charcoal is still produced, but only on small scale. Despite the reforestation programmes in the 1970s and the 1980s, the *total area of forest is still dropping*. According to Soini (2005) 37% of the forest area was cut between 1989 and 1999. Today only 400 ha of indigenous forest are retained. (Pelikka et al., 2005; Soini, 2005)

From the 1920s onwards the *population* in the area has grown rapidly. In 1948 this *growth* was even reinforced by the relocation of people outside Tsavo East. The total population of the Taita-Taveta District increased from 90,146 (1962) to over 300,000 persons nowadays. Of these people around 42,000 live in urban centres, most of them in Voi. In the hills population density follows the climatic and ecological conditions.
The *population density* varies from 150 persons per sq km in the upper highlands over 1680 m altitude to only 45 persons per sq km at the foothills. (Pellikka et al, 2005; Soini, 2005)
Around 60% of the population in Taita-Taveta District lives below the *poverty* line. Also Coast Province has a problem with providing themselves with enough *food*. Taita-Taveta District has been hit the most by this problem, however *agriculture* is the *main source of income* for most people in the Voi River catchment.
Population growth causes *increasing needs* for food, water, firewood, timber and houses. The population pressure results therefore in *shifting land use*. In search for food and income agricultural land has been expanded. Even to marginal plots or places which are totally not suited for agriculture, like steep slopes or shallow grounds. People are moving from the more humid and fertile Taita Hills to the less fertile and dryer plots on the plains, because land is still available there. This results in removal of trees and vegetation for agricultural plots. (Soini, 2005) To fulfil the local and global needs for (hard)wood, forests are cut and vegetation is becoming less.
So consequences of population pressure are decreasing vegetation and water storage and increasing erosion.

The most important urban area in the research area is Voi. The town lies, 150 km inland from the Indian Ocean, 327 km southeast of Nairobi and 159 km northeast of Mombasa. Voi lies at the highway and railway between Nairobi and Mombasa. Also the important road to Tanzania begins in Voi. The place developed from a small village to a busy junction town because it is an important pivot in the transport of goods, people and other resources between Nairobi, Mombasa and Tanzania. (Bindlos et al., 2003). There are different estimations on how many people there are living in Voi. According to estimations from 1999 there are 33,077 inhabitants. Taken into account the population growth rate of 2% for this part of Kenya, there should be living nowadays 38,000 people in Voi (Hurskainen & Pelikka, 2004; Msagha, 2004).

1.1.3 Socio-economic characteristics

Of the research area will be given a short description of the socio-economic characteristics as observed in the field. This is important to know, because this information gives more insight in the local relationships for the research into local soil erosion prevention, chapter 5.
For this description the research area has been divided in two important parts: Voi town and the rural areas.

Voi town
Voi town is in the transition area between the Swahili culture at the coast and the Kenyan-African culture more inland. The real Swahili culture as at the coast is not there, but there are a lot of Arabs living in town. So an important part of the inhabitants are Muslim, a minority is Indian, and the majority is Christian. There are a lot of mosques and churches in Voi town. The contacts between Muslims, Christians and Indians are not really well. Maybe this is also because most of the Arabs and Indians are quite rich compared to the average Kenyan. The Arabs have big supermarkets were people can get everything and therefore they are dominating the market at least in certain goods. Also they have a big loaf factory, big hotel and other important companies.

The most important families are probably from Indian descend. Some Indians have big shops and one family is the owner of Voi sisal and orange estate. This family is very rich and is also having a doctors post. Maybe they are also involved in other business, but this was not quite clear. At least they owned the estates with relatives in Mombasa who were having interests in shipping of goods.
Most Kenyans however are jobless and some have small shops, small pubs or small hotels. The Kenyans are descending of a lot different tribes, but especially Kikuyus are doing some business. Most of the Africans are living in small clay huts and live is very hard for them. Some people who have small shops are sometimes better of. Lots of youth are mining building materials like stones and sand, most of the times illegal, to make some living. Also some are working as driver or conductor on the matatus and busses. The town market is totally in hands of African who are selling here all kind of cheaper things. Also the hawkers are always from African descend.
Further a lot of truckers and businessmen are passing by. Businessmen are sometimes doing business or they are looking for a place to sleep and eat. The truckers are mostly looking for a place to sleep and eat and further to get booze and girls. Therefore quite some Africans are running hotels and places to eat and drink. Also some African girls are prostituting themselves.

Rural areas
In the rural areas are mainly living three African tribes: Sagala, Gamba and Taita. The Sagala are living near the Sagala Hills. The Sagala came down from the hills in search for more land and are now cultivating the southern parts of the hills and the foothills. They are poor non commercial small scale farmers and are living in clay huts. For cultivation they are depending on rain only.
The Gambas are mostly living on the plains and are also small scale farmers and poor. They are living also near the Voi River. Here they irrigate crops, but further away from the river they are depending on rain.
In the Small Taita Hills are the Taita living. These people have moved from the Taita Hills in search for more land. Compared with the Taita Hills they are now cultivating the less fertile lands, because of population pressure. The Taita are also small scale non commercial farmers. In the research area they are cultivating the better soils, because in that area it is raining more often. These farmers are also richer. Many farmers have stone houses and even rather big. Also they have more knowledge about farming.
Everywhere in the rural area are grazing herds of goats and cows, especially on the plains. Many farmers have besides there plots some cattle. Cattle are valued very high in society. Cattle, especially cows are seen as a kind of real estate. The consequence is that too many animals are grazing in this arid area and vegetation cover because of that is decreasing.
Another thing that is causing decreasing vegetation cover is charcoal burning and cutting of firewood. Most people in Kenya are still depending on wood as fuel. “Some 90% of the households energy needs and 75% of the total energy used in Kenya is based on wood” (Pahkasalo, 2004). Everywhere in the area people are searching for wood. Firewood is mostly used for domestic use. But some farmers are also illegally making charcoal, what they sell in Voi town to get some money. Many times this charcoal is sold to truckers who make a lot of profit on it when they sell the charcoal in Mombasa or Nairobi.

1.2 System analysis

1.2.1 Morphology of the catchment

The activity of the river system is defined by the morphology of the landscape. The position of the Sagala Hills, Mwakingali Hills and Taita Hills mountain-ranges determine the working of almost the whole catchment. From the Indian Ocean up to Sagala Hills and Mwakingali Hills the altitude of the land is increasing steadily from approximately 40 m above sea level to approximately 551.1 m above sea level near Voi (Yahoo weather, 2006). Near Voi the altitude increases rapidly. Voi is situated in the valley of the Sagala and Mwakingali Hills. The position of these mountain-ranges results in a funnel. The Sagala Hills are situated south from Voi with an average height of approximately 1100 to 1200 m above sea level and the highest peak is 1518 m. These mountains form a massive range of mountains. The hills are very steep, especially at the northern side of the range. This side is bushy and

has a lot of rock-faces. North of Voi are the Mwakingali Hills. This mountain-range exists out of some small hills and two somewhat bigger hills of approximately 1000 m above sealevel. Voi is built on the southern foothill of this mountain-range. The mountains have a very characteristic shape. The slope increases slowly from the foot towards the foothill of the top. Just before the highest point of the mountains the slope increases extremely. The tops of the hills are steep and rocky and vegetation is sparse. The southern foothill is the steepest. On this side is a lot of erosion, because there is almost no vegetation and because of human settlement. Large gullies are going through the outskirts of Voi. The gullies swept away houses and have laid water pipelines bare.The plains with an average altitude of 700 m are located behind the funnel. The plains pass into the Taita Hills, which have an average height of 1500 m with the highest peak Vuria (2208 m). In figure 1.6 the morphology of the catchment is presented. (Pelikka et al., 2005)
The Voi River takes its rise in the Taita Hills. The river is totally worn out. In the Taita Hills the river is a wild mountain river with lots of waterfalls scouring the hills. The first part of the river on the plains has mainly a sandy riverbed. Lots of sediment carried by the river from the Taita Hills has settled down here. The second part of the Voi River is less wide and the bottom is more often rocky. Along the river there is a lot of riverbank erosion, mainly caused by water that with great strength from the mountains and the plains flows in the direction of the Indian Ocean. In the national park the river becomes a sand bed where only surface water is flowing after very heavy showers filling up Aruba Dam.

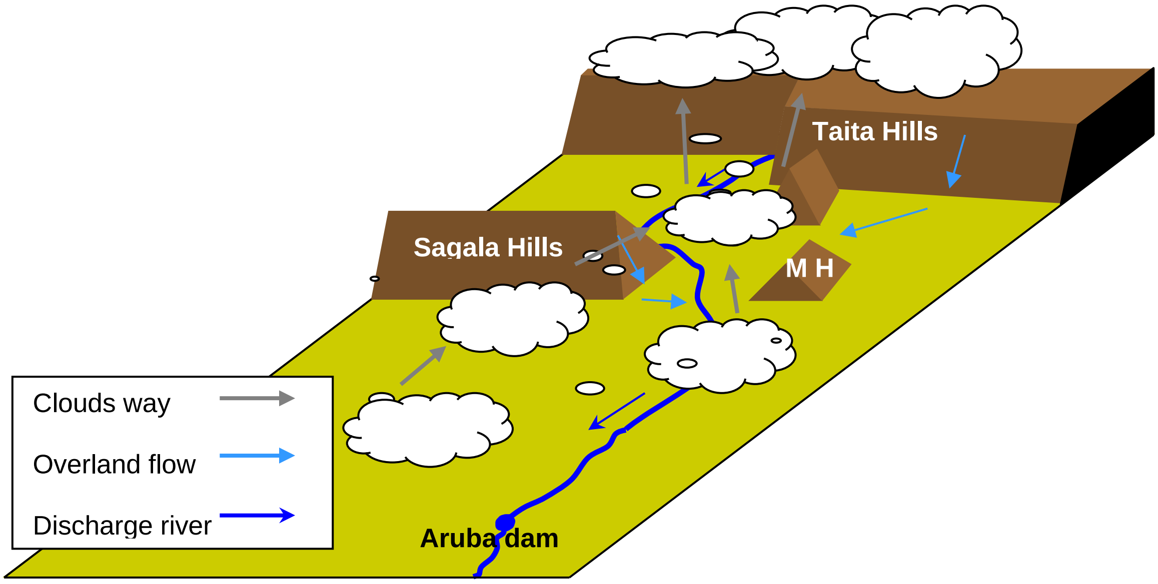


Figure 1.6 The morphology and hydraulic cycle of the Voi River schematically presented

1.2.2 Climatologically data

There are two rainy seasons, the long rains from March to May/June and the short rains from October to December. Rainfall varies widely from year to year and from place to place, especially in the lowlands. (Pellikka et al., 2005) According to Soini (2005) the catchment area can be divided in six agricultural zones. In table 1.1 the six agricultural zones are presented. The temperature data had to be estimated on data from Bindloss et al. (2003) and (Floor, n.d.). The plains around Voi belong to the semi-arid zone of East Kenya in which temperature ranges between 20 to 40 ºC (Bindloss et al., 2003). Temperature decreases with increasing height; as fist rule can be taken 6.5 ºC per 1000 m (Floor, n.d.). The climate class given to the zones is based on Koeppen's Climate Classification. Koeppen distincts five climate zones: A (Tropical), B (Dry), C (Temperate), D (Cold) and E (Pole). The semi-arid plains with rainfall around 250 mm belong to the dry climate zone (B), subgroup semi-arid (S), and biome is savannah. The mean annual temperature is above 18 ºC, so the subcode h is added. The climate zone is BSh. (FAO-SDRN Agrometeorology Group, 1997)

The hills belong to a more tropical zone (A), with more rainfall, cooler temperatures and endemic forests. Furthermore the hills are influenced by a dry season in the monsoon cycle (m). So the hills belong to the climate zone Am. (FAO-SDRN Agrometeorology Group, 1997)

Table 1.1 Climate information of the Voi River catchment. (Soini, 2005; Bindloss et al., 2003; FAO-SDRN Agrometeorology Group, 1997; Floor, n.d)

Zone	Height (m)	Precipitation (mm)	Temperature (min. and max. in ºC)	Climatologic class
Pasture/plain zone	<790	250-500	20-40	BSh
Livestock-Millet zone (Hills)	790-980	480-700	18.7-38.7*	Am
Marginal cotton zone (Hills)	910-1220	600-800	17.4-37*	Am
Sunflower-Maize zone (Hills)	1220-1520	700-900	16.5-36*	Am
Marginal coffee zone (Hills)	1370-1680	900-1200	15.5-34*	Am
Wheat/Maize-Pyrethrum zone (Hills)	>1680	1200-1500	13.5-30*	Am

**Temperature data has been estimated, because there is not much data available on temperature.*

1.2.3. Hydrological cycle

Most of the precipitation in the Voi River catchment is coming from the Indian Ocean. Water evaporates above the Indian Ocean because of the heat of the sun. The steam is forming clouds which are driven by strong winds to the mainland of Kenya. There the heavy clouds hit the land and they have to climb, which results in rainfall. From thereon the clouds can easily flow in the direction of Voi. When the clouds are reaching Voi they are blown by very strong winds trough the funnel of Sagala and Mwakingali Hills. The clouds that do not fit anymore have to rise for these hills, especially for the Sagala Hills, which are also situated more to the Oceanside. Sagala Hills and Mwakingali Hills are receiving therefore quite a bit of precipitation, but the latter not as much as the first. The clouds, when they are blown through the funnel or over the hills, enter the planes. Here are often strong winds (wind speeds of 176 km/h are not uncommon (The Weather Underground, Inc., 2006)), because of the influence of the funnel and winds falling down from the mountains. The clouds are than driven to the Taita Hills, which form a barrier. The clouds have to rise at least approximately 800 m. Therefore the Taita Hills receive a lot of rain (see table 1) and are the main water catchment.
After precipitation a part of the water infiltrates into the ground, evaporates, or is intercepted by plants, but most part is flowing over land towards the Voi River. Because vegetation is decreasing in the catchment area (see paragraph 1.1.2) overland flow is causing a lot of soil erosion, especially on and near mountains. This results in rill and gully erosion. The Voi River carries the water, not evaporated or used by men, plants and animals, from the Taita Hills towards the Indian Ocean. In the rainy season the river floods often, causing a lot of damage to houses, trees, crops and plots by taking the fertile topsoil or sweeping parts away. Also a lot of sediment settles down on the plots, decreasing the fertility of the ground. Most of the time however, the river dries up near Aruba Dam, inside Tsavo East National Park. At the end of August and September the river is often dry.
Inside the park behind Aruba Dam, the area is becoming like a dessert. Severe droughts, fires and elephants have killed all the trees and all the grasses that where growing in the area behind Aruba Dam. Some decades ago big acacia forests where growing here still (Blijderveen & De Vries, 1993). On the moment especially elephants are destroying the trees that are left, looking for food. Water storage has become a problem in this area. The hydrological cycle is influenced resulting in less rain by evaporating and warming up of the area, because vegetation has been destroyed (ENS, 2006).

1.3 Problem analysis

The problem has been analysed with an RRA tool (see chapter 2), namely a Flow Diagram. In Appendix I is standing the Flow Diagram with all the main parameters influencing erosion and water storage. Of that Flow Diagram has been made a diagram which summarizes the problem to the core variables (figure 1.7).
The arrows explain the relationship between the variables. A summation sign means that if there is more of the variable the arrow is coming from this will increase also the other variable. A minus sign means the opposite, hence if there is more of the variable the arrow is coming from, there is less of the variable the arrow is heading to.

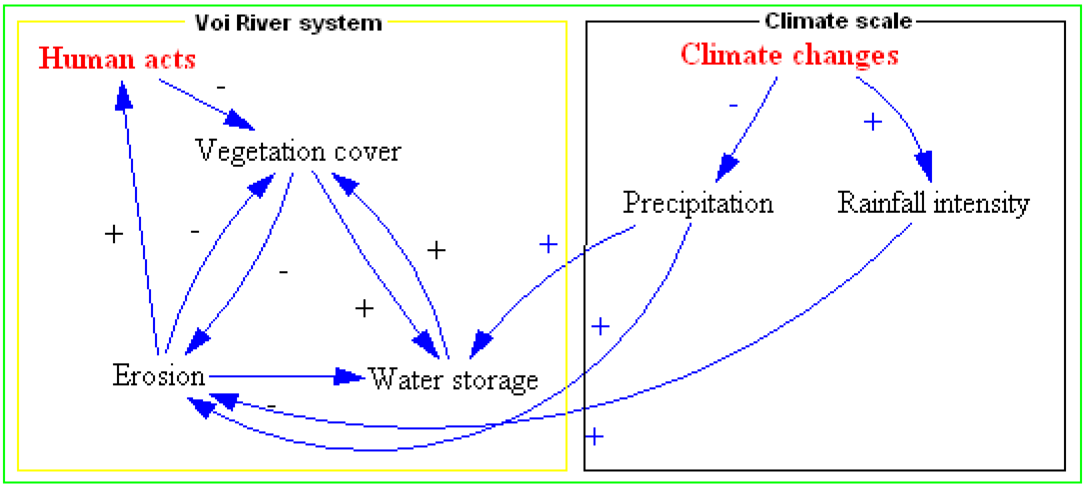


Figure 1.7 Flow Diagram of the main variables influencing erosion.

According to De Graaff (1993) are especially climate changes, human action and inappropriate agricultural technologies causing erosion in general by affecting soil, vegetation and water resources. The main problems for the Voi River catchment are also climate change, human activities and inappropriate farming techniques (see paragraph 1.1 and figure 1.7). Population pressure is causing land use change and the use of inappropriate farming techniques. From paragraph 1.1.2 it becomes clear that the main problems related to population pressure are deforestation and overgrazing. Climate change results probably in more periods of droughts for Kenya. (Sample, 2003; Burgers & Oldenborgh, 1999) Although climate change is a severe problem for the environment of the Voi River catchment, it is difficult to influence, because it is a worldwide problem. Problems related to human activities can be influenced better. Therefore a distinction has been made in figure 1.7 between variables that are caused also by influences from outside the catchment system (climate scale) and variables that have their origin in the Voi River catchment (Voi River system).

Climate change is causing less rainfall and will increase the rainfall intensity in the research area in the future. In figure 1.7 this is schematized with a negative relationship between climate change and precipitation and a positive relationship between climate change and rainfall intensity. The effect of less precipitation is that water storage will go down, because there is less water available for vegetation, resulting in dying of plants in which water can be stored. The area will become more susceptible to erosion, because vegetation cover will decrease.
The relationship between precipitation and erosion (seen absolute) causes that more erosion will occur when it is raining more, because there will be more rain splash erosion. But because vegetation cover will increase also and water storage too, this effect will be minimal.
The increase in rainfall intensity in the future will cause more erosion. Because if the intensity of rainfall is higher, water has less time to infiltrate so that runoff occurs sooner and also rain splash erosion will increase. Less rainfall combined with more intense rainfall is therefore causing more severe erosion. The described relationships in this paragraph are also presented in figure 1.7.

The need for space and resources for human activities as agriculture and firewood are causing that people are removing vegetation. Because of this vegetation cover is decreasing despite vegetation is very important. Because plants and the roots of plants ensure rainfall infiltration, restrain seed supply and seed growth, and diminishes the effect of water erosion. Because of the removal of vegetation for human activities the soils get bare. These soils will get very hard by the sun and are susceptible of erosion. By rain these grounds suffer rain splash erosion, compaction, overland flow and removal of the organic top soil. Water can not be stored well and soil moisture is going down. In figure 1.7 this relation has been presented with the negative link between human activities and vegetation cover. (Sirviö et al., 2004)
A cause of deforestation in the area is that too little water can be stored. In the rainy seasons the rainfall can be very heavy. Because there is almost no storage capacity, the morphology of the area makes water rushing from the hills and the plains towards the Voi River, causing a lot of damage, flooding, and severe (gully) erosion. Erosion even exaggerates this process by increasing runoff capacity and destruction of vegetation cover. So, less water is available for vegetation and domestic and agricultural use. (see paragraph 1.2). If there would be more storage capacity, for example sand storage dams and trenches, it is possible to decrease the effects of erosion. More water storage results also in more water for nature and people, hence an increase in vegetation cover. In figure 1.7 this is presented with the links from vegetation to erosion and the links between vegetation and water storage and the links between erosion and water storage.
Other consequences of erosion (and shortage of water storage) are devastation of roads, constructions, bridges, plots, and silting of rivers. Especially agriculture and cattle breeding are suffering from the effects of soil erosion. The farming plots are decreasing in quantity and in quality. The gullies are going straight through plots and the water takes the fertile ground with it. Therefore pressure on land becomes even higher, because yields are going down. Erosion causes therefore that more forests need to be cut for agricultural plots so that people keep good yields and the cycle goes on. Besides this population growth is strengthening the cycle because it is already causing that more land is needed and that there are more human activities. The core of this cycle is schematized in figure 1.7. In Appendix I is standing a Flow Diagram of the most important sub-variables and Cause Trees for erosion and water storage.

In figure 1.8a the situation is schematized as it is under present developments (Westerveld & Van Westerop, 2002). Present developments result in the long term in desertification. Vegetation is reduced, erosion is severe and water storage is limited. Almost all the precipitation falls in the Taita Hills and not on the plains. (Westerveld & Van Westerop, 2002)
In figure 1.8b the desired situation by WCT is presented. Vegetation and water storage are restored and erosion is negligible. Desertification is stopped, because plants have water again and a stable ground to grow in. WCT tries to reach this outcome by building dams in the Voi River, which can store water and sediment and by trenching the surface, so that water can be stored in the field and erosion can be stopped. (Westerveld & Van Westerop, 2002)

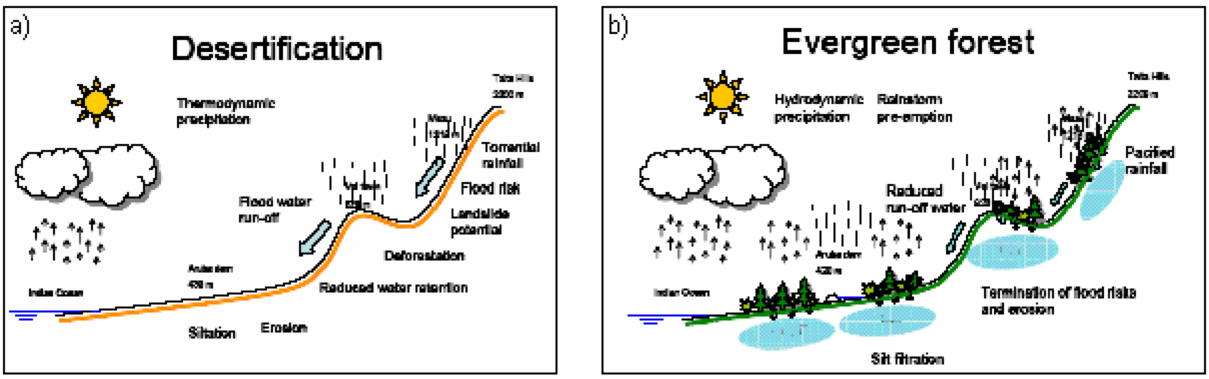


Figure 1.8 The present situation leads to desertification (a). However the objective is an evergreen area (b). (Westerveld & Van Westerop, 2002)

The key problems in the Voi River catchment are human acts causing deforestation and vegetation removal reinforced by climate changes causing more droughts and decrease of vegetation cover. The consequences of a decrease in vegetation cover are an increase of erosion and a decrease of water storage capacity. The goal is to develop a plan that can contribute to get the desired situation presented in figure 1.8b.

Problem definition
The problem in the Voi River catchment is that the capacity of water storage is too low and erosion too high because of decreasing vegetation cover.

1.4 Objective and research questions

The purpose for this research is to make a preparatory study on erosion. There are several objectives. The first objective is to map which places are eroded or are vulnerable for erosion (erosion hazard assessment). The second objective is to determine how soil conservation has been rooted in the socio-economic structure of the communities. The third objective is to make recommendations for soil conservation based upon the outcomes of the other two objectives. This results in the following overall objective:

To give recommendations on soil conservation measures for a part of the Voi River catchment based on an erosion hazard assessment and data on how soil conservation is rooted in the socio-economic structure of communities, obtained by field measurements, interviews and observations.

The objectives are chosen in this way, because before it is possible to give recommendations on soil conservation measures needed (objective 3), it is important to know some technical and social data. First of all it is important to know which areas are eroded and which areas are susceptible to erosion and by what kind of erosion. With this data it is possible to determine how severe erosion problems are what kind of technical solutions are possible etc (objective 1). However before recommendations about technical solutions can be given, it is wise to know what local people are doing to prevent erosion, what their motivation is, and what their capacities are to prevent erosion. The recommendations have to be formulated in such a way that local people support them, can use them and bring them into practice. So it is important to take local knowledge and competence into account (objective 2). Therefore information is needed about if the people think that erosion is causing them problems, what the motivation of people is to prevent erosion, and what the capacities of the people are to prevent erosion. With this information and the technical information it is possible to make good recommendations about soil conservation measures taken local circumstances into account, i.e. recommendations adjusted to local motivation and capacities. In this way it is possible to avoid failures because there has not been paid attention to local conditions. As research group has been chosen farmers (men and women), because it was easier to interview them and also a big part of the research area is agricultural land, so that a lot of erosion already can be excluded if there is no erosion on the plots. In Voi erosion was also severe, but it was not possible to speak to important people who could play a major role in soil conservation, so that the effectiveness of soil conservation here would be less.
The research questions are formulated in such a way, that the overall objective can be reached. The main question can only be answered if the first (erosion hazard assessment) and second objective (knowledge about local soil erosion prevention) are reached. The main question therefore is needed to reach the third objective and is based on sub-question 1 and 2. Sub-question 1 is linked to the first objective, to make an erosion hazard assessment and sub-question 2 to the second objective.

The main research question derived from the objective is:

What are the recommendations for soil conservation taken into account the erosion risk of areas and socio-economic characteristics of erosion prevention by local communities?

The sub-questions are:

1. What is the erosion risk of sub-areas in the research area?
    a. Which areas are susceptible of erosion in the Voi River catchment?
        i. Which parameters are needed to investigate the susceptibility of areas for erosion in the Voi River catchment?
        ii. What are the measurements on the parameters indicating regarding susceptibility of areas for erosion?
    b. What is the erosion intensity in the Voi River catchment?
        i. Which parameters give an indication of the severity of erosion in the Voi River catchment?
        ii. What are the measurements on the parameters indicating regarding severity of erosion in eroded areas?
    c. What kind of erosion is affecting the eroded areas?
    d. How are the different parameters in the erosion risk assessment rated?

2. To what extent is erosion control actively practiced by local farmers?
    a. Do local farmers regard soil erosion as a problem?
        i. What is the overall perception of erosion by the sample group?
        ii. Is there a difference in perception of erosion between men and women?
        iii. Is there a difference between perception and observations on erosion?
        iv. What is the difference in perception of erosion between the different sub-areas?
    b. What is the motivation of people to prevent soil erosion?
        i. Do the people want help for taking soil erosion measures?
        ii. What are the experiences of Westerveld Conservation Trust to make communities active in soil erosion prevention?
    c. What are the capacities of local people?
        i. What are the farmers doing themselves to prevent soil erosion?
        ii. Do the local people maintain the soil conservation measures?
        iii. Have local farmers organized themselves?
        iv. Is their labour division between men and women in farming work?

Book-mark
In chapter 2 is described which methods are used to find answers on the research questions and why these methods are used. In chapter 3 information about the theory of erosion has been presented to give the reader more insight in the mechanics and processes of erosion by water and the types of erosion. Especially gully erosion is discussed well, because it plays such an important role in the measuring method for determining which areas are eroded.
The sub-questions 1 and 2 are answered in chapters 4 and 5. The questions under sub-question 1 are answered in chapter 4. Sub-question 1a has been answered in paragraph 4.1. Here is explained which parameters are used to measure erosivity and what the results are of the measurements. In paragraph 4.2 has been described with which variables erosion intensity has been measured and what the measurements are indicating. Paragraph 4.3 discusses sub-question 1c. In this paragraph observations about types of erosion are presented. In paragraph 4.4 is the rating for the erosion hazard assessment described (question 1d). Sub-question 1 is also answered in this paragraph, because the erosion risk of every sub-area has been determined. In paragraph 4.5 are the results of the study critically discussed.

In chapter 5, sub-question 2 has been answered. In paragraph 5.1 the research is divided in several sub-areas. This has been done because in these areas are different tribes living and the morphologic characteristics of the area are almost the same. Sub-question 2a has been answered in 5.2.1, sub-question 2b is answered in 5.2.2, and sub-question 2c in 5.2.3. In 5.2.4 is given an end conclusion about Opportunity, Motivation and Capacities of the local farmers in soil erosion prevention.
In chapter 6 the main research question is answered. The knowledge of chapter 4 and 5 is combined in this chapter. The first paragraph gives an overview of kinds of soil conservation measures. In paragraph 6.2 soil conservation recommendations in general for the whole research area are discussed first and after that per sub-area. In the last chapter, chapter 7, the conclusions are presented and some recommendations are given for further research.
In this report a glossary of key-terms has been included also. All the important terms of this report are defined in the glossary.

Figure 1.9 Landscape near Voi. Sisal estate and mountain-ranges.

2 Method

The methodology used for this study is Rapid Rural Appraisal (RRA) combined with some indication measurements. This is a methodology developed for social studies which later on developed to a very common approach for combined studies, i.e. social-technical studies. In the first paragraph will be explained what the methodology and the tools are. In the second paragraph will be explained for what purposes the tools are used. In the last paragraph will be explained how the fieldwork has been conducted.

2.1 Rapid Rural Appraisal

RRA methodology has been created by social sciences to get quick accurate analyses of the complexities of systems (Hettema, 2004). Nowadays it is used for a lot of researches in social sciences and in combined social and technical sciences. It is used widely in developing countries for pre-project exploratory work, the selection of appropriate sites and target groups, implementing development actions and so on. (Hettema, 2004)
RRA, just as Participatory Rural Appraisal (PRA), recognizes that development success can be best obtained by making use of the indigenous knowledge and expertise of rural people (Euroconsult bv/WAPCOS, 1996).

RRA is a semi-structured process carried out in the field to acquire quickly new and accurate information. Fundamental for the approach of RRA is triangulation and optimal ignorance. Triangulation is “the use of several different sources and means of gathering information” (Hettema, 2004: chapter 3; p.12.). The goal of the use of multiple techniques is to get a “(…) progressively accurate analysis of the situation under investigation” (Hettema, 2004: chapter 3; p.12.). Optimal ignorance is: “(…) the amount and the detail of information required to formulate useful hypotheses in a limited period of time are regarded as expenses to be kept to a minimum” (Hettema, 2004: chapter 3; p.12.). The five key features of RRA are:

1. iterative;
2. innovative;
3. interactive;
4. informal;
5. in the community.

RRA is iterative, because interviews are held with different people in an area after each other. In that way it is iterative. It is not based on the answers of one person. This makes sure that all kinds of facets are taken into account of the local circumstances. Also RRA is iterative, because it uses triangulation. In this research it was sometimes quite difficult to triangulate everything, because of lack of literature, but overall triangulation was quite well. It is iterative, because literature, observations and interviews are all used to get data about one topic. In this way it is possible to check the accuracy of data.
RRA is innovative, because for every area it is needed to use another research approach. Cultural differences or geographic differences causes that you have to do things differently. Also all kinds of data gathering tools can be used. So there is a lot of development in tools. For this research for example a lot of quantitative indicators are used (slope, soil texture, infiltration rate), which is not very common in RRA.
This method is interactive because interviews are held with local farmers. So there are important contacts between the interviewees and the researcher. The method is also interactive because the researcher observes in the field what people are doing and what is happening in the area. Strength of these contacts is that local knowledge is taken into account. A weakness on the other hand is that only a small group is interviewed, so that it is possible that there is a lot of bias in the answers. But this bias is tried to avoid with triangulation and other mechanisms as not using leading question etc. Another weakness is that a researcher can interpret things wrong what he observed in the field. It is easy for a

researcher to pay only attention to the things he wants to see. This bias can only be excluded by staying critic and to let other people judge about your findings.
RRA is done partly in the community, because interviews are done and other measurements are done in the field. But except for interviews, fieldwork is carried quite indirect in the community. For research you are going through the area and it is possible to observe the people and area, but most of the time local people are not needed to lead you round. This is however not directly bad, but contacts with the community are sometimes a little indirect. Therefore it is more difficult to get indigenous knowledge.

2.2 Data gathering tools

The main data collection techniques, used in this research, are: secondary data review, direct observation, semi-structured interviews, ranking, and diagrams.

Secondary data review
To get insight in research that was already conducted on erosion and other related topics and to know something of the background of the research area. It is also used for getting insight in methodologies, conducting erosion studies and fieldwork. Data has been obtained from published and unpublished documents, project reports, survey results, maps, satellite images, photographs, travel books, and news papers.

Direct observation
"Direct observations encompass any direct observation of field objects, events, processes, relationships or people that is recorded by not or diagrammatic form" (Hettema, 2004: chapter 3; p.19).
Direct observations have been used for getting technical and social data. Observations are done on land capability classification, land use, morphology of the area, plant cover, gullies, which kind of erosion is responsible for gullying, effects of erosion on society, farming methods, erosion prevention by local communities, differences in farm work between men and women, crops cultivated, and socio-economic differences between areas and people.

Semi-structured interview
For the research, interviewing local people was very important. The interviews were conducted in informal, conducted interview sessions. The basis of each interview was the same. But if the answers were interesting further question were asked. The interviews have mostly been conducted with individual farmers, men and women. Much attention has been paid in the way interviews were done, so that bias as much as possible could be prevented. Bias is important to avoid, because bias can cause that the results of a research are totally different from the circumstances in reality, because people give wrong answers on purpose to protect their own goals. So it is important to avoid answers that are not true. This is very difficult but by using some techniques you can at least try to avoid as much bias as possible. Therefore logos, writing blocks or leading questions were not used. Also the purpose of the visit was kept as vague as possible, because else the people would only give the answers you wanted to hear. The farmers have been chosen at random. The objective was to get 3 farmers, men and women, per 16 km^2, but in some sparsely populated areas only 2 was feasible. Because it was more difficult to get women than men, it was tried to get one third of the interviewees women.

Ranking
Ranking has been used in the semi-structured interview sessions to get insight in the priorities of farmers regarding their five most important problems in farming. First farmers were asked what the five major problems for them were in farming. After that they were asked to rank them in order of priority.

Diagrams
"Diagrams are simple, schematic devices which present information in a readily understandable visual form (Hettema, 2004: chapter 3; p. 32)." Maps are the diagrams that are used the most in this study. Of observations done in the field regarding land use, gullies, water flow directions, slope and land capability classification, has been made maps. Also a Flow Diagram has been made to get more understanding of the causes of erosion and water storage decrease.

Indicators
Indicators are "events, processes or relationships which are easily observed or measured but can be used as an indicator of some other variable that is more difficult or impossible to observe." (Hettema, 2004: chapter 3; p.20) Quantitative indicators are not directly an official RRA tool, but are also not uncommon. According to Hettema (2004) quantitative measurements are not done in RRA studies. But because data on slope and soil characteristics were needed for determination of which soils are vulnerable for erosion, some indicative measurements have been done. For cross checking contour lines on the topographic map, slope measurements have been done ad random at several places in the research area. Also ground samples and infiltration tests have been conducted to know some soil characteristics. At random around 3 tests have been done per 16 km^2. So the quantitative measures are still only an indication.

2.3 Methods

2.3.1 Methods used for erosion hazard assessment

The objective (paragraph 1.4) of this research is to give recommendations on soil conservation measures in the research area. Because there was totally no information available about erosion in the research, it was needed to carry out an erosion hazard assessment (Morgan, 1986). Therefore first data was needed about how severe the area was eroded and which areas were susceptible to erosion. Normally this research is done by using aerial photographs of the area on which can be seen where the gullies are, how deep they are, how steep the slopes are etc. (Morgan, 1986; Sirviö, Rebeiro-Hargrave, Pellikka, 2004; Sirviö, Rebeiro-Hargrave, 2004) Of these photographs are made maps with the risk areas on it. The findings are checked in the field by doing random checks. In this research aerial photographs were not available, so that the only way in which it was possible to map the eroded areas and the areas susceptible to erosion was by mapping everything in the field.
Other methods, in particular the Universal Soil Loss Equation (USLE), could not be used, because they all rely on the information gathered in this research and more data which was not available. The latter was the reason why these methods were not possible to use. The extra data needed for USLE and other methods was not possible to measure or to obtain during the research because of lack of equipment, time and certain required weather conditions like rain etc. Also USLE and other methods are used more for modelling or design of structures than for studying erosion risk. That is why it was justified to use this method.

The erosion hazard assessment is based on tools presented by Morgan (1986), i.e. drainage density, drainage texture, land capability classification, slope and rainfall aggressiveness. More information on these tools is standing below. Of each tool it has been determined if it was feasible to use them, taken into account fieldwork conditions and time. It was not possible to obtain good weather data of the research area, because there was only a weather station in Voi. The weather data of this station does not reflect the weather well of the morphologic divers area. Data of this station could only be used for the area in the vicinity of Voi. Therefore it was not possible to use tools related to weather data. The indicator tools used in this assessment can be divided in two types, i.e. erosivity tools and erosion intensity tools. The tools used for erosivity, or susceptibility of areas to erosion (question 1a), are slope, rainfall aggressiveness, difference between present and recommended land use, soil texture, and infiltration rate. For erosion intensity (question 1b) are used drainage density and drainage texture.

Erosivity
Erosivity is used for determining regional differences on macro and semi-detailed scale in susceptibility of areas to erosion. By measuring erosivity it is possible to answer question 1a. The indicators used to measure erosivity are slope, rainfall aggressiveness and land capability classification.

Slope
Slope is taken as indicator because "erosion would normally be expected to increase with increases in slope steepness, and slope length as a result of respective increases in velocity and volume of surface runoff." (Morgan, 1986: p. 56) Slope steepness has been measured with a Sola slope measure as presented in figure 2.1. This tool exits of a stick at which is connected a spirit level fixed to a graduated arc. If the spirit level is turned horizontally, it is possible to reed the degree of the slope of the graduated arc.
This tool has been used by placing it on an average slope with an average length. These aspects have been observed on sight. The slope was measured at least at every very important slope change. If the slope was increasing or decreasing very fast it was measured. Especially when climbing a hill it was important to measure the slope many times, because here slope was changing rapidly. On the plains was measured around every 800m during a trip at least. This can be seen very well on the slope maps in Collective Appendix, Maps, type B. The routes followed in the field can be seen well. It has been tried to walk through a grid in such a way that of every area an indication of the slope was obtained. Observations about slope were also very important. In the field much time was spend at observing differences in slope. If there were big differences, it was tried to measure these. But for many hill parts, especially the peaks it was not possible to measure them. Here the slopes have been calculated with the help of a contour line map of the American army. In between the different contour lines have been calculated the average slope by using the difference in height between the line and the horizontal distance between the lines. With geometry it is possible to calculate the average angle and slope. The contour lines of the map and the calculated slopes are also presented in Collective Appendix, Maps, type B. Sometimes there was a difference between the slopes measured in the field and the calculated slopes on the map, because the calculating is an average. Than it was tried to use observations of the field to determine to which point the measurements were valid and from which point the calculations. In this way it was possible to make quite precise slope maps.

Figure 2.1 Sola APN, slope and angle measure device. (Sola-Messwerkzeuge GmbH, 2004)

The slope maps are used as indication of areas susceptible to erosion. The slope classes are used as an indication for erosion risk for the areas. A high degree slope is more vulnerable to erosion than a level slope, because water is running faster and soil loss is more severe (Morgan, 1986). In this way it was possible to indicate areas with great erosion risk according to slope.

Rainfall aggressiveness
Rainfall aggressiveness is expressed by the ratio p^2/P, with p the highest mean monthly precipitation and P the mean annual precipitation. Rainfall aggressiveness is the most commonly used index to get an idea of the intensity of rainfall and the protection of the soil by plant cover, because in the dry season for example the plant cover decays. Only weather data on monthly maxima could be obtained of Voi weather station, because this is the only weather station in the whole research area. Hence only

one ratio could be calculated for the whole research area. This gives only a very rough indication, because it rains a lot more in the Taita Hills. Rainfall aggressiveness is a good indicator for the risk of gully erosion (Morgan, 1986).

With the data on rainfall aggressiveness it is also possible to calculate soil loss for the research area. The relationship is as follows:

$$\log(Qs) = 2.65\log\left(\frac{p^2}{P}\right) + 0.46\log(H)(\tan S) - 1.56$$

With:
Qs: mean annual sediment yield [g m^{-2}]
p: highest mean monthly precipitation [mm]
P: mean annual precipitation [mm]
H: mean altitude [m]
S: mean slope of the basin [m]

Soil loss is determined by using the data on rainfall aggressiveness and by calculating the average slope and average height of the research area. The average slope has been determined with the slope maps made in the field (Collective Appendix, Maps, type B). Of each slope class has been determined how large the area was on the maps covered by these slope classes. Of the classes was taken the average. The average of the slope class and the area covered by each class have been multiplied and summed. The total of all classes summed have been divided by the total size of the research area, which gave as result the average slope of the research area. The same procedure has been followed for height.

The data about soil loss and rainfall aggressiveness are tried to compare with data from other parts on the world, so that it is possible to conclude of the values are high or low, which give information about the risk of erosion for the areas according to rainfall aggressiveness and sediment yield.

Difference between present and recommended land use

The difference between present and recommended land use is very important to investigate. Especially if you take into account that most of the erosion problems in the area are caused by human activities.
Therefore maps have been made of the present land use in the area. These maps can be find in Collective Appendix, Maps, type A. In the field land use has been mapped, by drawing maps with land use on it from hilltops. For these drawings a compass has been used to determine the position of the different land uses. With the compass it was possible to determine at which angle the spot was compared with the point from which the measurement was done. When this line was known it was possible to estimate at which position the spot was from the drawing point. The maps are validated in the field. The points where measured again with the compass. The tops of three hills were used to determine the point we were standing. On the map the points of these tops were known, so that is was possible to determine the point quite precise. In this way it was possible to record all types of land use.

In the field has been determined what the present land use was by doing observations. In Collective Appendix, Maps, type A, is for every 16 km² precisely mapped what the present land use is and what the recommended land use is according to the United States land capability classification system (Morgan, 1986). The United States land capability classification system recognizes eight different classes. The first four are in decreasing measure suitable for agriculture and cattle keeping. The classes five up to and including eight are unsuitable for cultivation. Grazing and forestry is only under strict conditions possible. The classification of the lands has been done by doing observations in the field paying attention to the factors mentioned in the land capability classes table (table 1), which stands in Collective Appendix, Land Capability Classification tables. In the field is tried to classify the area under investigation to the descriptions of table 1 and by estimating the ground layer thickness and determination of tillage conditions, erosion, and slope and using the descriptions of table 2, Collective

Appendix , Land Capability Classification tables. Table 3 of Collective Appendix, Land capability classification shows how the capability classes were determined in the field.
Ground layer thickness could most of the times be determined by using the depth of gullies and the descriptions of table 2, Collective Appendix, Land capability classification. If a gully was deeper than 1.5 m the ground was deep. If a gully was not that deep, the rock bottom was most of the times also visible so that the thickness of the ground layer was easy to measure. If there were no gullies, ground layer thickness was not possible to determine, but this happened only a few times.
Tillage conditions were determined by looking at the soil and the descriptions of table 2, Collective Appendix, Land capability classification. If the soil was crusted by the sun, tillage conditions were not really good and the tillage factor was t1 or t2. For determining which factor it was, water was used. If the ground would become like concrete, it got tillage condition t2. If the ground would only compact, the soil got t1.
The erosion factor was determined in the field with the descriptions of table 2, Collective Appendix, Land capability classification. Erosion factor 1 was given when there were no or almost no signs of erosion visible. Erosion factor 2 was given for moderate erosion; moderate loss of topsoil and some dissection by run-off channels. Factor 3 means severe erosion: severe loss of topsoil and marked dissection by gullies. Factor 4 was given to areas suffering of very severe erosion that had complete truncation of the soil profile and had deep and intricate dissection by run-off channels.
The land capability classes can be found in Collective Appendix, Maps, type B.

For determining the difference between present and recommended land use, the maps for present land use and recommended land use were put on top of each other. The differences in present land use and recommended land use were coloured red. In this way it was possible to determine exactly which areas were vulnerable to erosion.

<u>Soil texture: particle size distribution</u>
Important for erosion characteristics is the resistance of soils itself, because particle size, humus content and so on determines the resistance of a soil to erosion. According to Morgan (1986) soils with particles in the range of 100 μm to 300 μm are most erodible by overland flow, which is presented in figure 2.2. According to Craig (2004) 100 μm to 300 μm is in the range of fine to medium sands (figure 2.3). To know the characteristics of the soils in the research area soil samples are taken, at least 3 per 16 km². The soil samples are tested on their particle size distribution with a test described by Van der Sluijs & Locher (1990). First the bonding of the soil particles has been crushed, by smashing the soil into small pieces, so that there were no big parts of soil in the sample anymore. The soil sample was put in a glass with water with a volume of 25 cl. Approximately 3.5 cl of the glass was filled with the soil sample and around 20 cl of water was added. The soil is mixed with water. After stirring, after one hour and after 24 hours sedimentation is measured, indicating respectively percentages sand, loam, and clay. With these data the soils have been named according to the *British Soil Classification System for Engineering Purposes* (Craig, 2004).
Also the compactive state of soils is determined in-situ by doing visual inspection of the soils and testing of clay soils with the fingers (Craig, 2004). Stiffness, or maybe it is better called physical behavior of soil under wet conditions, has been determined differently. During testing it became clear that soil samples were behaving very differently after the sedimentation test of Van der Sluijs & Locher (1990) as described above. One soil was like fluid when it got wet and another one was still compact. Because there was an assumption (one soil sample was of a heavily gullied area and another one of a normal area) to believe that this behavior also could explain why some areas were gullied, tests were done. The soils have been tested if they were stiff or soft. This was done after the sedimentation test and it was tested if it was easy to get the soil out of the glass in which the sample was tested. Because it was observed that some soils became liquid and other soils remained their strength. Soils were called very soft if they flooded out of the glass and soils were called firm if they stayed in the glass and almost did not move, even when turned up side down. Soils showing behavior in between were called soft. The reason why this test could be used is that the assumption was that soils in areas that were eroded very much, were more easy transported by water than soils in areas were gullying was not so severe, however other conditions as vegetation cover etc. were the same. It was very strange to see, as presented in chapter 4, that areas were gullies were very big (Taita Hills

grid 7 & 8, Collective Appendix, Maps, Type D) the soil samples were easy to flush away and were very soft. Because of restricted equipment it was not possible to find theoretical explanations for these findings, but in this research the results were good.

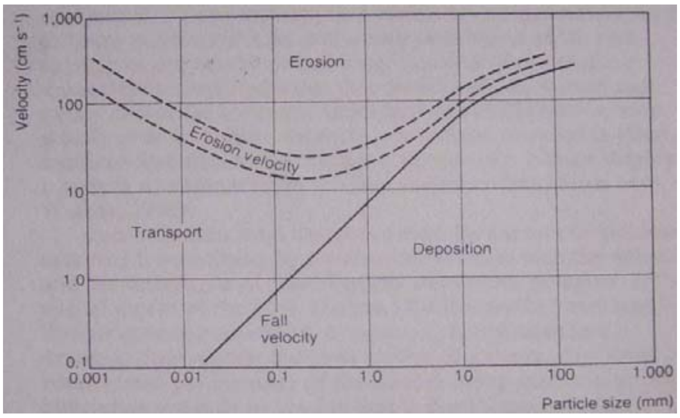


Figure 2.2 Critical water velocities for erosion, transport and deposition as a function of particle size. (Morgan, 1986: p. 22)

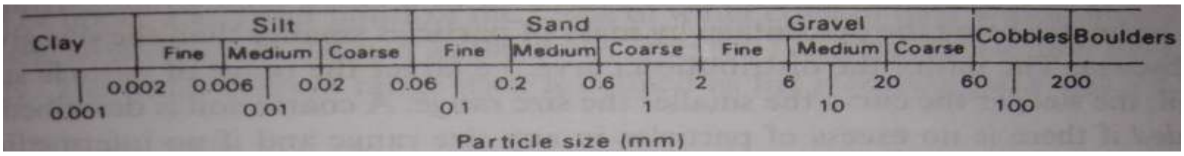


Figure 2.3 Particle size ranges. (Craig, 2004: p. 5)

<u>Infiltration rate</u>
Infiltration rate was important to measure, because it is determines weather runoff is likely to occur or not. Runoff cause erosion, because soil particles are taken with the running water. Infiltration capacity is very difficult to measure and quite inaccurate. According to Morgan (1986) tests with infiltrometers had sometimes coefficients of variation of 70 to 75%.
The infiltration capacity of the soils has been measured with a 12.5 mm water head test in the field, based on the United States land capability system (Morgan, 1986). A plastic tube was put into the ground without disturbing the soil. Because of the hard crust on most of the soil this was very difficult. Therefore it was most of the times difficult to place the tube deep enough in the soil, causing a slight error. A water head of approximately 15 mm was placed on top of the soil by pouring gently some water on top of the soil. The time it took for the water to infiltrate has been measured.
Because of lack of equipment it was hard to do good tests. It was tried to make the tests as accurate as possible, but in reality the tests carried out were not of real good quality because the soils were very hard and equipment was not good enough.

Erosion intensity
Question 1b is measured by measuring erosion intensity. Erosion intensity is used in macro scale generalized assessments of erosion risk. Because this research is a pre-study and the research area is 128 km^2, it was possible to use this parameter. The indicators for erosion intensity are drainage density and drainage texture. "Drainage density is defined as the length of streams per unit area (km streams per km^2). Drainage texture is defined as the number of first-order streams per unit area, which equals often gully density (number per km^2)" (Morgan, 1986, p.63).

<u>Drainage texture</u>
Drainage texture is measured by counting gullies and rivers per km^2 from maps of the grids with all the gullies on it (Collective Appendix, Maps, type D). These maps have been made by counting gullies from a peak of hill and by mapping them. In the field gullies have been counted and are direction and length of mapped also on the basis of depth, direction and morphology (see for more information drainage density below). In this way it was possible to exclude that a gully would be counted twice.

Drainage density

Drainage density is measured by estimating the length of gullies and rivers per km^2 by observing their depth, direction and the morphology of the area during field visits. Also gullies were mapped from high points in the surrounding. The depth of a gully says something about the runoff and force of water a gully experience in the rainy season (Morgan, 1986). If a gully is very deep, most of the times it is also very long, because it carries a lot of water with great force. The direction is a good indicator for where a gully is heading to, but this has to be combined with the morphology of the area, because gullies have sometimes steep knick-points. It was sometimes observed that gullies could turn from left to right in a knick of for example 90º. Therefore it was needed to combine the direction of gullies with the flow maps of water, Collective Appendix, Maps, type C. Water in gullies is just like normal water also streaming from a high point to a point with less energy. Therefore it was possible to use this technique.

Types of erosion

Question 1c has been answered by paying a lot of attention to erosion in the field. This question is totally answered by observing signs of erosion and by determining which kind of erosion it was on sight. Overland flow can be recognized by soil loss over a big area without channels. Only around stones, rocks and vegetation this flow has been broken and is still the old top soil there (Morgan, 1986). Rills are small channels formed by concentrated overland flow and most of the time they are not permanent (Morgan, 1986). "Gullies are relatively permanent steep-sided water courses which experience ephemeral flows during rainstorms" (Morgan, 1986: 29). Landslides are leaving always a distinguishable scar in the landscape. It is a place where a lot of mud has been moved downslope. Wind erosion can be recognized by dust storms or big scars in the direction the wind is most of the time blowing. In this way it was possible to recognize all the types of erosion in the field.

Erosion hazard assessment

The erosion hazard assessment (question 1) has been carried out by projecting all the erosion risks of the different erosion variables of erosivity and erosion intensity on top each other. For every 0.33 by 0.33 km grid has been determined the overall erosion risk of all the variables. Therefore all the ratings of the different variables are scaled into different risk groups which have all a risk score. The sum of all the scores of the variables indicates the overall risk for a grid. The overall risk scores are also scaled into different erosion risk groups which give the overall erosion risk rating per grid of 0.33 by 0.33 km.

2.3.2 Methods for research into local erosion prevention

The methods described in this paragraph are used to give answers on sub-question 2. Question 2a, 2b and 2c have been tried to answers by interviewing people, literature research and observations in the field. Literature research however was quite difficult because of the restricted access to databases etc. in Kenya.

Triade-model used as basis of research into local erosion prevention

In this research the theory of Poiesz (Weenk, 2000) has been used to analyse soil conservation practised by local people. Poiesz (Weenk, 2000) formulated a human behaviour theory, i.e. the Triade-model. Poiesz defines human acts according to Weenk (2000) on the following relationship: human acts = M*C*O, with M for motivation, C for capacity and O for opportunity:

- Motivation: what someone wants to do or what not, what makes someone doing something or not;
- Capacity: what kind of things somebody is capable of, by himself or with tools depending on characteristics, skills, knowledge, resources, and instruments that are necessary for a particular behaviour;
- Opportunity: the given circumstances, which a person can not influence by himself only, that are making a particular behaviour possible or not. (Weenk, 2000)

Differences in one of the factors that determines human activities are cancelled according to Poiesz (Weenk, 2000), because Motivation, Capacity and Opportunity are influencing each other. If Motivation and Opportunities are high for example, but Capacity is low, a person will try to get the capacities that he needs to act, because he is motivated. If he fails to get it, Motivation will go down. This is called the balance effect. More information on this theory can be found in Appendix VI.

The theory of Poiesz has been used as a think model. It has been used as a basis for a structured interview in which all the main concepts that are influencing human behaviour in soil conservation are pointed out. The factors Motivation, Capacity and Opportunity are factors existing out of factors of all kind and therefore it is very difficult to define them (Poiesz, 2002). In this research this was also a problem, because many factors are relevant. Only the most important factors could be included in the research. Also a benefit of the theory of Poiesz (2002) is that the factors Motivation, Capacity and Opportunity include all causes of human behaviour. This was very important for this research. Because this theory has been used as a basis for the research, it was tried to include all possible important circumstances that could be influencing soil conservation in the research area.
A critique could be that this theory is only suitable for the western society, because it has been developed here and that it is therefore based on the situation of how people are thinking in the western world. This critique however does not apply to this research, because the factors are used as a way to think and are therefore used abstract. So it is not based on biased ways of thinking. It only recognizes three important factors that influence human behaviour everywhere in the world, because it is value free. Therefore it was justified to use this theory for this research.

Set-up of interviews
The interview sessions have been done in cooperation with Van Bodegraven (2006), who wanted to get insight in local water storage. Therefore the number of indicators for the research into local soil erosion was restricted. The interview questions on local soil erosion can be found in Collective Appendix, Interviews. The questions are formulated in such a way that they give an indication for motivation, capacity and opportunity. Opportunity has been tried to measure by finding out if farmers experienced erosion as a problem. Because if farmers experience erosion as problematic, Opportunity is high for them to act. If they do not act yields will drop and land will be lost. Motivation has been tried to measure with the indicators: need of help by preventing erosion, land ownership, and experiences of WCT. Motivation is very difficult to measure and it is only possible to measure indirect. Very important for measuring motivation of people is to know if they want to do something to stop the problem. It is tried to get insight in this by using indirect factors as need for help, land ownership and experiences of WCT. These factors need for help have been chosen, because it indicates of a person is motivated to act if he gets help. A person was not asked if he wanted to solve the problem, because experiences in the first two weeks of fieldwork made clear that they started to complain about lack of money, because they hoped to receive money, food etc. of a NGO. So it has been asked indirectly if people were motivated by asking if they wanted to have help, because field research showed that people would answer more honest and also most of the time they would specify the help needed. In this way a lot of bias could be avoided. Land ownership is very important for motivation according to Soini (2005) and Rwelamira (1999), because investments make only economic sense if the person who is renting a plot can use it also the years ahead. The experiences of WCT give of course an essential point in the motivation of people. Capacity is measured with: self-intiative to take conservation measures, maintenance of conservation measures, organization rate, and labour division between men and women. Self-initiative and maintenance give directly insight in the capacities of the farmers, what are they doing already and do they have enough skills for that. Organization rat and labour division are more indirectly giving information about the capacities of people. Organized communities have more manpower and are therefore capable of bigger conservation measures. Labour division is also giving information about this point. If men and women are allowed to do the same the potential labour force is bigger. For more information about the set-up of the interview see Collective Appendix, Interviews.
A rule for interviewing is that it may not take too much time of a person, not more than 1 hour (Hettema, 2004). Therefore it was not possible to take more indicators into account, because two interviews (also that of Van Bodegraven (2006)) had to be conducted at the same time, one about

erosion and one about water storage, and the interview took already almost 1 hour. For the overall answer to the main research question *"To what extent is erosion control actively practiced by local farmers?"* the theory of Poiesz (Weenk, 2000) was also used to analyze what the community is doing. The sub-questions are formulated in such a way that it becomes clear why the people are behaving in the way they do with regard to Motivation, Capacity and Opportunity. The total analysis for the sub-questions can be found in Appendix VI. In this chapter only the main results are presented of this analysis.

In the research area farmers were interviewed; 13 men and 5 women. In the Sagals Hills, Mwakingali Hills and Voi no interviews have been conducted, because in the hill-areas no people are living, and in Voi it was not feasible to speak to people who could play an important role in soil conservation, i.e. local government officials. Farmers were chosen as sample group, because farmers own land and live of it. This implies several things. First, this group has at least interest in conservation measures and is probably even quite active in soil conservation, because else their yields and income will decrease. So the base for future projects is good. Second, farmers own big parts of the land in the research area and are therefore a major spill in erosion and water storage problems. So if farmers are active in soil conservation, erosion problems in a big part of the research area will be gone. Third, farmers are private persons so that projects can be implemented straight forward. For an NGO it is easier to control budgets and supervise projects with private persons. Fourth, it was possible to get indications for possible future projects (paragraph 1.3 & Collective Appendix, Interviews).
Another advantage of interviewing farmers was that they could be easily interviewed on their shambas during field visits. Sometimes they were interviewed at their homes. It was only possible to get 5 women in the responders groups, because mostly men were working in the field, a few women were too shy to tell something or their English was not that well. It was tried to get 3 interviewees of every 16 km² grid, but for some areas this was not feasible because of time constraints and low population density. The interviews have been conducted with a standard questionnaire as basis. For more information on the interviews regarding method and answers is referred to Collective Appendix, Interviews.

2.3.3 Recommendations on soil conservation

The method used to give recommendations on soil conservation measures, needed in the area, is quite simple. The factors causing erosion risk, as described in chapter 4 are combined with the factors Opportunity, Motivation and Capacities as described in chapter 5. This resulted in general recommendations for soil conservation in the whole research area and in recommendations sub-area specific. It is tried to give an identification of the feasibility of the plans and the priority for implementation. This is done qualitative and in relation to other recommendation. The recommendations however are a summing up of everything that is needed to make the area stable again. Also recommendations that are not possible to implement on the moment are therefore presented, so that these recommendations will not be forgotten in the future.

2.4 Fieldwork

The fieldwork has been done from the 17th of August up to and included the 5th of October 2006.
The first two weeks of fieldwork (17-31 August 2006) have been used to explore the research area and to test the measuring methods. The area has been explored by climbing hills and wandering through the area. From the mountain-peaks land use and water flow maps have been drawn by using a compass. Furthermore the area has been explored on foot and by bike. With the information on how many kilometres could be covered on foot and by bike, the final research area has been determined. Also measurements on infiltration, slope and ground samples have been tested.
Slope measurements have been conducted with a Sola slope measurement device. How much clay, silt and sand a particular soil contained has been determined by observing the sedimentation processes of a soil sample mixed with water. Directly after stirring, an hour and 24 hours the sediment has been measured, which indicates respectively the percentages sand, silt and clay. Infiltration tests were

carried out by measuring the time it took for of 12 mm of water to infiltrate into the ground. At the end of these two weeks the research area has been divided into 8 maps of 16 km^2. More information about the methods used for each measurement tool are discussed in paragraph 2.4.
After these two weeks fieldwork has been conducted for all of these 8 maps. The areas have been investigated on foot and by bike. During the field visits random interviews, slope and infiltration measurements and ground samples were taken. Also observations on land use, land classification, water flow directions, gullies, kind of erosion, and socio-economic data were obtained.

2.5 Discussion

As with every methodology there are several pros and cons for RRA. For this research the benefits of RRA were more important than the disadvantages. This because RRA maximises sensitivity to the local conditions, facilitates the essential participatory component of the monitoring work, saves time and money for future repeat assessments, and is quick in providing of quite good data (Hettema, 2004). Especially the factor time and obtaining of qualitative good data were important for this research, because a large area had to be covered in less than 3 months. Another important benefit of RRA in this study was that it combined quantitative and qualitative data very well. It was very important to use both types of data to come to well based recommendations. The combination of quantitative and qualitative data is very important as also stated by Petersen (1992), because a combined method seems to produce more reliable data. RRA was therefore ideal.
But of course there are also some disadvantages of RRA, i.e. it is not very precise and gives only indications, and it is susceptible of bias (Hettema, 2004; Pedersen, 1992). That RRA is not very precise was not very important for this research, because it is a preparatory study on soil conservation recommendations, so that indications of measures that have to be taken are good enough. Bias of course is a big problem. It is tried to keep bias as minimal as possible by doing interviews in an informal and low profile manner (not using company logos, writing blocks during interview, asking leading questions and so on) (Hettema, 2004). The most important critique according to Petersen (1992) however is that researchers who use RRA think that information can be obtained very rapidly and because of that there is less time needed to talk with local rural people. Instead of this perception Chambers argues, according to Petersen (1992), that this should release even more time for contacts with the indigenous population. This is also an important critique from the direction of PRA users that RRA researchers do not pay enough attention to local circumstances. In this research it has been tried to solve this problem by doing a lot of interviews and having informal contacts in the field.

3 Theory of erosion

In this chapter will be explained what erosion is and how it works. Also will be discussed how erosion can be measured. In paragraph 3.1 will be give a definition of erosion. In paragraph 3.2 the processes and mechanics of erosion are described. In paragraph 3.3 will be explained with which methods erosion has been measured in this research. In paragraph 3.4 the formation of gullies is explained.

3.1 Definition of erosion

Before research can be done at aspects of erosion, erosion has to be defined. According to the dictionary erosion is: "*the attrition or scooping out of soil by the working of wind, running water, sea or ice*" (Koenen & Drewes, 1992). Morgan (1986: p. 12) however defines soil erosion as: "*a two-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind*."
Morgan (1986) gives a more technical and precise definition and recognizes more potential erosive agents then the definition of Koenen & Drewes (1992). Morgan (1986) argues later that it is a three-phase process, because he also recognizes sedimentation. Fore this research has been used the definition of Morgan (1986) extended to a three-phase process, i.e.: *a three-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind and the sedimentation of those soil particles* (Morgan, 1986). It is important to keep this definition in mind, because the process of erosion and how to prevent erosion is defined by this definition. The definition gives insight in which way the processes of erosion are working by defining the processes. If soil conservation measures are developed in such a way that the processes can be prevented, erosion is not a problem anymore. Only investigation has been made of soil erosion by the agent water. This, because soil erosion caused by water is the most severe in the foothills of the Voi River catchment (Sirviö, Rebeiro-Hargrave, Pelikka, 2004).

3.2 Processes and mechanics of erosion

From the definition of soil erosion given in paragraph 3.1 can be derived the working of erosion. First individual soil particles are detached by a detaching agent. Than the soil particles are transported by erosive agents and after transport deposition of particles takes place. According to Morgan (1986) there are the following kinds of soil erosion: rain splash erosion, overland flow, subsurface flow, rill erosion, gully erosion, mass movements and wind erosion. The detaching agents are rain splash of raindrops, overland flow, wind and weathering by temperature differences, biochemical processes and human activity. The potential energy of the agents results in detachment of soil particles. The transport of the soil particles which are detached is carried out by external factors as wind, rill flow, gully flow, and rivers and by internal soil factors as mass movements such as landslides and mud streams. The transport agents are converting the potential energy of the soil particles in kinetic energy. If the kinetic energy is gone because of resistance forces the soil particles will settle down. (Morgan, 1986)
There are two important types of erosion which determine the severity of erosion, detachment limited and transport limited erosion. Detachment limited erosion means that more soil particles can be transported than that there are detached. Transport limited erosion is the opposite, i.e. more material is supplied than can be transported. It is important to know which kind of erosion is the most important for soil conservation measures (Morgan, 1986).
"Processes of water erosion are closely related to the routes taken by water in its passage through the vegetation cover and its movement over the ground surface" (Morgan, 1986: 14). Water erosion is therefore interrelated with the hydraulic cycle as described in paragraph 1.2.3. When it is raining, part of the rainfall falls directly on the soil, while other raindrops are intercepted by plant cover. The raindrops, intercepted by plants, lead to stem flow, dripping of leaves or the water evaporates. Raindrops and leaf dripping are both causing rain splash erosion. The water that reaches the ground infiltrates, evaporates or is stored in small pools. Water infiltrates into the ground until the soil can not take more water. Infiltrated water is stored as soil moisture or groundwater. If more water is infiltrated than the soil is able to store, it results in subsurface flow and sometimes erosion by piping what can

cause gullying. The excess water causes runoff on the surface, what may cause erosion by overland flow, rills and gullies (Morgan, 1986).
The infiltration rate and type of soil are important for the characteristics of water erosion. This because the infiltration rate determines at what moment surface runoff will occur. The infiltration rate is high at the beginning of a shower. The rate decreases with time to a constant rate of water that can infiltrate into the ground. Horton argues, according to Morgan (1986), that surface runoff will occur when the infiltration rate is exceeded by rainfall intensity. If the rainfall intensity is lower than the infiltration rate, surface runoff will not occur unless soil moisture content is limiting. The type of soil determines the latter. The type of soil determines also if a soil is sensitive for erosion or not.

The important factors that are influencing erosion are: “rainfall, runoff, wind, slope, plant cover and the presence or absence of conservation measures” (Morgan, 1986; p. 1). According to De Graaff (1993) especially the quality of soil is important. Erosion can be measured directly by measuring soil loss of an area by determining how much soil is transported by water during runoff. Also there are a lot of more indirect measures to measure erosion. In this research are used only indirect measures. Erosion intensity has been measured by drainage density (km gully km^{-2}) and drainage texture (number of gullies km^{-2}) which indicates how severe areas are eroded by gullies and other first order streams. For measuring erosivity, how susceptible areas are to erosion, are used slope, rainfall aggressiveness, difference between present and recommended landuse, and soil texture. For more information about these measures see chapter 2. Plant cover and runoff are not measured just as soil loss, because this was not possible. Runoff and soil loss could not be measured because it was not raining during fieldwork. Plant cover is changing significantly over a year in the research area, so that data is needed over a longer period than three months will it be useful.

3.3 Theory of gullying

The theory of gullying will be explained in this paragraph, because gullies play an important role in the erosion hazard assessment (paragraph 3.3). Gullies are defined by Morgan (1986: p.29) as “relatively permanent and steep-sided water courses which experience ephemeral flows during rainstorms.” Gullies carry a lot of sediment.
Gullies can develop in three different manners. The first manner is induced by surface erosion. Small depressions created by weakening of the vegetation cover by for example grazing, fire or removal of vegetation etc., are enlarged by water. Several depressions coalesce, forming a channel. Erosion is concentrated at the headcut (the upslope end of the channel) of the channel. The headcut is almost perfectly vertical, causing supercritical water flow if water passes. The result is that the soil below the headcut gets scooped out, detached and transported downhill. Because of the scooping out, the headcut will collapse causing the retreat of the headcut upslope. The water flowing trough the gully channel causes also stream bank erosion by scouring of running water and gully wall collapse caused by soaking of the stream bank. In Appendix II the development of gullies is presented schematically. (Morgan, 1986)
The second way in which gullies can develop is by piping. Erosion by piping exists on hillsides where water is removed by subsurface flow through underground channels. Vegetation removal causes that the ground is not bound together anymore resulting in the scooping out of the channels. After a while the ground surface collapses and the gully network becomes clear. (Morgan, 1986)
The third manner in which gullies can be initiated is at places where steep-sided scars are left of previous mass movements as landslides. Water is streaming supercritical over the edge after rainfall and scoops out the soil at the headcut, causing severe gullying. (Morgan, 1986)
Gullying is caused by too much water which is running off at one moment in time caused by either climatic change and/or alteration of land use. Runoff of water, subsurface or on the surface, caused by climatic change is a result of more and more intense rainfall or less rainfall, which reduces vegetation cover. Water surplus caused by land use change is a result of for example deforestation, overgrazing and vegetation burning. (Morgan, 1986) As described in paragraph 1.1.1, more droughts can be expected in the research area because of climate changes. As becomes clear of the problem analysis land use is changed because of population pressure. So it is possible to conclude that the area is vulnerable for gully erosion.

4 Results erosion hazard assessment

In this chapter the erosion hazard assessment will be explained. In paragraph 4.1 will be investigated which areas are susceptible of erosion. In paragraph 4.2 will be investigated which areas are eroded and what the intensity of the erosion is. In paragraph 4.3 is discussed which kinds of erosion are affecting the area. In paragraph 4.4 is determined what the overall conclusion is of the erosion risk in the research area. In paragraph 4.5 the erosion hazard assessment conducted is discussed.

4.1 Areas susceptible of erosion

4.1.1 Indicators

To measure the susceptibility or erosivity of areas first the indicators have to be defined with which the erosivity is measured. Morgan (1986) recognizes slope, rainfall aggressiveness, rainfall erosivity index (R), and land capability classification compared with present land use, and soil texture as measures for indicating areas susceptible to erosion. In this research slope, rainfall aggressiveness, and land capability classification compared with present land use are used as indicators for erosivity.

4.1.2 Erosivity of areas

Slope

According to Morgan (1986), erosion increases with increasing slope steepness and slope length. This because steeper slopes result in more runoff and higher water velocities and increasing slope length causes increasing water volume intercepted. Another reason is that on slopes more soil particles are detached by raindrops. The reason for this is as follows. Soil particles are detached randomly to all sites on level slopes. On hill slopes soil particles are more detached downslope than upslope, causing soil erosion. These characteristics increase with increasing slope steepness.
So slope is therefore a good indicator for erosivity. Of the research area has been made a slope map. Slopes are measured with a Sola slope measure (see paragraph 3.3). These measurements are combined with the calculated steepness between the contour lines of the map and observations in the field which resulted in the definitive map. Measurements are combined with calculations and observations because it was not possible to do measurements everywhere. Measurements combined with the contour lines of a map and observations give therefore the most reliable slope map. The slope steepness has been divided in seven classes, i.e. 0º-5º, 5º-10º, 10º-15º, 15º-20º, 20º-25º, 25º-30º, >30º. These classes are also a good indicator for erosion risk. Erosion risk has been divided in seven categories, low (0º-5º), below moderate (5º-10º), moderate (10º-15º), above moderate (15º-20º), high (20º-25º), very high (25º-30º), and extreme high risk (>30º) (Morgan, 1986: p.88). These classes are chosen in this manner, that soil conservation recommendations can be made easily and erosivity can be determined. Above slopes of 30º mechanical soil conservation measures are not possible anymore (Morgan, 1986) and for the other six classes different mechanical soil conservation measures are recommended. Only focused is on mechanical measures, because soil management and agronomic measures can be taken on all kind of slopes (Morgan, 1986).
Erosion risk has been combined with the slope classes, because an increasing slope results in greater erosion risks and less simple soil conservation techniques that can be practiced adequate.
In figure 4.1 the erosion risk of slope is presented globally. For clearness reasons the erosion risk classes on the map are different. For the precise erosion risk see Collective Appendix, Maps, type B.
As becomes clear of figure 4.1, erosion risk of slope is very severe in all the mountain-ranges, especially in the Mwakingali Hills and the Taita Hills where large parts are falling in the classes moderate to severe erosion risk. It has to be taken into account that the slope map on a lot of places differs from the reality because the slope map represent an average gradient for a part of a mountain. So at some places the slope is almost flat, while at other places the slope is much steeper. For some places this can have severe consequences, because erosion at the foot of a rock face could be very extreme.

Legend:	*white*	*0°-10°*
	yellow	*10°-20°*
	orange	*20°-30°*
	black	*>30°*

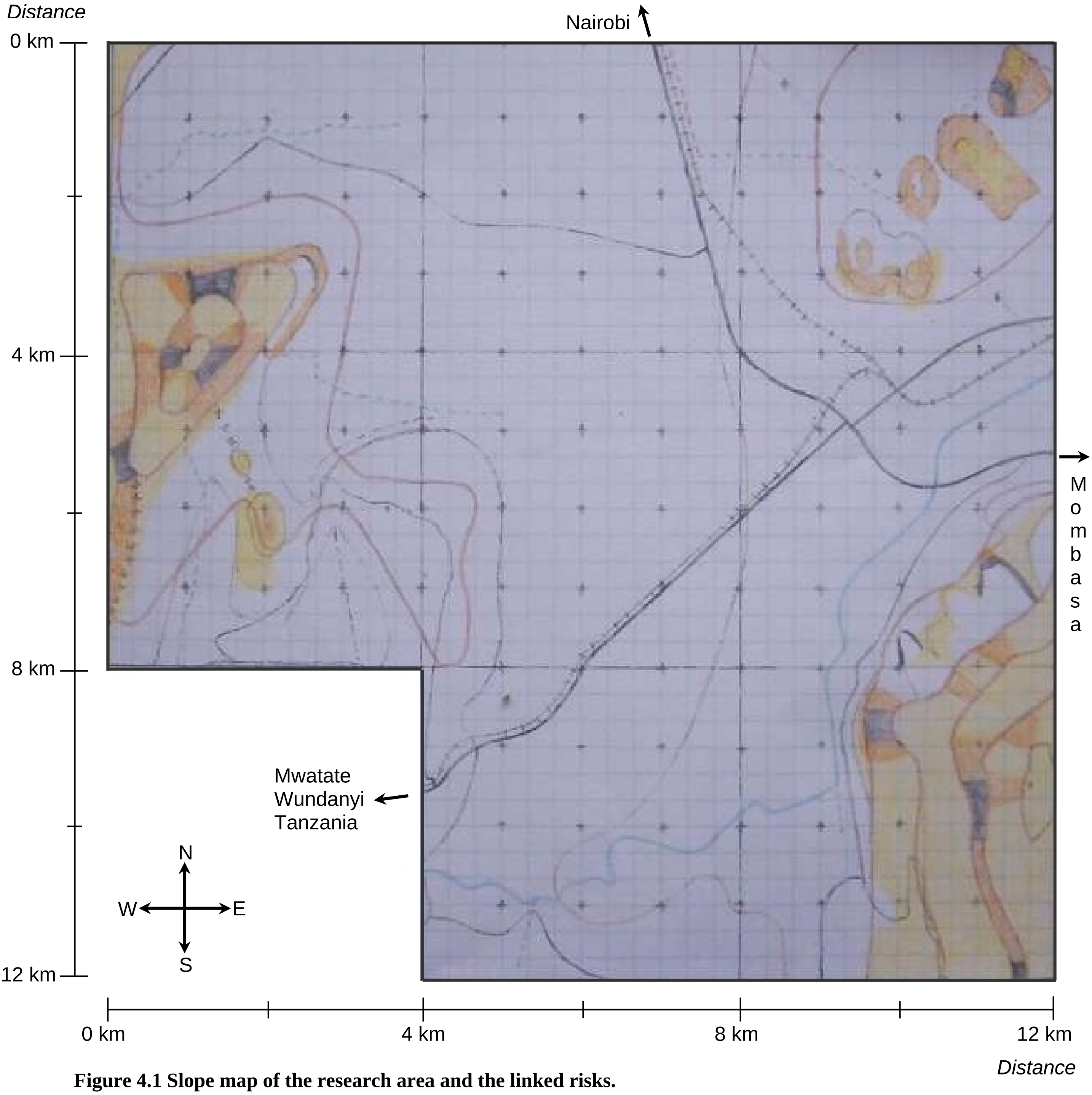


Figure 4.1 Slope map of the research area and the linked risks.

Rainfall aggressiveness

Rainfall aggressiveness is the most commonly used index for erosivity studies. It has a high correlation with sediment yields in rivers. Rainfall aggressiveness is the ratio p²/P, with p the mean monthly precipitation and P the mean annual precipitation. It indicates therefore the precipitation into one single month and indicates also the rainfall intensity. High values indicate a seasonal precipitation pattern, with rainfall only in a few months per year and a dry season in which the plant cover decays and erosion protection by plant cover becomes less.
With rainfall aggressiveness it is also possible to estimate the mean annual sediment yield for the research area. The empirical relationship of rainfall aggressiveness is as follows:

$$\log(Qs) = 2.65\log\left(\frac{p^2}{P}\right) + 0.46\log(H)(\tan S) - 1.56 \qquad (4.1)$$

Qs is the mean annual sediment yield (g m^{-2}), H is the mean altitude (m) and S is the mean slope of the basin (S), and p²/P is rainfall aggressiveness ratio. (Morgan, 1986)

It was not possible to get weather data for the whole research area. Because there is only one weather station in the research area, located in Voi. Therefore it is only possible to give one rate for rainfall aggressiveness in the area. The data consists of two sets. The first set covers a period of 13 years from 1953 to 1966 (Yahoo weather, 2006). The second set consists of data of last year, October 2005 to September 2006 (The Weather Underground, Inc, 2006). The data provides information on the average annual rainfall in Voi per month and per year and of last year of the largest showers per month (see Appendix IV). With this data rainfall aggressiveness per month has been calculated and also per largest shower per month. The result of these calculations is that May in the dataset covering 1953-1966, is the month with the highest rainfall aggressiveness rate and April for the set covering last year. This difference is a result of a gap in the first data set, which did not contain data for April. The rates for rainfall aggressiveness were 33.22 and 19.20 for respectively 1953-1963 and last year. As mean annual precipitation has been taken 590 mm, because this data has been based on a period of 13 years and is therefore probably more reliable than data of last year, despite climate changes. (Yahoo weather, 2006) But it may be presumed that in April the rainfall aggressiveness rate is the highest, because data of last year and of Bindloss et al. (2003) are indicating this. The highest rainfall aggressiveness rate, 33.22 is compared with studies in tropical Malaysia not so high. There the rates were all in between 50 and 100 (Morgan, 1986). But if you take into account the different factors, i.e. that Voi is arid instead of tropic and that plant cover because of that is lower, this ratio is still quite high. Especially if you take into account that the plant cover starts growing a few weeks after the start of the rainy season. The showers with the greatest intensity have passed already because rainfall aggressiveness is highest at the start of the rainy seasons from April/May till June and October till December (see Appendix IV). Data of last year, presented in figure 4.2 shows also clearly that rainfall intensity follows the monthly precipitation pattern, as also mention by Morgan (1986).

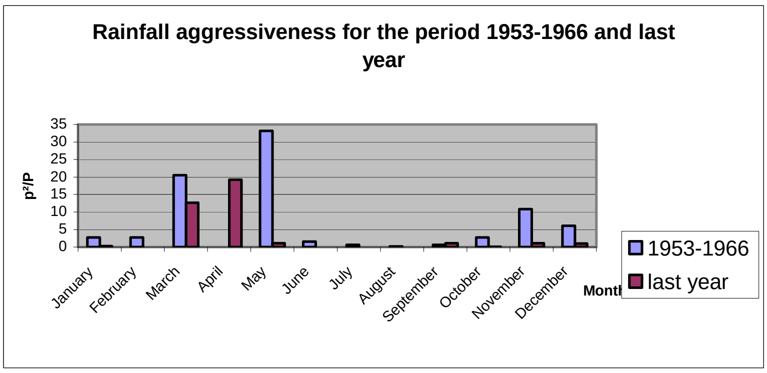


Figure 4.2 Rainfall aggressiveness for the period 1953-1966 and last year.

Also the mean annual sediment yield for the research area has been estimated using formula 4.1 (for more information see Appendix IV). The mean annual sediment yield estimated for the research area is 430 g m^{-2} or 430 t km^{-2}. This calculation is in line with the annual sediment yield for this part of Africa as can be seen in figure 1.5, where soil loss has been determined above 250 t km^{-2}. This rate is high. Under natural conditions there is only between 0.003-0.10 kg m^{-2} y^{-1} and under cultivated conditions or bare soil it lies between 0.01-15.00 kg m^{-2} y^{-1} for West Africa (table 4.1). Compared with cultivated land or bare soil the sediment yield for the research area is more or less in agreement, especially if you take into account that it is an average of natural, cultivated and bare soils.

Table 4.1 Rates of erosion for several countries (kg m^{-2} y^{-1}). (Morgan, 1986: p.5)

	Natural conditions	Cultivated	Bare soil
China	< 0.20	15.00–20.00	28.00–36.00
USA	0.003–0.30	0.50–17.00	0.40– 9.00
Ivory Coast	0.003–0.02	0.01– 9.00	1.00–75.00
Nigeria	0.05 –0.10	0.01– 3.50	0.30–15.00
India	0.05 –0.10	0.03– 2.00	1.00– 2.00
Belgium	0.01 –0.05	0.30– 3.00	0.70– 8.20
UK	0.01 –0.05	0.01– 0.30	1.00– 4.50

Difference between present land use and recommended land use

Human acts have great consequences for the erosivity of areas. If people use land in ways for which it is not suitable, this could cause erosion. So it is important to compare present land use with recommended land use.

Comparison of present land use and recommended land use

To determine which areas are susceptible to erosion, the present land use is compared with the recommended land use by using a GIS (Geographic Information System). Meant with GIS is projecting the differences between present and recommended land use, by placing the present land use and recommended land use maps on top of each other so that differences can be identified. An overall map of present land use and an overall map of recommended land use according to the United States system can be found in figures 4.3 and 4.4. On the basis of these maps has been determined which areas are susceptible for erosion, by determining differences in present land use and recommended land use. In figure 4.5 the results are presented; areas susceptible of erosion are toned red.

Of figure 4.5 it becomes clear that big parts of Mwakingali Hills (1), the area near Maruwenyi (4), and the area near Mkwachunyi (8) are susceptible to erosion. At the foothills of the Mwakingali Hills (1) and Taita Hills (8) many people settled. The village Maruwenyi (4) is situated on top of a hill. Because of human acts in these areas many trees were cut and runoff surfaces were enlarged for the construction of roads and houses. In these areas the recommended land use is however VI, VII or VIII. This means that *vegetation cover has to be preserved* and land may be used under strict conditions only. However, the people are using the land without precautions. In the areas 1 and 4 the people do not take any soil conservation measures and in area 8 the measures are not severe enough and not practiced everywhere. On the hills themselves, herds are grazing their livestock (mostly goats) everywhere they like. Herds have been seen even on the most steep and rocky places, with slopes of more than 45%! Observations made clear that goats, compared to other livestock, are especially worse for vegetation, because they eat everything from grass to the bark of trees and bushes. Because of that seedlings do not get the time to develop. Furthermore people are cutting branches and trees *uncontrolled* for firewood and charcoal burning. Because of that trees are growing only sparsely on Mwakingali Hills and near Maruwenyi these days. Near Mkwachunyi the area covered by trees and bushes is decreasing fast.

For Sagala Hills (2), the area west from Kalambe (3), and at the foothills of the small Taita Hills (7) the problems are that people cut trees *uncontrolled* or *illegal* for firewood and charcoal burning. Also herds are herding their livestock *uncontrolled*, mainly goats, on the (steep) slopes of the hills, while land classification is V or more. On some places in the Sagala Hills with land classification VIII *uncontrolled* gemstone and/or construction material winning on small scale has been observed also, causing decrease of vegetation cover. In the areas 5 (Magogo) and 6 (Mrabenyi) *uncontrolled* grazing and cutting of trees are also problems. Besides that, agriculture is practiced on the slopes of the hills. This while the land capability classifications are VI and even for some parts VIII.

Legend: see Collective Appendix

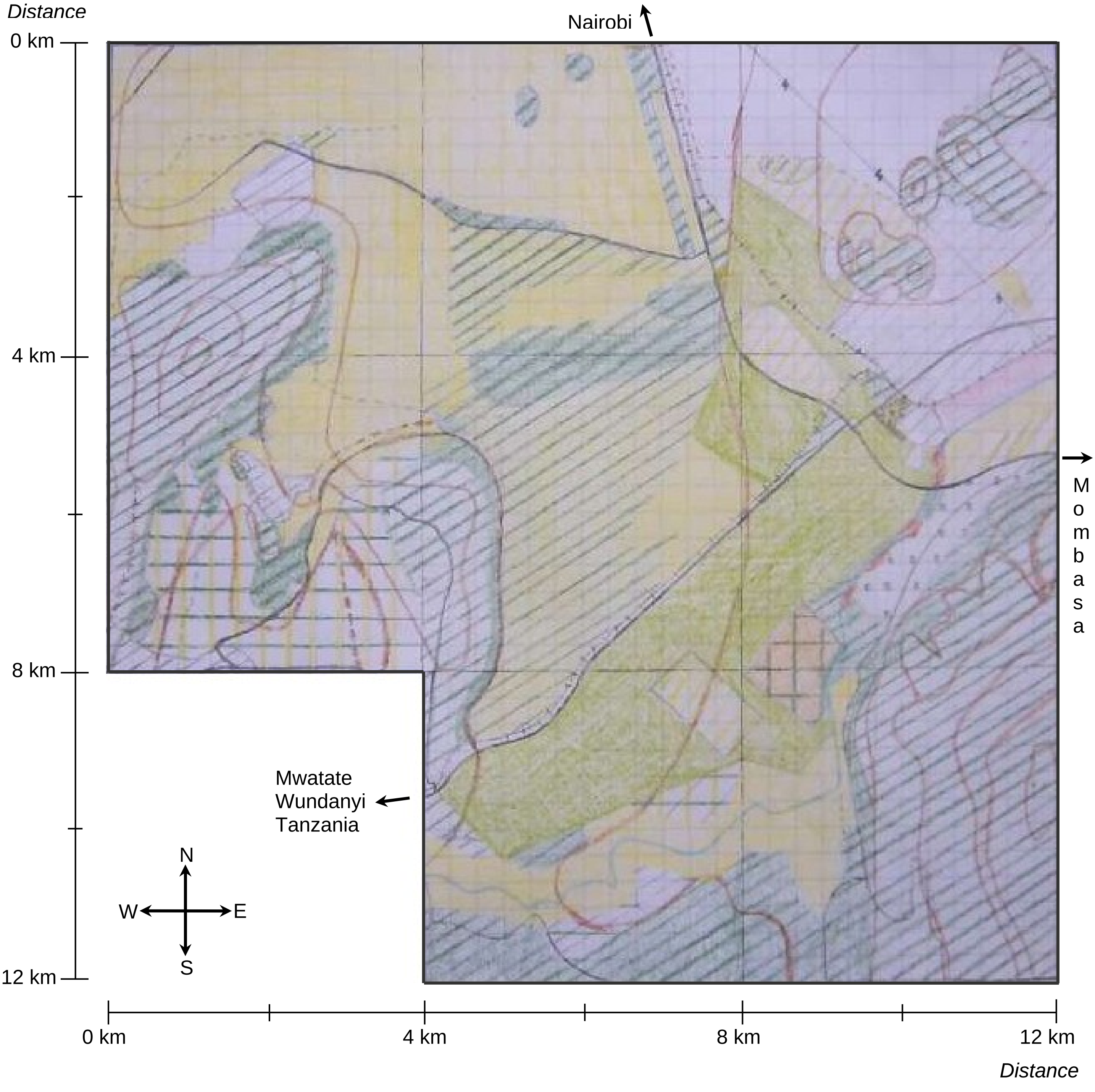


Figure 4.3 Present land use.

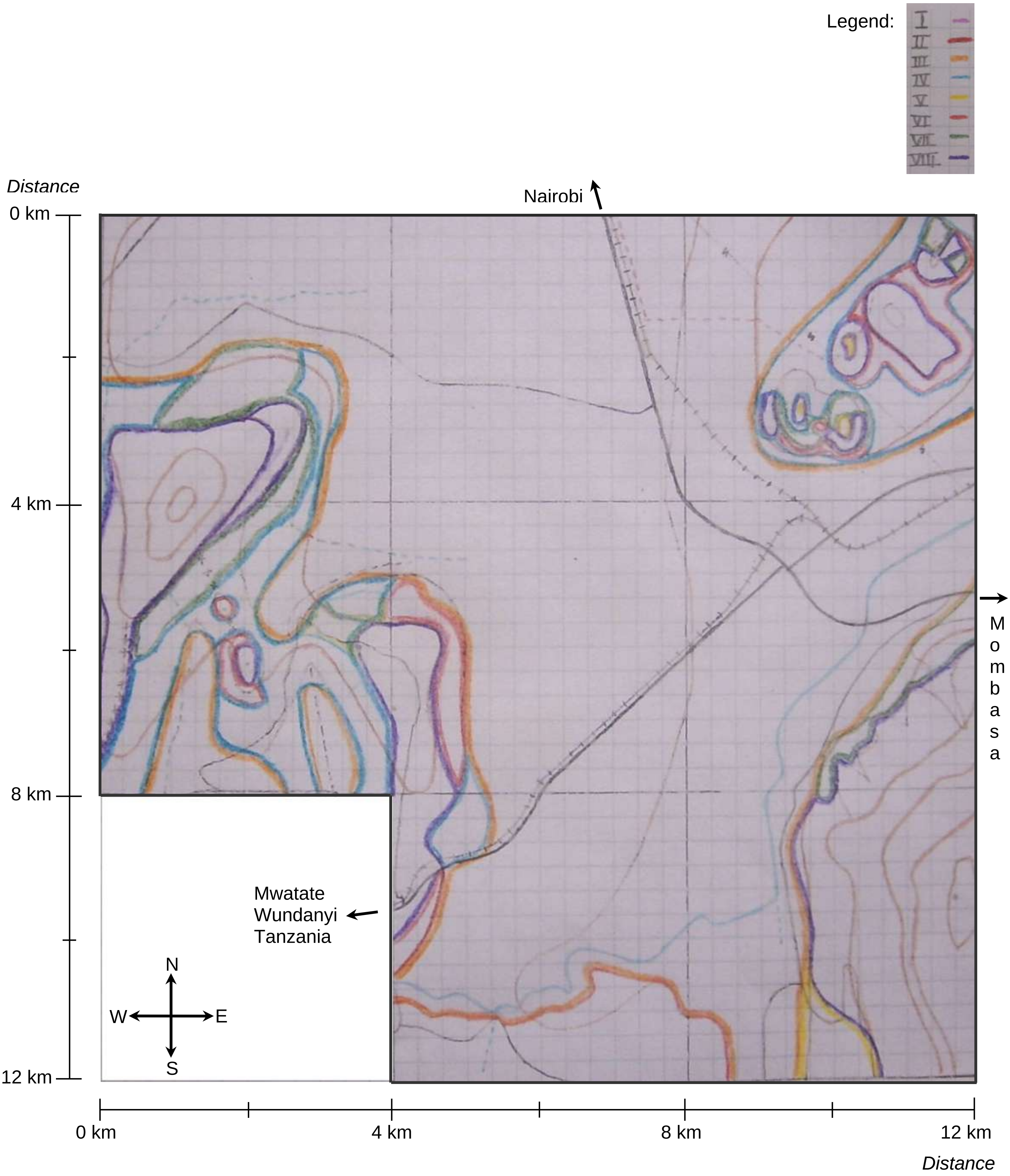


Figure 4.4 Recommended land use.

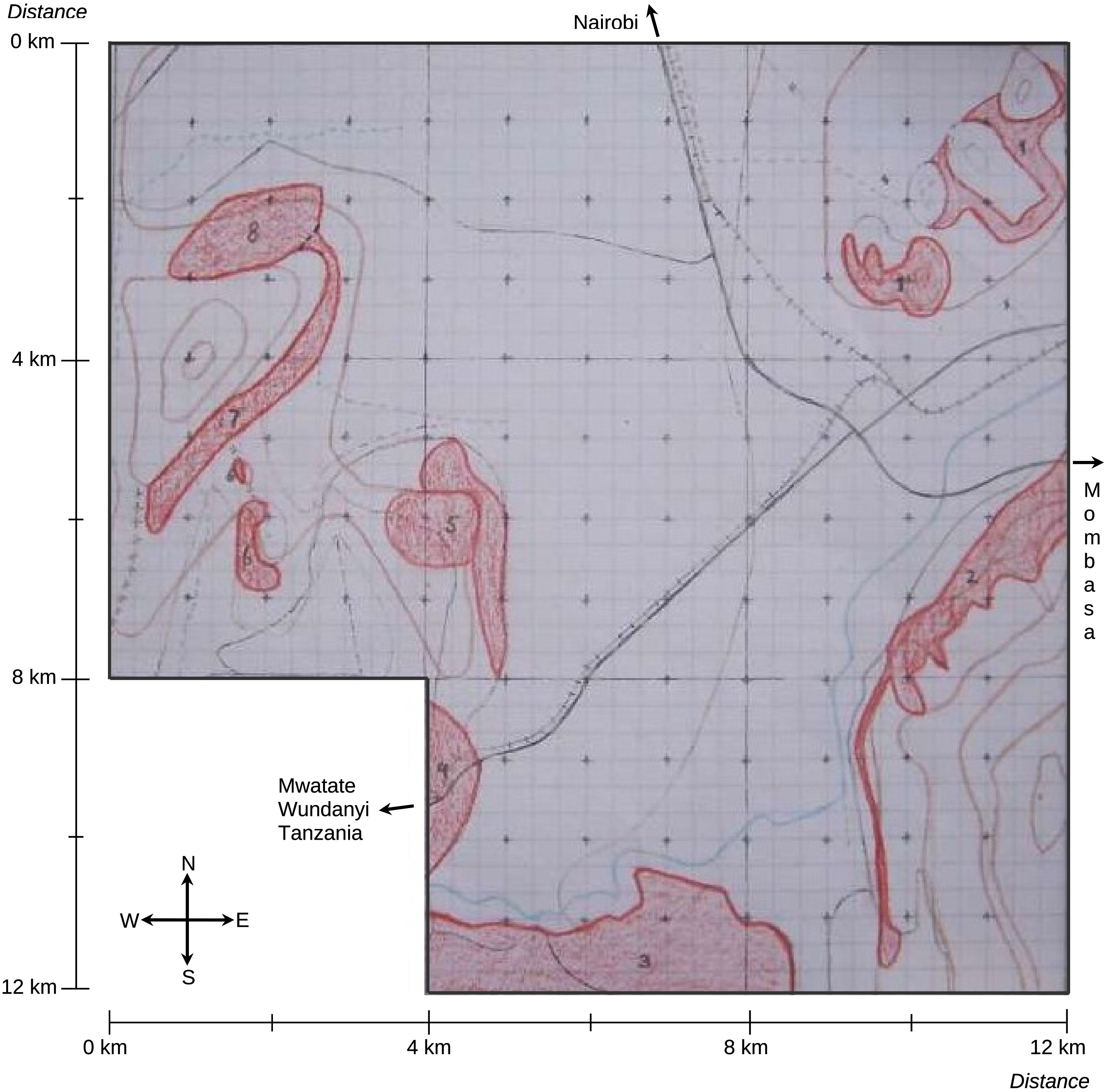


Figure 4.5 Difference between recommended and present land use. The areas susceptible to erosion are red due to difference between recommended and present land use.

Soil texture

The results of the soil texture tests as described in chapter 2 are standing in Collective Appendix, Soils. From the data it can be concluded that all the soil samples have an important fraction of sand and silt. Half of the soil samples are sandy soils and the other half silty soils. Almost all the soils have more than 15% silt and less than 80% sand. So almost all the samples are both, very sandy and very silty. The most erodible soils are medium to fine sand soils, so in between sand and loam soils. Because all the samples have important fractions of both sand and silt, it may be concluded that all the soils have also a substantial part in the particle size range of fine sand soils. This explains the severity of erosion in some areas.

Also the data seems to indicate that soils with a substantial part of clay (7% or more) are more often firm soils than soils with only a small part of clay. This could be explained by the less cohesion in such soils caused by clay particles, because “clay soils are harder to erode because of the cohesiveness of clay minerals which comprise them.” (Morgan, 1986: p.22) On one spot a soil sample has been taken of an eroded area and an “uneroded” area. The area was everywhere eroded, but around a tree erosion was much less or not present, because the roots of the tree kept the soil. At that time the height difference between the eroded area and the uneroded area was already 20 cm! It became clear that the top soil of the eroded area was very soft and the top soil of the uneroded area was much stronger. The sample of the uneroded area contained much more silt and humus than the sample of the eroded area. So this also indicates that clay minerals are playing an important role in the differences between very soft and firm soils. However, there were no signs of the data that there is a strong relationship between less humus in a soil sample and softness of the soil, what would have been expected, because humus makes a soil more cohesive (Van der Sluijs & Locher, 1990). So therefore for soils erosion risk has been divided in three categories, low (firm soils), moderate (soft soils) and high (very soft soils). The results of this analysis are presented in figure 4.7.

The soils in the area around Sagala Hills and Mwakingali Hills are mostly firm, so erosion resistance of the soil is high. Erosion in Mwakingali and Sagala Hills is probably more caused by altering of vegetation cover and change in land use than because of bad soils (figure 4.7). Soils on the plains are mostly soft; erosion risk is moderate. There are three spots with very soft soils and high erosion risk. The spots with very soft soils and soft soils in the Taita Hills give a reason for the high erosion intensity and landslide in that area, because the soils are easily flushed away by water. Especially at the side of Mkwachunyi where has been a big landslide. Also it explains the gullying on map 4D (Collective Appendix) southwest under the river and a part of Sagala Hills because soils here are also soft or very soft. In figure 4.6 has been presented a picture of a soil vulnerable to erosion.

Figure 4.6 Soil vulnerable to erosion.

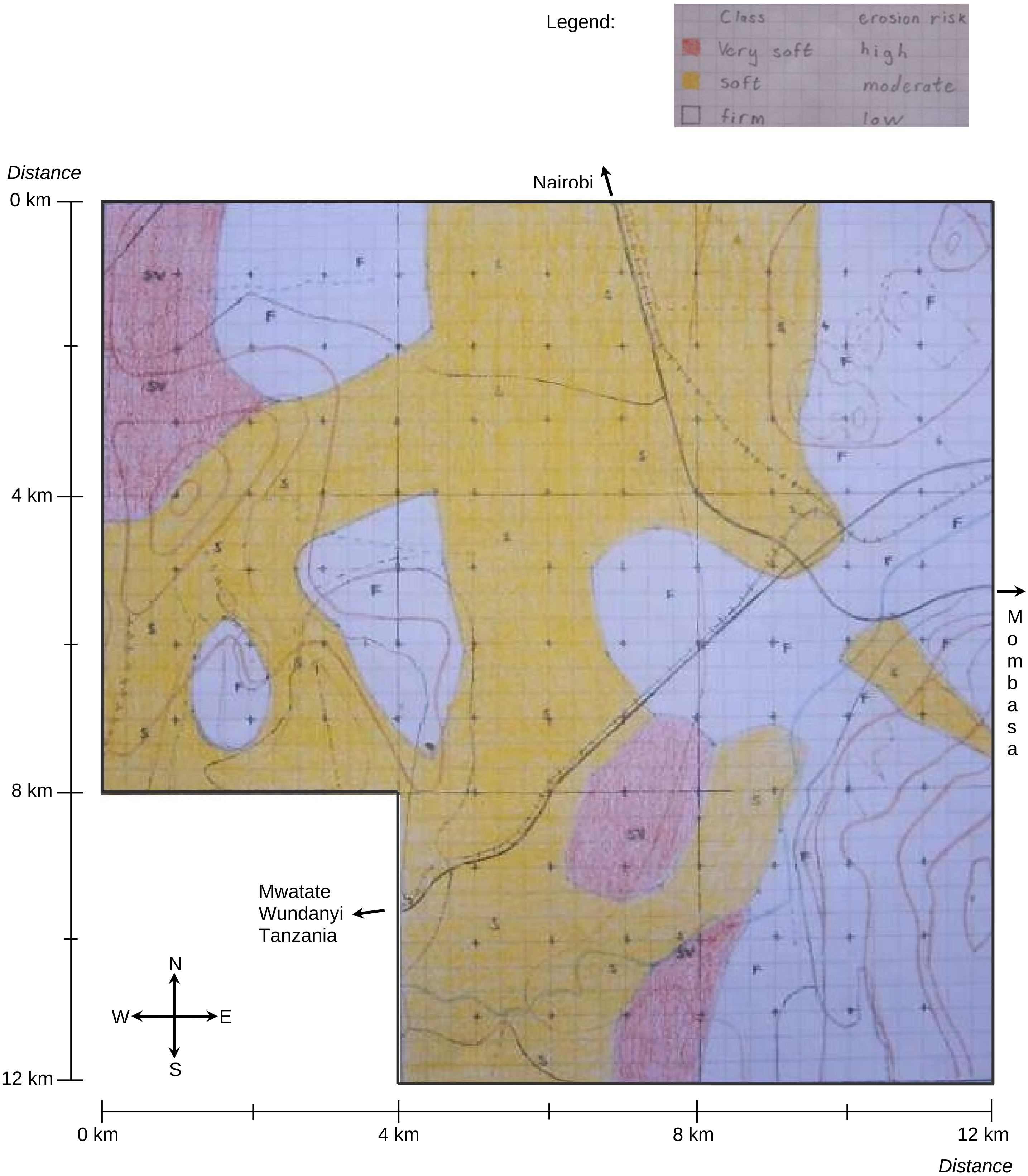


Figure 4.7 Soil behavior under wet conditions.

Infiltration rate
It is important to know the characteristics of infiltration for a soil, because it determines whether runoff (and thus erosion) is likely to occur or not. The infiltration rate is high at the beginning of a rainstorm, because capillary forces are high. But the infiltration rate decreases during the rainstorm because the spaces between the soil particles become filled. The infiltration rate is highest for sandy soils and lowest for clay soils (figure IV.V). (Morgan, 1986) Van der Sluijs & Locher (1990) however argue that it is not always the case that the infiltration rate of sand soils is the highest. If a soil is very dry, clay soils or loams have higher infiltration rates, because “Bigger pores can only be filled with water if the amount of water can not be drained by the smaller pores anymore”. (Van der Sluijs & Locher, 1990: p.150) According to Van der Sluijs & Locher (1990) this fact is caused by the air that is inside the bigger pores. Air gives resistance to water that wants to infiltrate. Wetter grounds do not have this problem because of the creation of H-bridges.
Infiltration capacity is very difficult to measure and quite inaccurate: “Field determinations of average infiltration capacity using infiltrometers may have coefficients of variation of 70 to 75 per cent.” (Morgan, 1986: p.16) Of the soils infiltration capacity has been measured by conducting a 12.5 mm test in the field for every soil based on the United States land capability system (Morgan, 1986). Therefore a plastic tube was put into the ground without disturbing the topsoil and a water head of approximately 15 mm was placed on the topsoil by gently pouring water on the ground. The time it took for the water to infiltrate has been measured. The results of these tests are presented in Collective Appendix, Soils. The infiltration rate of all soils was very high. The average infiltration rate of a water head of 15 mm was 109 s (396.33 mm h^{-1}). The lowest measured rate was 431 s and the highest 24 s. This rate is quite high, because “infiltration rates can range from more than 200 mm h^{-1} for sand soils to less than 5 mm h^{-1} for tight clays”, and according to the United States system infiltration rates above 250 mm h^{-1} are very rapid. (Morgan, 1986: pp.16, 85) Because most soils are very silty Sand soils or sandy Silt soils, it would be expected that infiltration rates would be lower. Reason for these differences is that the tests are done only for 12 mm water heads and are calculated to rates per hour, while infiltration rates decrease in time when a soil gets more saturated. Another reason is that the soils investigated were all very dry, while the infiltration rate of a soil decreases when it gets saturated (see figure IV.V). (Morgan, 1986) A reason why infiltration rates could be high is because most soils have a substantial part of sand and silt. Because of that water can infiltrate easily at the beginning and during saturation as already explained earlier in this paragraph. For some soils the tests were probably also not very accurate because the soils had a very hard crust, making it almost impossible to get the plastic tube good into the ground. Therefore water would not go straight down only, but also to the sight.
With such high infiltration rates much runoff would not be expected, because total precipitation is only 590 mm for Voi and the plains (Yahoo weather, 2006). Only the hills receive more rainfall. But runoff is plenty, even for small showers as witnessed in the field. Possible explanations for runoff are that the soils get slammed by water, as can be observed in Collective Appendix, Soils, tillage conditions. Most soils have very bad tillage conditions. Borst & Haas (2006) reported already that silt layers caused silting and crusting of the ground. Another reason could be that the soil moisture content for these soils is limiting, which results in runoff when the soil moisture content is exceeded (Morgan, 1986).

4.2 Erosion intensity of eroded areas

4.2.1 Erosion intensity indicators: drainage texture and drainage density

According to Morgan (1986) drainage texture and drainage density are good indicators for measuring erosion intensity (paragraph 3.3). However, research of Morgan (1986) indicates that drainage density and drainage texture are uncorrelated and therefore probably relate to different controlling mechanisms. “High values of drainage density are associated with the transport of runoff from regular, moderate rainfalls whereas high values of texture are a response to a more seasonal rainfall regime with rains of greater intensity” (Morgan, 1986: p. 66). For some areas in Malaysia drainage density was therefore sometimes regarded better as an index of runoff than of erosion (Morgan, 1986). This may be true, but still drainage density indicates how much km km^{-2} gully there is in an area and thus how severe erosion is. It is therefore still a useful indicator of erosion, besides that it maybe says something about runoff. Because of that drainage density and drainage texture are used as indicators for erosion intensity in this research.

4.2.2 Drainage texture of areas

Drainage texture has been determined by counting gullies in the field and drawing the gully length in on the map of the area. The gully length has been estimated as described in paragraph 3.3 by counting gullies in the field. With the data on the maps (based on the observations in the field) it was possible to determine the number of gullies for each square kilometer. The data on drainage texture can be found in table III.I and the gullies are presented on the maps of Collective Appendix, Maps, type D. In figure 4.9 the data of table III.I is presented visually.
The data has been divided in seven classes, just like slope, so that is possible to compare them. The classes are chosen quite arbitrary, because according to Morgan (1986) there are no clear rules for determining the classes. Therefore the erosion risk classes are based on observations. The impact of the number of gullies per square kilometer as witnessed in the field is therefore used as criterion. The classes are as follows (in number of gullies km^{-2}): 0-5 low, 5-10, below moderate, 10-15 moderate, 15-20 above moderate, 20-25 high, 25-30 very high, >30 extreme. Areas with more than 30 gullies per square kilometre are devastated. Agriculture is not possible anymore, houses, trees, etc. are swept away, animals and people can reach other places difficult etc.; so it has big social and economic consequences. Morgan takes 29 as number for high erosion risk, which is another reason to take 30 as upper value. Areas with only 0-5 gullies are influenced only a little, so risk can be considered low here. On basis of these two findings the number of gullies per square kilometre has been divided into linear classes as already shown above.
Becoming clear of figure 4.9 is that especially the area around the small Taita Hills is influenced by gully erosion. Especially the foothills are deteriorated. The erosion risk is here for some parts above moderate to extreme. This, because these hills are very steep and at the foothills a lot of agriculture is practiced, livestock is grazing, and trees are cut for charcoal burning and firewood (see paragraph 4.1.2 and Collective Appendix Maps, types A & B). Because the vegetation cover has decreased and changed less water is stored and rainfall is not intercepted anymore, causing erosion and even gullies (see chapter 3). Furthermore there are quite some gullies at the foot of the steep Sagala Hills and Mwakingali Hills. Here because of settlement, grazing and woodcut. Also can be observed from figure 4.9 that at least more than two third of the research area has been influenced by gully erosion, at least of low risk. Impressions of gullies can be seen in figure 4.8. Some other impressions of gullies can be found in Collective Appendix, Photo gallery.


Figure 4.8 Gullies. Photograph on the left: gully through outskirt of Voi laying water pipes bare. Photograph to the right: gully through acacia shrub on the plains.

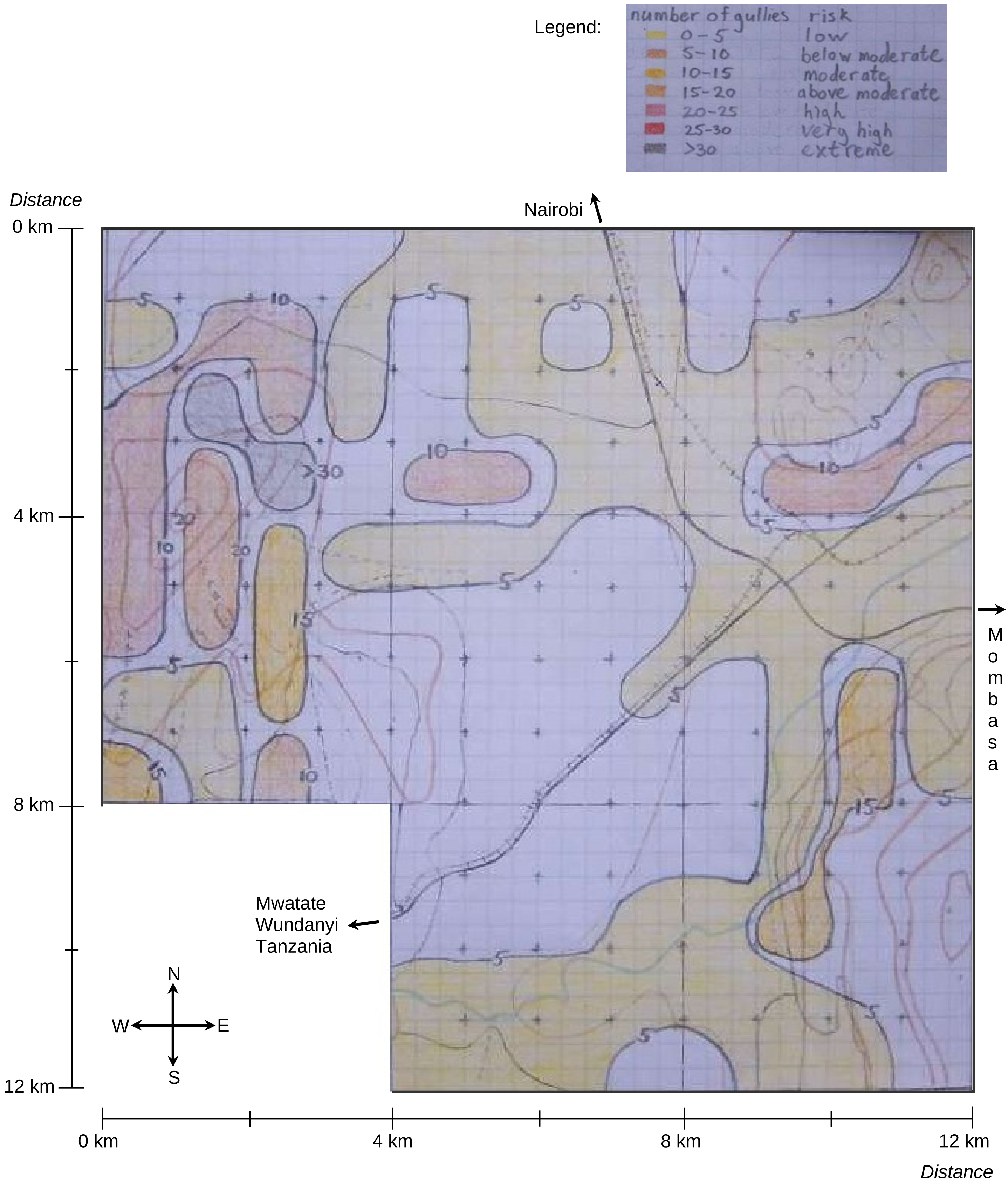


Figure 4.9 Drainage texture (number of gullies per km^2).

4.2.3 Drainage density of areas

Drainage density has been determined as already said by estimating the length of gullies by observing their depth, direction and the morphology of the area during field visits. The direction of a gully has to be combined with morphology of the area, i.e. in which direction water flows. Because gullies are going from high to low, just like water does. The direction of a gully was combined with a flow map for water (Collective Appendix, Maps, type C), so that it was possible to make a quite good estimation of the length of a gully as field tests proved. The results of these field tests are presented in table 4.2. In the field five gullies were estimated on direction and length, and afterwards the length was measured by using a land measuring stick of one meter. The direction was estimated all the times quite correct and the difference between estimation and length was around ±10%. The gullies mapped are given in Collective Appendix, Maps, type D. In figure 4.10 the data of table III.II has been presented visually.

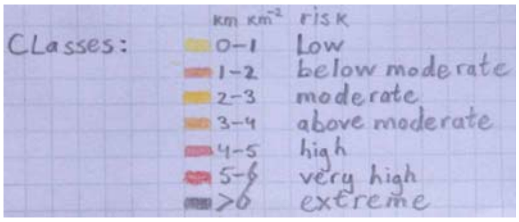
Table 4.2 Measuring of the length of a gully compared with estimations on length.

	Estimated length (m)	Measured length (m)	Difference (m)	Deviation (%)
Gully 1	850	907	57	-6.3
Gully 2	440	486	46	-9.6
Gully 3	1200	1068	132	+12.4
Gully 4	790	761	29	+3.8
Gully 5	290	313	23	+7.4

The drainage density has also been divided in seven classes to make comparison possible. The classes are, just as for drainage texture, quite arbitrary because according to Morgan (1986) there are no clear rules for classifying. The classes are: 0-1 km km^{-2} low, 1-2 km km^{-2} below moderate, 2-3 km km^{-2} moderate, 3-4 km km^{-2} above moderate, 4-5 km km^{-2} high, 5-6 km km^{-2} very high, >6 km km^{-2} extreme. Above 6 km km^{-2} has been set on extreme, for the same reasons as with drainage texture. Field observations made clear that these areas where all the times heavily gullied. A whole area was not suitable for agriculture and settling, grazing of cattle became difficult and people and animals had difficulties with passing the areas (see Collective Appendix, Photo gallery). This severe gullying has big social and economic consequences. Areas with drainage density between 0 and 1 were influenced only little, therefore erosion risk was set on low. On basis of these observations the other classes are divided linear.

Becoming clear of figure 4.10 is that especially the Taita Hills are suffering of extreme erosion. Big parts have a gully density higher than 6 km km^{-2}. Near Mkwachunyi has been a landslide, what causes severe gullying. Other reasons for erosion in the whole area are: steep slope of the hills, practicing of agriculture on the foothills without good soil conservation measures, uncontrolled livestock grazing on the foothills, and uncontrolled cutting of trees for firewood and charcoal. At the foothills of Mwakingali erosion is also severe. Erosion risk here is rated from moderate to very high. Here erosion is caused by settling of people and uncontrolled cutting of trees and grazing of livestock in the steep hills. The steep slopes of Sagala Hills are also causing a lot of erosion. Here erosion risk is rated from below moderate to very high. Besides the slope also uncontrolled grazing and cutting of trees are causing erosion. For all the severe eroded areas can be said that human activities cause a decrease and altering of vegetation cover.

Legend:



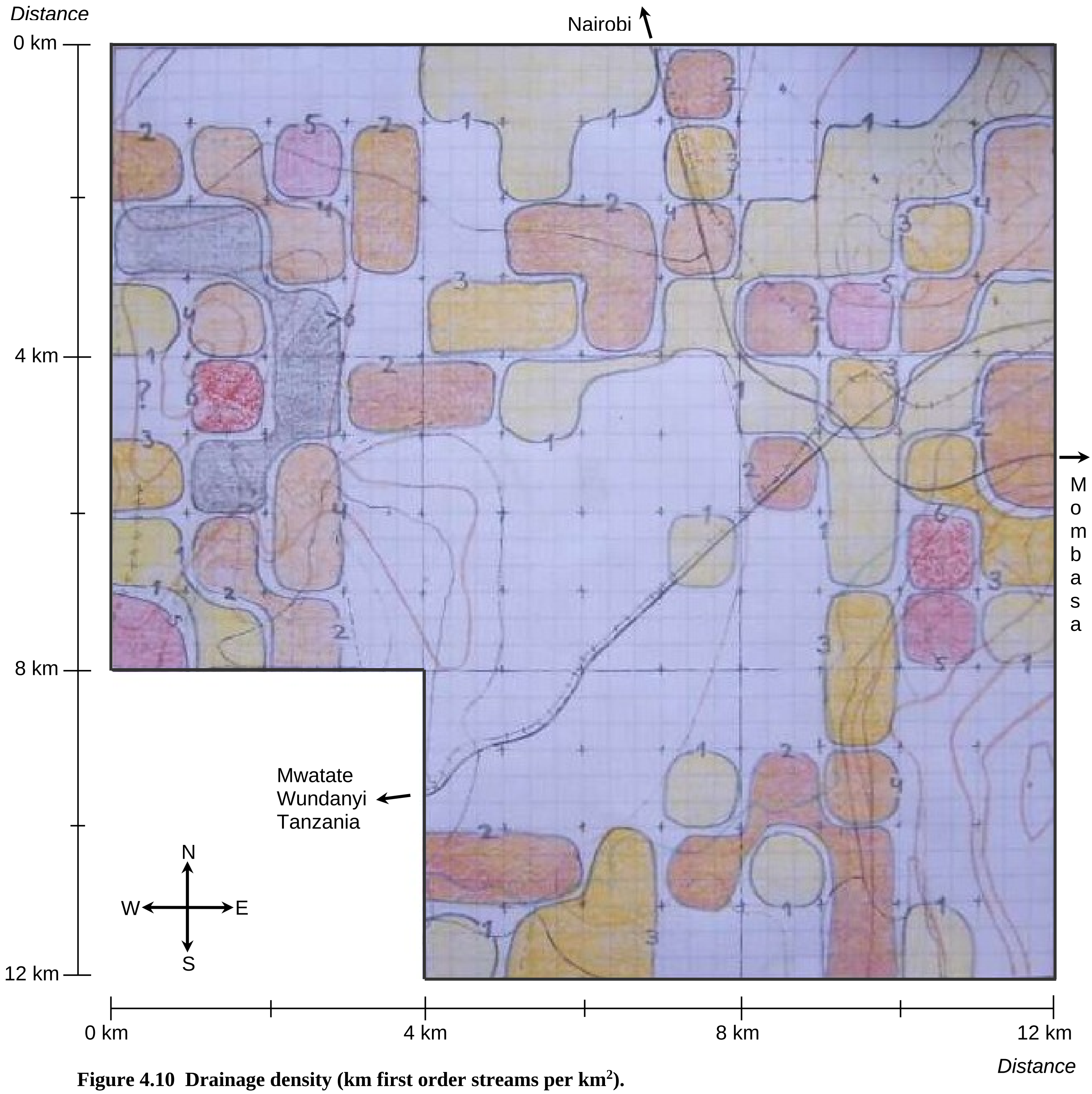


Figure 4.10 Drainage density (km first order streams per km^2).

4.3 Types of erosion affecting the areas

There are several types of erosion affecting the area. Observed types in the field are overland flow, rills, gullies, land slides and wind erosion, especially by wind hoses. This research has only been concentrated on gullies for indicating erosion risk. For gullying all three possibilities in which gullying could occur are seen, i.e. by altering of vegetation cover, by piping and tunnel collapse, and by the scar of a big landslide (see paragraph 3.4). Gullying in the research area is most of the time caused by changing of vegetation cover, mainly by grazing and cutting of trees for agricultural land, firewood and charcoal burning. In the research area was one spot where gullying was caused by a landslide (Collective Appendix, map 7D). The landslide however was probably caused by practising agriculture without soil conservation measures. In that area agriculture is even practiced on steep slopes of the Taita Hills. Therefore lots of trees are cut and there are no roots anymore to keep the soil tight. On two spots (map 6D, Collective Appendix) gullying caused by piping was seen. Here tunnels had collapsed showing a network of gullies. Vegetation cover was scarce, because the grounds were used for agriculture. Therefore there were no roots to give strength to the soil.
In the mountains erosion is most likely detachment limited, because the transport factor of gullies and rills is high. On the plains it is likely that erosion is transport limited, because transport agents as gullies are less common as can be seen of the maps in Collective Appendix, Maps, type D.

4.4 Overall conclusion on erosion hazard assessment

4.4.1 Rating

To determine the overall erosion risk for every square kilometre factorial scoring has been used (Morgan, 1986). To make sure spatial differences are maintained every square kilometre has been divided in 9 grids. There are five categories: drainage density, drainage texture, slope, soil texture and difference between present land use and recommended land use. All categories are rated on a scale of 1 to 7. Factorial scoring method divides scoring classes linear (Morgan, 1986). Therefore the class for extreme risk of erosion gets the rate 7 and the class of low risk 1. However all categories are not using 7 erosion risk classes, as becomes clear of table 4.3. Therefore it is not possible to compare all categories with each other just like that. Slope, drainage texture and drainage density have all 7 erosion risk classes, soil texture 3 and difference between present and recommended land use 2. The classes of the latter two are scored however on a scale of 1 to 7 so that it is possible to compare the different classes. For soil texture it was only possible to distinguish three erosion risk scales, high, moderate or low. Very soft soils are rated high. These soils are subject to landslides and severe gullying as observed in the field. Therefore high is scored with seven because the risk and consequences of erosion are extreme. Moderate is scored in between at a scale of 1 to 7, so is scored at 4 and low at 1. Difference in present and recommended land use can only be scored at high or low, because it is only possible to distinguish a difference or not. In the problem analysis in paragraph 1.3 it was already mentioned that human activities are one of the key problems for erosion. Therefore a difference between recommended and present land use has been rated at high risk and is scored 7. No difference is set on 1, because erosion risk is low.
Factorial scoring sums the scores for every category to get an overall erosion risk. All the maps of drainage density, drainage texture, slope, soil texture, and difference between present and recommended land use are processed on top of each other in a GIS way. For every grid the overall factor score has been calculated. These scores varied from 3 to 30. Overall erosion risk has been divided in 6 classes as presented in table 4.4: low (0-5), below moderate (5-10), moderate (10-15), above moderate (15-20), high (20-25) and very high (25-30). The reason for these classes is that this presents the observations in the field best and makes enough differences in risk of erosion for giving recommendations to prevent erosion.

Table 4.3 Erosion risk rating

Categories	Erosion risk rating	Factor score
Slope	Extreme	7
Drainage texture	Very high	6
Drainage density	High	5
	Above moderate	4
	Moderate	3
	Below moderate	2
	Low	1
Soil texture	High	7
	Moderate	4
	Low	1
Difference present and recommended land use	High	7
	Low	1

Table 4.4 Erosion risk

Major groups	Factor score
Low	0-5
Below moderate	5-10
Moderate	10-15
Above moderate	15-20
High	20-25
Very High	25-30

4.4.2 Outcomes of erosion risk assessment

The overall erosion risk assessment outcomes are presented in figure 4.11. As can be seen of figure 4.11 erosion risk is especially severe at the foothills as also observed by Sirviö et al. (2004) and Sirviö & Rebeiro-Hargrave (2004), especially in the Taita Hills. Erosion risk is also high in a part of the area southwester the Voi River. Here are some rocky hills, were not much vegetation is growing and livestock grazing and cutting of trees is common. Hence, especially soil conservation measures have to be taken in the foothills of Taita, Sagala and Mwakingali mountain-ranges and in the south western part of the area below Voi River.

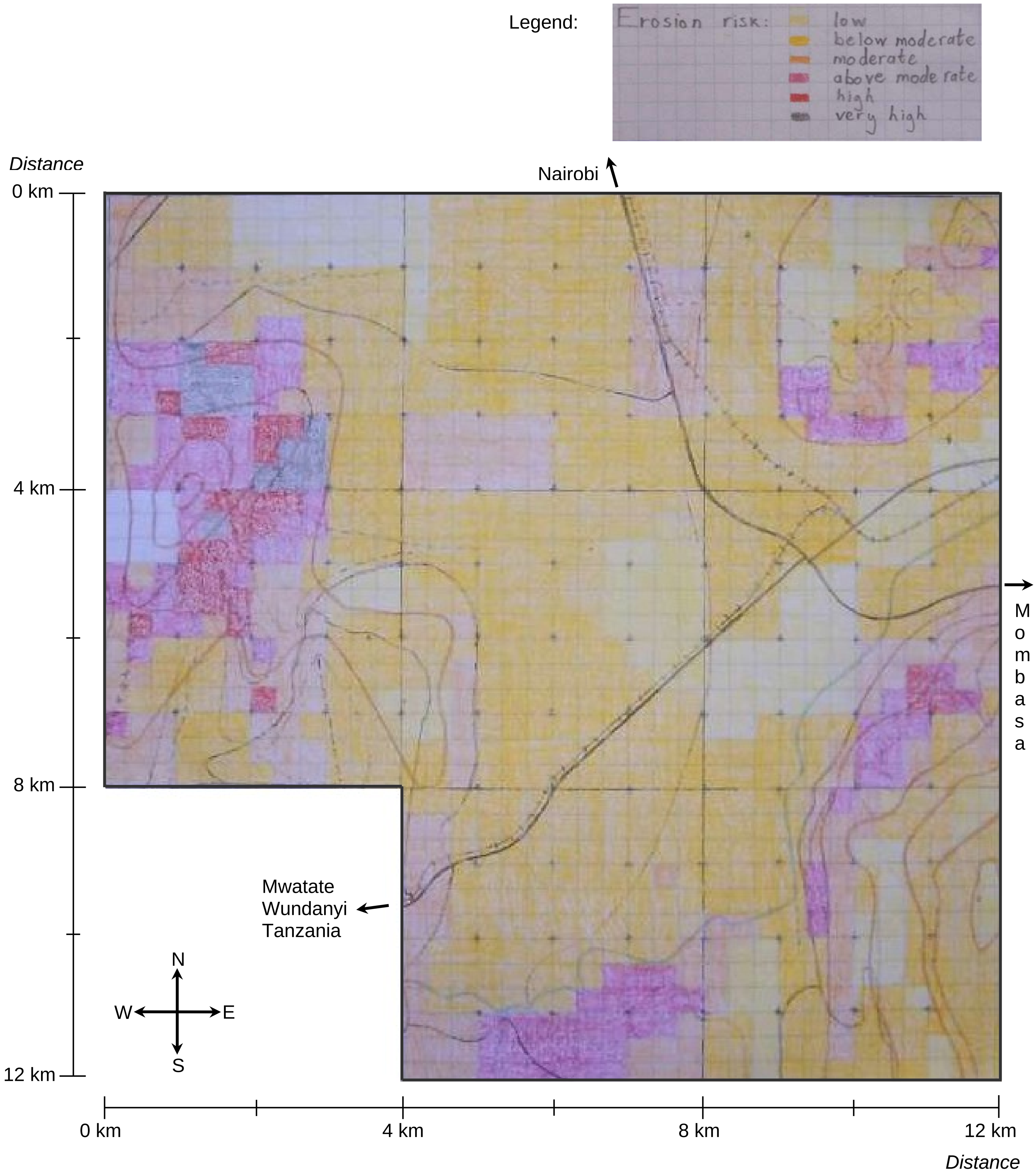


Figure 4.11 Erosion risk per 0.11 km ^{2} grid.

4.5 Discussion

The erosion risk assessment carried out for this research has to be regarded on several points with curiosity. However quite accurate data is presented, it has to be kept in mind that especially all the gullies are not measured and the direction and length is estimated to get first results for the planning of soil conservation measures for increasing water storage and plant cover. So the reader must not take the length of a gully as fact, but as an indication of the length. Also the data on soil texture and infiltration rate have to be treated carefully, while research methods were not that sophisticated because of lack of equipment. For the infiltration tests officially infiltrometers are needed and for the ground test laboratory experiments would be the best. But the data can be used very well as indication for soil characteristics for the planning of soil conservation measures if extra research is conducted on site.

The rating of the erosion classes for each category is subjected to subjectivity, while there are no strict guidelines according to Morgan (1986). Factorial scoring method especially faces some problems. According to Morgan (1986) the first problem is that the classification may be sensitive to different scoring systems, like defining groups differently. Secondly each factor is treated independently, while all factors are influencing each other. There is correlation between the different factors, which factorial scoring does not include. Thirdly the factor scores of each category are summed. There is no reason why this should not be done differently. Related to this is the fourth problem. The categories are also not weighted on importance. They are treated all the same.

However despite the problems and notes, it has to be said that factorial scoring is easy to use and categories that are difficult to quantify can be compared also (Morgan, 1986). Also the method is very easy to use and is not very complex, which saves time.

5. Local erosion prevention

For giving good soil conservation recommendations it is important to take socio-economic factors into account (Morgan, 1986; Lubwama, 1999; Rwelamira, 1999). Socio-economic factors determine which recommendations are possible and which kind of factors can determine success or failure for a recommendation. Socio-economic data give insight in the motivation and capabilities of people to prevent soil erosion and what they are doing already to stop erosion. Therefore interviews with local farmers and observations have been done in the field. The interview sessions have been carried out combined with questions about water storage (Collective Appendix, Interviews, 2006). The analysis of the results of these questions can be found in the report of Van Bodegraven (2006). The objective of the social research about soil conservation is: to get insight in local soil erosion prevention by doing interviews and field observations through the research area.

In paragraph 5.1 different sub-areas are defined to make it easier to compare different tribes and characteristic areas with each other in erosion prevention. In paragraph 5.2 the results of the interviews and observations for the different research questions are described. In paragraph 5.3 the research will be discussed critically.

5.1 Defining sub-areas

The research area is divided in several characteristic sub areas, i.e. Voi town & Mwakingali Hills, Sisal estate, Plains, Sagala Hills, Small Taita Hills, and Voi River. The reason for this division is that people and morphology of these sub-areas were significantly different as observed during fieldwork (for an impression see Collective Appendix, Photo gallery). Figure 5.1 shows a map of the sub-areas.

The different sub-areas are the same as in the research of Van Bodegraven (2006), so that characteristics and recommendations per sub-area can be matched. In Appendix V observations on the different sub-areas are presented to give an idea of the different areas. For the interviews however only the sub-areas Sisal estate, Plains, Taita Hills and Voi River are important, because of the other areas there are no interviewees, because there lived no people or there were no farmers (Voi-town for example).

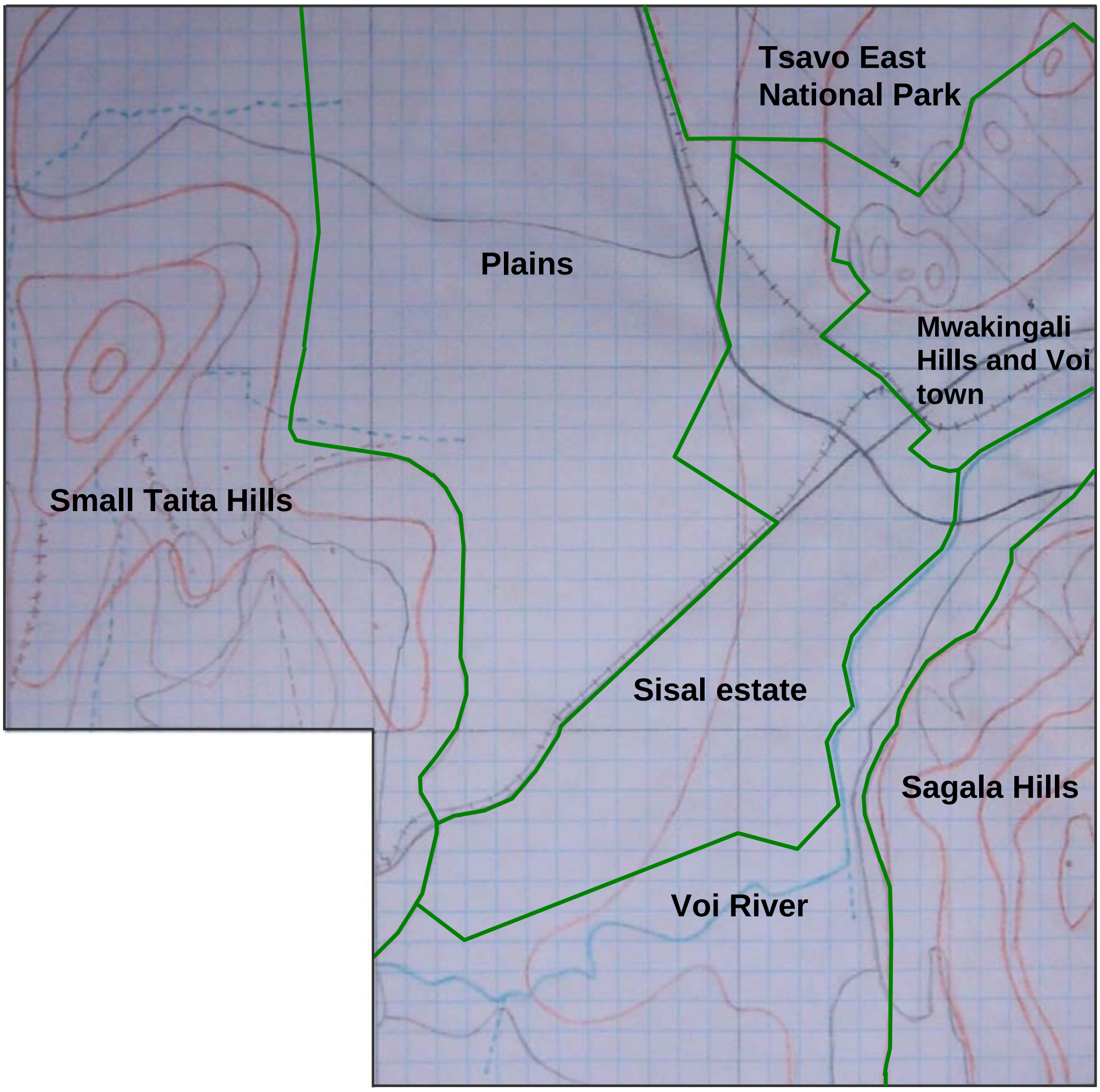


Figure 5.1 Sub-areas in the research area; based on differences in morphology and inhabitants.

5.2 Results of field observations and interviews

To know to what extent the communities are actively involved in taking soil conservation measures research has been carried out into their motivation and capacities and if the opportunity is there to act.

5.2.1 Opportunity: soil erosion is a problem

Firstly it was determined if the opportunity was there, by determining if the farmers regarded soil erosion as a problem. This was done by asking their five major problems in farming in order of importance and if they regarded soil erosion as a problem. The results of these questions were:

- In every sub-area the farmers had erosion in the top six of problems and taken over the whole research area erosion was problem number three. Problem number one was lack of water and drought and number two diseases of plants during growth and storage. Water problems are causing the biggest problems. Therefore it is wise to combine soil conservation with water storage. This will increase the motivation of people to act against erosion.
- 12 of the 18 farmers regarded erosion as a problem on their plots and six said that they had no problems at all.

- Six farmers had no problems with erosion according to them. For 2 of them observations confirmed the answer: the interviewees of the sisal estate. Field observations were in agreement with their statement. Between field observations and the other four farmers perception was a difference. In the field erosion was observed on their plots.
- It was not possible to determine a difference in erosion awareness between men and women, because the sample group was too small.
- Sisal estate had no severe problems with erosion, because they used strip cropping, earth walls and grass as conservation measures because erosion was regarded as a big problem. In Sisal estate, Small Taita Hills and Voi River awareness of erosion as problem was high. For Plains erosion perception was a little lower, probably because erosion intensity on the plains is lower (see chapter 4).

<u>Opportunity</u>
So it is possible to conclude on the basis of the results of these questions and observations that erosion is regarded as a serious problem in the research area. Hence the *Opportunity* for the people is stimulating them to take actions against soil erosion. Soil conservation combined with water storage will give a higher opportunity and motivation to act against erosion, because water problems are regarded most severe. Opportunity is highest in the sub-areas Voi River and Small Taita Hills. Opportunity on the Plains was a little lower, probably because the erosion intensity on the Plains is also lower. Opportunity for Sisal Estate is moderate high, because awareness of erosion as a problem is high and erosion is seen as an important problem, but not the biggest problem. Therefore a lot of measures are taken on the estates to prevent erosion. The Opportunity to act is moderate high, because the people are taking already adequate measures so that the problem is almost under control.
In places where the Opportunity to act is high, it is easier to make people aware of the need of the implementation of soil conservation measures, because the environment is forcing them already to do something.

5.2.2 Motivation of people to prevent soil erosion

Secondly the motivation of people to act has been researched by using indications on: need of help by preventing erosion, land ownership, and experiences of WCT. During fieldwork it became clear that it was not possible to ask if people were going to prevent erosion themselves, because they always started to complain about lack of money, hoping the get money easily. Field tests however made clear that it was best to ask people if they wanted help to get an indication of their motivation; for the details see Appendix V. This made clear that the people tried to earn money or to benefit in an other way of the help of others, more than it was them about the project itself. This aspect however is also possible to use to motivate people. People can be motivated already a lot by clearly communicating the benefits of projects to them. Land ownership was used because it was very important for motivation of farmers to act against problems, according to Soini (2005) and Rwelamira (1999). The experiences of WCT of course give insight in the real motivation of people during projects. The results of the research are:

- Ten of 17 respondents wanted help; 4 farmers did not specify the help needed, 4 respondents wanted to have knowledge about soil conservation measures, 1 farmer wanted help for implementation of an erosion prevention plan, and 7 persons said they did not need help.
- Sisal estate needed no help at all, observations made also clear that they did enough. The owners of the sisal estate were very motivated to prevent erosion. Of the farmers wanting to have help, farmers of Small Taita Hills wanted especially knowledge and of Voi River and Plains most of them did not specify the help needed.
- 15 of the 18 farmers were landowner. Only south of Voi 3 farmers were renting plots of a landlord. Motivation to prevent erosion was also lowest south of Voi as observed in the field. In the field was seen that farmers here did less to prevent erosion. Of interviews with farmers it became clear that motivation to act was very low. So different strategies are needed to motivate people to implement soil erosion measures. Landowners can be shown the benefits of soil conservation for the quality of their plots and the increase in income because of higher

yields. People who are renting plots are not willing to implement soil conserving measures, because the land is not theirs and land owners could claim the plots back so that the chance of return on investments is low. Solutions could be to motivate the landowners to implement soil conserving measures on the plots they have rented out or to make binding contracts between the landowner and the tenant about a renting period that is sufficiently long to make investments profitable.

- Experiences of WCT were that people only wanted to join projects if they got food or money for it. In Kalambe, near the Voi River, WCT started a project, hoping that people get motivated to join if they see the results. Trenching started just a few months back, so the farmers have not seen the results yet. Hence it is not clear whether this will motivate them.
- Observations made clear that Small Taita Hills was an exception, here motivation was quite high. For the other sub-areas motivation was moderate.

<u>Motivation</u>
Motivation in general is moderate in the research area as becomes clear of the experiences of WCT and observations in the field, however, there are regional differences observed. Motivation to prevent erosion was high in the Small Taita Hills (grid 8) and on sisal estate. On the plains Motivation varied from farmer to farmer. Near the Voi River motivation was low. Analysing the answers of the interviewees motivation seems higher. Most people in the area own land and they say that they want help. So there is at least interest in prevention of soil erosion. If it is communicated clearly to people what the benefits of a project are for them, it is possible to motivate the people already a lot.

5.2.3 Capacities of people in taking of soil conservation measures

Thirdly the capacities of people in preventing soil erosion have been studied. As indicators are taken: self-initiative to take conservation measures, maintenance of conservation measures, organization rate, and labour division between men and women. Observations are used to check the answers of respondents and to get more insight in the capacities of people. Clear sign of capabilities of people is what they are doing themselves to prevent erosion. Maintenance of soil conservation measures is a very important sign of the capacity of the local people. Good maintenance indicates that they have enough manpower and time to prevent erosion and motivation is high. Organization rate is indirect referring to capacities, because if a community is organized, they have more manpower and are capable of bigger things. Labour division between men and women can put restrictions on capacities of persons and a farmer’s family a lot. If it would be the case that a woman may not take soil conservation measures for example, this defines soil conservation to a men’s job, reducing potential labour force and capacities of women. The results are:

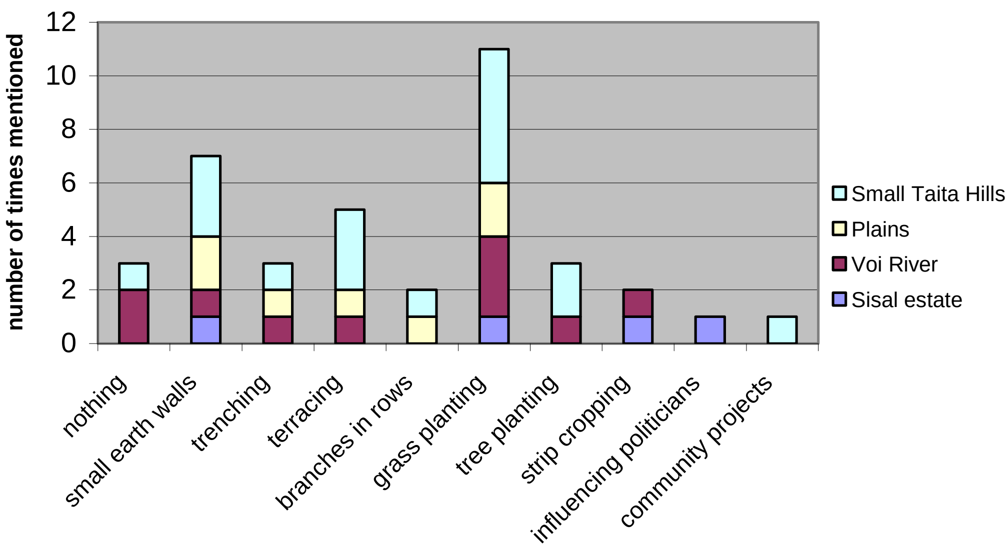
- In figure 5.2 is presented what kind of conservation measures were taken by people. In the Small Taita Hills people took the most measures, grass and tree planting and terracing were common, however most of the times not adequate just as in the rest of the research area. Small earth walls, grass planting and branches in rows were practiced in Plains area. In Voi River area only one farmer planted grass to prevent riverbank erosion and on the plots most did nothing and only a few planted grass and made small earth walls to prevent erosion.
- People were able to maintain simple conservation techniques as grass planting and their own simple measures. Maintenance of terraces and trenches was poor. Projects initiated by actors from outside had failed or it was not clear yet what would be the result while projects were still running (FDA & WCT). First results however were not positive, only sand storage dams had positive effects, because they increase the groundwater level and thereby plant cover. Only in Sisal estate area soil conservation practices were sufficient. This because the Sisal estate belonged to a wealthy Indian family who paid attention to soil conservation. There was no learning of local farmers of the soil conservation practises on the sisal estate, because crops and production process were very different and there was not much contact between the owners (Indians) of the Sisal estate and local farmers (Africans).

- Of the interviewees 7 of the 18 farmers had organized themselves and 11 of the 18 farmers had not organized themselves. The farmers that had organized themselves were all coming from the sub-areas Voi River and Small Taita Hills.
- Only 4 of the 17 farmers who responded said there was some sort of labour division in farming work. Observations supported this view related to the work done by women and men in agriculture, but women had also to take care of raising children, food, water and firewood. Men were more taking care of cattle and having jobs in towns.

Capacities

The communities are taking already quite some measures (figure 5.2), but most of the time they are inadequate or badly constructed. Maintenance of simple techniques is over the whole research area very well. Of terraces and trenches it is moderate and communal and projects of NGO’s moderate to bad. The organization rate is only high in the Small Taita Hills and Voi River. On the Plains and Sisal estate organization rate was very low. Men and women have in the whole research area the same capacities for taking soil conserving practices. However men have more time for farming than women because they don’t have responsibilities for the maturing of children, preparing food, and getting water and firewood. Therefore capacities of the farmers in the Taita Hills are above moderate. Capacities of the owner of the Sisal estate are already good enough. Capacities of people from Plains and Voi River are moderate.

Figure 5.2 Self-initiative for erosion prevention (n = 17)



5.2.4 Erosion control practiced

Awareness of erosion in the research area is quite high and all the signs are that the Opportunity is high for people to take actions against erosion. The Motivation in the research area however is moderate and the capacities of the people are greatly differing between sub-areas. In the Taita Hills and Sisal estate capacities are much higher than for the areas Plains and Voi River. Also there is a big difference between capacities used for communal affairs and own affairs. The overall conclusion and answer to research question 2 based on Opportunity, Motivation, and Capacities, is that erosion prevention practiced in the Taita Hills by local farmers on their plots is quite high, but most of the time still inadequate, on the Sisal estate soil prevention is good, and for Plains and Voi River it is moderate to low and inadequate, because most people are not very active in erosion prevention.

5.3 Discussion

The social study presented in this chapter gives a quite good impression of erosion prevention practiced by local people and why they are behaving in this way. However the weakness of this study is in the indicators chosen and the number of indicators chosen, because it was only possible to choose a few indicators for Opportunity, Motivation and Capacity because of time constraints as already explained in the methodology, chapter 2. Another problem with interviews is bias. In this study is tried to prevent bias, as also explained in chapter 2 and Collective Appendix, Interviews, but it is never possible to exclude bias totally. Bias prevention has been practiced by not wearing logos, using writing blocks or leading questions and critical analysis of answers by matching them with other interviews, observations, and secondary data review. Also the purpose of the visit was kept as vague as possible, because otherwise farmers would only give the answers you wanted to hear.
Another weakness of this study is the size of the sample group, especially of women. Because of time constraints it was not possible to interview more persons to get statistically better results, however that is also not the purpose of interviews in the RRA approach. The power of this study however is, that it gives quite accurate data and a lot of insight in the major aspects of soil conservation practiced by local people, obtained in a short time, because interviews, secondary data and observations are triangled, what is the basis of the RRA approach.

6 Recommendations for soil conservation

In this chapter soil conservation recommendations will be given for every sub-area based on the erosion risk assessment, social analysis and recommended land use. The erosion risk assessment and research into local soil erosion prevention made clear that soil conservation measures are desperately needed, especially at the foothills which are deteriorating fast. In paragraph 6.1 is discussed which types of soil conservations measures there are and which one is most preferable. In paragraph 6.2 soil recommendations will be given for every sub-area and in general.

6.1 Kind of soil conservation methods

In this paragraph will be shortly discussed which kinds of major soil conservation measures there are. The purpose of soil conservation is to reduce soil loss to an acceptable rate, the theoretically ideal situation would be that soil loss is equal to soil formation. For reducing soil loss, it is important to have conservation strategies focussed on (Morgan, 1986):

1. covering the soil against rain-splash erosion and detachment;
2. increasing infiltration of water into the ground to reduce runoff and transport of particles;
3. increasing the resistance of the soil against erosion by improving aggregate stability of the soil;
4. increasing roughness of soils to reduce velocity of water and wind and their scouring working and make sedimentation possible.

According to Morgan (1986) the soil conservation measures, aimed at the aspects mentioned above, can be divided in three categories, i.e. agronomic measures, soil management measures, mechanical measures. Agronomic measures are measures which make use of vegetation to reduce erosion by for example planting of trees, strip cropping, crop rotation and mulching. Soil management focuses on improving the soil quality and tillage conditions so that dense vegetation cover and resistance of the soil to erosion are promoted. Examples of soil management are application of manure and mulch, and tillage techniques. Mechanical measures are focussed on controlling the ways of wind and water by manipulating the surface topography. Examples of mechanical measures are terraces, trenches, waterways and dams.

For soil conservation agronomic measures are most preferred according to Morgan (1986), because they are directly handling the problem by covering the soil, increasing infiltration and reducing runoff, increasing resistance of the soil to erosion, and increasing roughness of the soil. Also agronomic measures are cheap and easily to implement in a farming system. Mechanical measures on themselves are not capable of preventing erosion, because they are not able to prevent detachment of soil particles. They have to be used always in combination with other measures. Also they are very expensive to implement and are not favoured by farmers because they give problems, for example with grazing of cattle and need a lot of maintenance (Morgan, 1986; Mekonnen, n.d.). Also, there is a risk of failure in severe storms of terraces by land sliding. Soil management on its own is also not capable of stopping erosion, because it can not control the velocities of transport agents. This however does not mean that mechanical measures and soil management are not needed. In some combinations mechanical measures and soil management measures are needed because of land use practiced or it is needed for implementation of agronomical measures (more water stored, fertility problems etc.).

6.2 Soil conservation recommendations

6.2.1 General recommendations for the research area

1. The first problem is that water management besides roads is very poor. Many roads had no furrows so that water could flow away controlled. It is recommended:
   - To make *furrows* beside the roads, because many gullies started besides roads because runoff water got channelled. With support of the local government and community it is feasible to implement this. The best is that local people themselves start to dig the furrows with support of the local government and WCT by giving them tools and supervision.
   - To *plant grass* on the verges of the roads, but this is probably not a possible measure to protect erosion, because of overgrazing. It is needed to find other ways to protect the verges at low costs. The grass could be cultivated by local people so that it is easy to get grass for planting. If the community supports the project costs are low.

2. The second problem relates to inappropriate farming practices. To change these problems it is recommended to increase the knowledge of farmers on the following topics.
   - Crop residues must not be burned but used as *mulch*. Mulch increases: soil cover and therefore protection against erosion, yields and plant cover because fertility goes up, soil moisture because of lower temperatures and improved soil structure, and resistance of soil against erosion because humus and mineral content goes up. (Morgan, 1986)
   - *Trees* have to be *replanted* when they are cut and more trees have to be planted to decrease erosion and increase income with higher yields and profit of timber or fruits (Daily Nation, 23 August 2006)
   - More *manure* (of their cattle) and at least mulch (low costs) have to be used. Farmers in the research area used almost no manure or fertilizers as witnessed in the field. Some farmers said that soil fertility was high enough. This attitude results in a decrease of soil fertility and yields (Morgan, 1986). Bad fertility and bad yields were also mentioned by other farmers as important problems for farmers (Appendix VI). This indicates that fertility is a problem for farmers.
   - *Crop rotation has to be applied well*, especially besides the Voi River. They cropped whole year trough without giving the land permission to get rest and increase in fertility again. Also they planted the same crops on the same spot too many times because they wanted to crop whole year through, especially maize, tomatoes and peppers. According to Mr. Mukusya (Collective Appendix, Interviews) it is only allowed to cultivate the same crop on the same spot once in the two years, to keep fertility of the ground high enough and to keep diseases away. Low fertility of soil leads to susceptibility of erosion (Morgan, 1986). So the farmers have to give the land rest again and may only harvest the same crop on the same spot once in two years.
   - *Mixed cropping patterns* are needed. The current custom is to plant one crop on a plot. According to Morgan (1986) it is better to plant for example maize and cassava together. This reduced soil loss with 31% in Nigeria. In the field different crops have been seen, so it is easy to implement this technique in farming methods. In table 6.1 the crops seen during fieldwork are presented so that further research can be done at good mixed cropping patterns and rotations. The crops that are bold are grown the most.

Table 6.1 Crops grown in the research areas as observed during field work.

Trees		Plants				Shrubs
fruit trees		**maize**	pumpkins	kale		cassava
papayas		local crops	water melons	spinach		**cow peas**
bananas		beans	sweet potatoes	sisal		green peas
coconuts		**tomatoes**	cabbage	**peppers**		pigeon peas

- *Good irrigation practices are necessary.* Irrigation practices of farmers near the Voi River were not very well as also stated by Mr. Mukusya (interview). Farmers are using boxes, rectangular plots with earth walls around it, to crop. They practice flood irrigation so that the whole box will be under water. The roots of the crops are standing too long in water and start to decay because of that. Because flood irrigation is used the disease will spread through the ground with the water, infecting other crops. Farmers should better, as Mr. Mukusya suggested, use rows in which they plant the crops and irrigate only the furrows between the rows. In this way roots will not decay so soon because they are less than 48 hours wet and diseases will not spread with the water (Morgan, 1986). Plant diseases reduce vegetation cover and strength of vegetation protecting soil against erosion; therefore it is needed to change this. Also farmers could abandon their plots for cultivating new plots and clearing therefore vegetation, causing decrease in vegetation.

If these techniques will be taught to farmers with emphasis on their benefits and they are accompanied for several years, it has to be feasible to implement these farming techniques. The farmers could be taught these techniques in seminars, but what is most important is that these techniques are learned in all the projects started by WCT. So education through projects and the structure of projects have to be so that farmers will learn these techniques.

3. The third problem is about re-vegetation of the research area. Because vegetation cover is low throughout the research area it is important to increase vegetation as soon as possible so that soil loss can be reduced, soil moisture could go up and ground temperature could go down, and the environment and opportunities of people could be changed. (Morgan, 1986)
   - For re-vegetation *mixtures of trees and shrubs species* have to be planted, to increase soil strength and plant cover. Mixture of trees and shrubs species is recommended because it is difficult to predict which specie of trees or shrubs are going to do well and more the same species are more vulnerable to diseases. It is preferable to use indigenous species for the re-vegetation programme, to keep biodiversity good and to protect local nature. (Morgan, 1986) The best is that the trees are matured by local people themselves, but some areas need to be re-vegetated fast so that it could be wise that WCT plant trees. This is of course extremely costly.
   - *Soil quality* has to be determined regarding pH, humus content and so on. On basis of these tests tree and shrub species and soil management practices like applying fertilizers, have to be chosen. (Morgan, 1986; De Graaff, 1993)
   - If it is *possible to make terraces* on the hill slopes without risk of failure, it would be advisable to plant trees on small terraces. But it has to be stated clear that more research into the latter is urged; for every slope again research needs to be conducted! This to make sure that the stability of the hill is well. Terraces enhance the infiltration of rain water and trees are heavy, so that soils that are not stable will flush away if too much water will increase (Morgan, 1986). So it is important to do research to the characteristics of storms with a return period of 10 years, soil texture, soil strength etc. All these data is needed for the design of a stable and save terrace system. It is also important to take the design of water ways into account, which can be used as drainage for excess water. For every hill slope this research is needed, to take specific local conditions into account.
   - Re-vegetation needs to consist also of planting of different *grass species*, so that the ground is better protected to rainsplash erosion and overland flow. Recommended are *napier grass and vetiver grass* because of their deep rooting. In areas where grazing is practiced they are also good fodder, so that farmers can increase their income. (Mekonnen, n.d.; Morgan, 1986; Interview F7) In the area napier grass is already widely used, so that it is feasible to plant more of this grass with local grass production.
   - However re-vegetation is not feasible as long as people have no better opportunities to get firewood or pasture for their animals. So people have to be *taught* how *to collect firewood* in a *sustainable* way, by cutting and replanting just as in Machakos, Kenya (Daily Nation, 23 August 2006). In Machakos farmers increased the number of fruit trees they cropped tenfold by taking initiatives to conserve their environment. The people have to learn the value of tree

cropping. Now they see trees more as a "kind of common good that may be cut". Sustainable forestry by replanting trees with seedlings they matured for trees they harvested is feasible. People can mature enough seedlings as observed in the field and in Machakos (FAO, 1991.; Daily Nation, Nov 11, 2006), if their attitude is right.

- Grass cover can only recover well, if the *cattle carrying capacity is not exceeded* anymore. In the research area is kept a lot of cattle, mainly cows and goats. The herds are wandering through to bush in search for food. Cattle is grazing everywhere, even on the steepest and rocky parts, causing tremendous damage to vegetation. Especially goats are damaging the vegetation, because they eat besides grass also the bark of trees and shrubs as observed in the field. According to Rwelamira (1999) this problem could only be solved by *abolishing the communal land tenure* that is practiced for livestock grazing. He argues that people start to keep fewer cattle if it is their own land that is deteriorating. However this plan is only feasible with local government support. Local government has to give title deeds to people and to prevent them from grazing in the bush. Another way to decrease grazing of cattle in the bush is by *stimulating zero-grazing*, but for most farmers this will not be possible of the high costs of keeping dairy cows. Probably more research is needed to find ways to let the people make use of pasture in a sustainable way.

6.2.2 Recommendations per sub-area

Voi town & Mwakingali Hills

In the outskirts of Voi erosion risk is high and soil conservation measures are needed fast because the environment is deteriorating. Gullies are forming a big threat to the people and their property, because they are sweeping away houses and plots and are undermining roads and water pipelines and have therefore great social consequences. For recommendations on soil conservation measures has been looked at the morphology of the landscape, erosion risk, and socio-economic factors.

- It is important to *manage the water streams* at the southern foothill of Mwakingali Hills, so that it is possible to control soil loss and to re-vegetate the hills. Around Mwakingali Hills therefore it is needed to make *trenches* that can lead the excess water to the Voi River and gives water more time to infiltrate into the ground. (Morgan, 1986) This is necessary because it is not feasible to get a vegetation cover at the beginning to stop overland flow, because of the dry climate which does not favours vegetation growth. Also the rains are so intensive that it is not possible for plants to store all the water of a shower. So trenches are needed to give the water time to infiltrate trough the crusted soil and to reduce soil loss. In this way it is possible to prevent overland flow and channelling which could lead to gullying. Furthermore overland flow was in the whole area also a problem as witnessed in the field during rains. So where possible *trenches* have to be made in the outskirts, so that water gets more time to infiltrate into the ground and vegetation cover could be restored. For more information about making of trenches see Appendix VI. For leading the water from the mountains to the Voi River the bigger gullies could be used as *waterways*, if protected well with stones and grass. This plan is feasible, if support of local government and local people is obtained. Very important is that local people and/or the government are helping with equipment and labourers, to keep costs down. Else it is not feasible for WCT to do the project. Support is likely to get, because gullies are threatening property of rich and poor people, so it is a problem of all the people.
- The outskirts and hills need to be *re-vegetated* with mixtures of tree and grass species. For more details see 6.2.1, recommendation 3. Also the southern slopes of the mountains with land classifications VI, VII en VIII have to be closed for animals and men to give vegetation a chance to come back. A fence around these areas is needed, what is costly for WCT because local government will not support these plans. On these places of the hills overgrazing and cutting of trees and shrubs is at the moment a very big problem. Closing of the area however will not be feasible, because it is expected that local support will not be obtained. The only way to re-vegetate the hills is by trying to re-vegetate the *outskirts* with enough *trees for sustainable firewood* production and to re-vegetate the hills at the same time. This project would cost WCT a lot of money (if they buy the seedlings) or it will take years to reach this

state if local people have to mature seedlings themselves and to get their support for the project. Another less likely possibility is to make the hills a part of Tsavo East National Park, so that park rangers can protect the area. The latter however is not advisable, either because this will only make the problem move or confrontations between wildlife and men severe. So re-vegetation is difficult and therefore the feasibility is low.

- *Gully reclamation* measures need to be taken. Therefore *check-dams* have to be constructed in the gullies at several places in combination with *agronomic measures* as *grass* and *tree planting*. (Morgan, 1986) It is advisable to use dam building materials that the local people can get themselves at low costs. Because as becomes clear of chapter 5 and observations in the field, people are poor, motivation is moderate and knowledge is sometimes insufficient. Therefore it is important that local people get a sense of ownership, get the knowledge to take the measures, and that it is feasible for them to build the dams and maintain them *by themselves* (European Commission, 2004). Advised are *double fence-dams and loose-rock dams*, because it is possible to get the building materials for these dams in the area and these dams are strong enough to withstand the forces of water streaming with great force through the gullies (Morgan, 1986). In Appendix VI is explained what a double fence-dam and a loose-rock dam are and how gullies can be reclaimed. For every gully exact plans still have to be made regarding place, design and forces to withstand, agronomic measures and so on. With support of local government and people it is possible to stop gully erosion.

Sagala Hills

The Sagala Hills are very steep, rocky and bushy. Therefore water rushes from the hills towards the Voi River. At the foot of these hills too much cattle is grazing and people are collecting firewood. Because of that gullying is at some spots severe and erosion risk is above moderate to high (paragraph 4.4).

- The areas with land classification VII and VIII have to be *closed* for animals and men, to *restore and protect vegetation*. Especially at the foothill, classified as VII, grass cover is deteriorated. The area classified with VIII is easy to close, because the hills are forming already a barrier themselves. The foothills are difficult to close as described in 6.2.1, recommendation 3, bullet 7. A fence or something else is needed to close this area. This is very costly and not really effective probably. Local government support is needed to make it official and support of local people to make it successful.
- The foothills need to be *trenched* to increase water infiltration and storage so that plant cover could be restored and to reduce soil loss. Hence, trenches are needed to make the implementation of agronomic measures successful and to prevent channelling and loss of water by giving water time to infiltrate. So trenches are in this area, because of its arid characteristics, important for the implementation of agronomical measures. The soils at the foot of the Sagala Hills are firm and therefore strong enough to avoid landslides and the slope is low to below moderate (chapter 4). The trenches should be dug as much as possible with the help of local people. In this area however this could be a problem because of the low population density. So it is possible that WCT has to hire people to trench some important parts in this area. Feasibility is therefore moderate, because it is not sure if there is enough support of locals to help dig the trenches. If this is not the case costs will be very high. For more information about making of trenches see Appendix VII.
- *Waterways* have to be established at the foothills at places that are eroded severe to carry *excess water* controlled away, just as at Mwakingali Hills. Therefore some gullies have to be channelled and planted with grass. Trenches have to be placed at spots where much water is running down from the hills to convert it to the channels and to give water time to infiltrate into the ground. It is important that the spillways are made in such a manner that the area can carry such an amount of water that the chance on land slides is negligible. So it is important to pay attention to the risk of landslides in the preparation of trenches. But because the slopes are strong not much problems are expected. The waterways have to be constructed with the help of local people, because else the project will not sustain in the future. It needs the maintenance of locals. Because gullies are such an important problem and danger for people, local support is very likely to get.

- Gullies, which are not used as waterways have to be *reclaimed* by using *double-fence brush dams* and *agronomic measures* as tree and grass planting is needed to prevent erosion as is described for Mwakingali Hills and in Appendix VI.

Sisal Estate
The recommendations for the sisal estate are simple: *just keep it as it is*. Soil conservation is practised already well, because there were no clear signs of erosion. Only besides some roads there were some small rills but this was negligible and erosion prevention here was not economic, because rilling was not severe enough and soil was intercepted by grass and sisal besides the roads. On the sisal estate *strip cropping* is sufficient, because it is used at slopes below 8.5º (Morgan, 1986). On the orange estate *vegetation cover is high*, because of trees combined with grass. There were only problems with erosion under the canopy of the orange trees, but this problem was solved by putting the trees in a ditch with an earth wall around it. (Interview F6)

Plains
The Plains are dry and most farmers are depending on rain only. Vegetation cover exists out of acacia shrub and sparsely growing grass. Grass is on most places gone, because of overgrazing by big herds. Also lot of acacias are cut for firewood and agricultural plots. So vegetation cover is decreasing rapidly. Luckily erosion varies from low to moderate. But to keep erosion risk low and to improve the environment of the research area, it is needed to restore vegetation.

- *Re-vegetation* has to be done in two ways. First of all the *farmers* have to be learned to *plant more trees* for their own benefit. It is difficult to change farmer's behaviour, especially on the Plains, because overall motivation is moderate and capacities are moderate. But it is possible as showed in Machakos, Kenya (Daily Nation, 23 August 2006). Secondly the bush parts have to be re-vegetated with a mixture of tree and shrub species and grasses as described in 6.2.1, problem 3. The re-vegetation is therefore only possible with support of the farmers. They have to be taught to mature seedlings for their own benefit and that of the area. Thirdly the area needs to be *trenched*. Trenching on its own is enough to bring soil loss to acceptable levels, because erosion risk is moderate and the slope is lower than 5º (Morgan, 1986). It is important that grass is planted on the sidewalls of the trenches to protect it from collapsing, while soils are soft (Chapter 4). Napier grass or vertiver grass are good for this purpose, because they are rooting deep, filtering soil out of the water and are good fodder. (Morgan, 1986; Interviews & observations) Trenching is good, because it increase infiltration of water and helps therefore to restore vegetation cover and it brings soil loss down. Trenching of the Plains is feasible; however it is not sure if the whole Plains could be trenched by local people themselves, while population density on grid 5 is very low. Therefore it is best to start on the plots of farmers themselves. These areas are also most vulnerable to erosion because of bigger changes in vegetation cover. More information about trenching can be found in Appendix VI.
- A few gullies need to be used as *waterways* for excess water. These gullies need to be protected well against the scouring actions of water by planting of grass and/or using a stone layer. The gullies that need to become waterways are the wadi running from the Taita Hills on grid 8 to grid 5, the wadi coming from the Taita Hills on grid 7, the two long gullies on grid 6, and the very long gully from Irima to Voi River. This plan is very feasible taken social conditions into account.
- On the Plains *the other gullies need to be reclaimed*. The *gullies caused by changing of vegetation cover* can be *reclaimed by using loose-rock dams or double-fence brush dams.*. Some of the *gullies* on grid 6 however are *caused by piping* and therefore it is not possible to reclaim them in the same way (Morgan, 1986). These gullies can only be stopped by creating a uniform infiltration pattern so that tunnels are not fed. Trees with long tap roots are therefore not recommended. The best method therefore is to establish a dense grass cover. In this area this is probably not feasible because of overgrazing and the dry climate. Therefore *shrubs and trees with a lateral system of roots* have to be used (Morgan, 1986). This plan is very feasible taken social conditions into account.

Taita Hills

In the Taita Hills erosion risk is most severe and motivation and capacities are highest of the research area. The need and opportunities of projects is therefore highest in this sub-area of the research area (chapter 4 & 5). The Small Taita Hills are just as Sagala and Mwakingali Hills very steep.

- Areas with land classification VIII need to be *closed* for men and cattle. Vegetation cover in this area is still high so that further measures are not needed. It is feasible to implement this plan, because the hills are forming by themselves already quite a natural barrier because of their steep slopes. However local government support is needed.
  The foothills of the hills, with land classification VII need also to be *closed* for men and cattle to *restore vegetation cover*. Gullying, overgrazing and woodcutting in this area are severe. Because of decrease in vegetation cover even a landslide took place near Mkwachunyi, grid 7, as witnessed in the field. The problem however is the same as for Mwakingali and Sagala Hills: people have no other opportunities to get pasture for their cattle and fuel wood for cooking. So the same solutions are also recommended for this area as described in 6.2.1, recommendation 3. A fence is needed to close the area and local support is needed to protect the area. Feasibility of these recommendations is for Taita Hills maybe higher, because motivation and capacities of these people are higher.
- *Gully reclamation* has to be *examined*, because it is doubtful for some parts in this area if economic benefits are high enough compared to costs, because gullying on some spots is very severe. Were it is economically feasible, loose-rock dams and double-fence dams are recommended. Gully reclamation has to be planned well with the planning of *waterways* to control *excess* water of the mountains. Some gullies are needed to act as a waterway. The plans however are feasible, because motivation and capacities of people are high.
- The *areas with land classification III or IV, with slopes above 5º* need to be *terraced* to control soil loss (Morgan, 1986). Level bench terraces, combination of trenches and level terraces, are strictly ***not*** recommended! It is needed first that more research will be conducted on the characteristics of a storm with a return period of ten years for the areas and soil texture and strength are determined etcetera (Morgan, 1986). This is needed, because according to Morgan (1986) bench terraces were susceptible to failure by saturation in the Uluguru Mountains, Tanzania. This area is probably also susceptible to land sliding because there has been already a landslide. Only *ladder terraces, also called fanya juu,* are suitable without risks (see Appendix VI). This kind of terraces rarely breaks down (Morgan, 1986). Also fanya juu is a simple technique to implement (De Graaff, 1993), because the technique can be derived from local practices and takes less effort to construct compared with other types. However in most parts of Kenya bench terraces are suitable (which infiltrate more water than fanya juu) (Morgan, 1986). So, *extra research* is needed on this topic. It is important that in the terrace plan *waterways* are taken into account to get rid of excess water of storms with a return period of ten years and that the terraces are designed for storms with a return period once in the twenty years according to Morgan (1986). The ends of the terrace banks have to be planted with grass to reduce soil erosion. (FAO, 1991) The waterways can be made of grass or grass with stones, depending on steepness of the slope. Terracing in the Taita Hills is necessary because of the present agricultural land use. On the moment large parts of the area are used as agricultural plots. So vegetation cover is important parts of the year low in between the cropping seasons. Only agronomical measures as grass planting are not as effective and sufficient as terraces combined with agronomical measures because of the steep slopes in this area. Terracing is however, according to Mekonnen (n.d.), not a sustainable solution, because farmers have only hinder of the terraces and maintenance costs are too high. Morgan (1986) also states this. According to Mekonnen (n.d.) the reason, that grass planting is more effective in countering soil erosion in Ethiopia than terraces, is that grass planting increases farmers income by selling fodder. He argues that farmers are not motivated to maintain terraces, because this cost them a lot and does not create them direct income. From chapter 5, the social study, it becomes also clear that grass and tree planting is more favoured by farmers in the research area because they have income of it. However grass planting only can not reduce soil loss enough to prevent depletion of the soil which will enhance soil loss. Therefore it is still recommended to implement terraces to save the area of deterioration. *Before starting* a

terracing project it is important to know if the community is going *to maintain* it, because the risk of failure will otherwise be too big. If it is uncertain that farmers will maintain their terraces, it is better to start with planting of grass and trees just as in Machakos and Ethiopia. (Daily Nation, 23 August 2006; Mekonnen, n.d.) Grass planting fits at least in local cultivation practices as recommended by De Graaff (1993). Terracing as well as grass and tree planting are feasible, because the people in this area are motivated and have quite some capacities. If the attitude of the local farmers towards terraces may not be good, it is better to start only with grass planting projects instead of combined grass and terracing projects.

- The bush parts have to be *re-vegetated with a mixture of tree and shrub species and grasses* as described in 6.2.1.

Voi River

In this sub-area measures have to be taken on the plots along the river and at the riverbed itself. For the river riverbank stabilization measures are needed, because flush floods are deteriorating the riverbanks and erosion risk for the riverbanks is high (see Collective Appendix Maps, type D).

- Farmers need to plant *grass* for *riverbank stabilization*. Best is vetiver grass because of its deep rooting. In the field it was observed at F7 (Collective Appendix, Interviews) that it worked very well and also Mekonnen (n.d.) reported positive result of this grass in soil conservation for Ethiopia because the farmers can use the grass for fodder and therefore it generates income. But if it is too difficult to get vetiver grass or farmers prefer napier grass better, this is also a good option. Napier grass is already very common in the research area under farmers, so it is easy to implement. It is feasible to implement this plan, because the fodder of the grass can generate income for farmers, the grass protects their plots and costs of planting and getting the grass are low. So capacities and motivation don't have to be high.
  At some places, where riverbank erosion is very severe or the river starts to change her course, it is needed to use *gabions* (rectangular steel wire-mesh baskets, packet tightly with stones) for riverbank protection. The costs of this measure are higher and farmers have not much direct benefit of it, by increased income as for grass. Therefore feasibility is probably lower. Also gabions have to be anchored in the riverbank, so *civil engineering skills* are *needed*.
- *Sand harvesting* in Voi River should be *regulated* better by local government, because it makes the river change her course, it increases riverbank erosion by scouring out of the banks by people, and it decreases the ground water table as witnessed in the field and stated in *Daily Nation* (Friday, Nov 11, 2005). Also it is not carried out in the sustainable way as asked in the *Sand harvesting guidelines for Eastern Province* (Muusya Mwinzi, 2006). Sand is harvested near riverbanks, on riverbanks, to great depths, near bridges, and without using sand storage dams and so on, not taking into account environmental consequences and restoration of the environment as observed in the field and asked by the National Environment Management Authority of Kenya (NEMA) (Muusya Mwinzi, 2006). Sustainable sand harvesting is only feasible if the government regulates it better. For WCT it only possible to built with the sand harvesters a *sand dam* to decrease environmental impacts. This could be done in combination with building of *sand dams to mitigate floods* that are severe in the rainy season, sweeping away crops and deteriorating plots (Interviews F3 & F8). In China dams are used a lot to mitigate floods and it is quite effective according to Chun-Tian Cheng & Chau (2004). In this way also more water is stored (Westerveld & Van Westerop, 2005). The feasibility of building dams is high, because WCT has a lot of experience with dam building and local people as well as the harvesters will support the plans. The costs however are also high, because the building materials for dams are costly.
- *Trenches* are needed to control soil loss, increase infiltration for restoring vegetation and to mitigate the effects of flooding. Because capacities and motivation are moderate success of these plans is moderate. To increase the feasibility and motivation of people to start water storage and erosion prevention projects, it is important to start on the plots of the farmers and to do after that crucial bush parts.

6.2.3 Overview

Of all the recommendations made in paragraph 6.2.1 and 6.2.2 has been made an overview in the tables 6.3 and 6.4. Also these tables present more clearly if the recommendations are feasible and what the priority is to implement them. There are some important remarks on the tables.
The basic recommendation for a successful implementation of soil conservation activities is that it is important to *make the local farmers owners of the projects*. It is very important that the local people have a sense of ownership and that they are motivated to solve the problems in their region (EC, 2004). De Graaff (1993) says about this topic that soil conservation projects are only successful if all the actors in sustainable land use are taken into account. To get the local community motivated and owner of the project is it important that (De Graaff, 1993: p. 66):

- soil conservation activities have to be integrated with landholders' normal husbandry practices;
- once farmers have recognized the advantages, they should be able to benefit individually;
- activities outside individual landholdings and beyond the capability of individual landholders should be a public or community responsibility;
- villagers should participate in all stages of planning, design, implementation and monitoring of conservation activities, so a village approach is needed.

The local people are than willing to offer time and labour. In this way it is possible for WCT, who has a limited budget, to get enough labour etc. to implement the projects low budget. If support of the local people is not obtained, project costs will be very high and the projects will probably fail because there is no support of the people.
So it is also very *important to get local support*. This can be obtained best by starting *small scale pilot projects*, just as WCT is doing now (De Graaff, 1993). For these projects the budgets can be low and if done well it is possible that people start to join if they see the benefits. In this way it is possible for WCT to continue their work with the budgets they have now. On the moment however WCT does not have a local NGO that is working fulltime on the project. If WCT wants to re-hydrate this area however this is important, because it is possible to keep in touch with local people, to do more research, to keep the project going etc. On the moment there is not a local project organisation which is causing a discontinuous process and poor contacts with local people. So it would be best to have *a local NGO based in Voi* working on the re-hydration project.
It is very important to *learn the people capacities in the projects*. So it is not only important to get the trenches etc., but it is also wise to learn them how the trenches are constructed etc. This has been very important in Machakos area. In this area have been many projects of NGOs and the government to solve the problems of dehydration, but most of them have failed. After the NGOs and government stopped their help, the people started to act and the area is now the success story of Kenya or even Africa (Daily Nation, 2006). With the capacities they learned in these projects they managed to improve their own area. So ownership, as can be seen of this example, is very important besides learning of capacities of people. This can also be explained with the theory of Poiesz. Poiesz sais that Opportunity, Motivation and Capacities have to be all there before a person will act. So Opportunity is there as determined in chapter 5. If the Capacities are increased, it is easier for a person to get more Motivation because the other factors are already high and "forcing" him to get Motivation. So if the people have got more capacities and the project would fail, the chances are higher on continuation of the project by people themselves.
To get the people involved and motivated it is best to *start on the plots of the people*. This because people are most interested in their own direct benefits. So if the plots are improved and yields will go up, they will be more interested to solve the problems for less important areas. They will understand that the less important areas will give them also benefits as more water available in the area, less erosion, more wood etc. So in this way feasibility and willingness of people to join are increased.
In this light it is also *important to think about the order in which recommendations are implemented* in projects. Before re-vegetation is possible, it is important that there is enough water. So it could be wise

to make first trenches and to plant the vegetation after the first rains. The plants will have than at least quite some water.

In table 6.2 has been given a summarization of all the characteristics of the different sub-areas. The erosion risk (chapter 4) and Opportunity, Motivation, Capacities (chapter 5) are presented. On basis of the results of chapter 4 & 5 and observations in the field have been made a ranking. This ranking is used to determine where it is most needed to start with projects. The ranking is based on a combination of the severity of the problem in the area and the motivation and capacities of people. In the Taita hills erosion risk is highest just as the capacities and motivation of the people. So it is best to start in this area to get people in the rest of the region motivated and to keep costs down. In Sagala Hills en Voi town & Mwakingali Hills the problems are the biggest. About Opportunity, Motivation, and Capacities is no information available, because no interviews have been done here. But because the problems are so severe, erosion prevention is needed fast. In the area Sagala Hills erosion prevention is probably less complicated than in the area Voi town & Mwakingali Hills, because it is not the city. However there are not so many people living in the area Sagala Hills. Observations in the field however gave the idea that it was more feasible to start near Sagala Hills because people were farmers so that it is possible to start on their plots. Also it is expected that the local government would not interfere in the Sagala Hills as is assumed it will do in the area Voi town & Mwakingali because it is there ground. After that erosion risk is the biggest in the area Voi River. Motivation and Capacities however are not really good. On the Plains erosion risk is less severe as in the area Voi River and Opportunity, Motivation and Capacities are moderate. Because erosion risk in the area Voi River is higher and the other factors Opportunity, Motivation and Capacities of both areas are not well, Voi River area has rank 4 and Plains 5.

Table 6.2 The characteristics of the different sub-areas.

Sub-area	Erosion risk	Opportunity	Motivation	Capacities	Priority
Voi town & Mwakingali Hills	(above) moderate	-	-	-	3
Sagala Hills	above moderate	-	-	-	2
Sisal estate	below moderate	moderate high	high	high	-
Plains	(below) moderate	moderate	moderate	moderate	5
Taita Hills	high	high	high	above moderate	1
Voi River	below moderate	high	low	moderate	4

Of the sub-areas Voi town & Mwakingali Hills and Sagala Hills are no data about Opportunity, Motivation and Capacities, because there have not been conducted interviews here. In the sub-area Sagala Hills the population density is low and in the sub-area Voi town and Mwakingali Hills it was not feasible to speak to people who could play an important role in soil conservation (more information paragraph 2.3.2).

In tables 6.3 and 6.4 is also standing the feasibility and priority. Feasibility is scaled as follows: very bad, bad, below moderate, moderate, above moderate, good. This scale is qualitative and based on the description of the recommendations in paragraph 6.2 and the results of the research as presented in chapter 4, 5 and observations in the field.
Priority is scaled as follows: low, below moderate, moderate, above moderate, high, very high, extremely high. Priority has been based on how erosion can be solved the most and the best and what will have the most effect at stopping erosion.
Van Bodegraven (2006) has taken all these recommendations into account in his report. He has made an integrated plan for soil conservation and water storage for this part of the Voi River catchment. Therefore is also not given a Multi Criteria Analysis in this report, because in the report of Van Bodegraven is presented the integrated plan.

Table 6.3 Overview of general recommendations and their feasibility and priority.

General recommendations:	how	feasibility	priority
Water management besides roads			
furrows	digging of furrows by locals with support of government and WCT	moderate	very high
grass planting on verges	cultivation of grass and planting by locals	bad, because of overgrazing	high
Inappropriate farming techniques	seminars	good	very high
mulch	projects to learn people techniques		
(re)planting of trees	education through structure of projects to learn people techniques		
manure			
crop rotation			
mixed cropping			
irrigation practices			
Re-vegetation			
planting of mixtures of trees & shrubs	research into best species, planting of trees	moderate	extremely high
soil management	determination of soil quality and on basis of that strategy	good	high
terracing	research into planting trees on terraces; more water available	good	moderate
planting grass	planting napier or vetiver grass	good	high
sustainable use of trees for (fire)wood, fruits	seminars and tree nursery programmes	moderate	very high
sustainable cattle keeping	stimulating zero grazing, abolishing communual land tenure	very bad	high

Table 6.4 Overview of recommendations per sub-area and their feasibility and priority.

Recommendations for sub-areas:	how	feasibility	priority
Voi town & Mwakingali Hills			
waterways & trenches	canalizing gullies, trenches; help local government & people needed	good	very high
trenches for infiltration of water	digging of trenches with help of locals	moderate	very high
re-vegetation of outskirts and hills	with support of locals and maturing of seedlings by locals	below moderate	very high
closure of areas VI, VII, VIII	fence; support of local government needed	bad	low
gully reclamation	double-fence brush dams and agronomic measures	good	very high
Sagala Hills			
closing of areas VII & VIII	support government and local people; fence	VIII good; VII bad	moderate
trenching of foothills for water storage	digging of trenches as possible with help of locals	moderate	high
waterways	canalizing gullies; trenches with spillway	above moderate	very high
gully reclamation	double-fence brush dams and agronomic measures	above moderate	very high
Plains			
re-vegetation	projects for farmers to mature seedlings and plant them	good	high
waterways	canalizing some gullies	good	moderate
trenching	digging of trenches as possible with help of locals: start on plots	good	high
gully reclamation (changing vegetation cover)	double-fence brush dams/loose rock dams & agronomic measures	good	above moderate
gully reclamation (gullies by piping)	N.B. Piping: dense grass cover or shrubs with lateral roots!	moderate	above moderate
Taita Hills			
closing of areas VII & VIII	support government and local people; fence	very bad	moderate
gully reclamation examination	research to benefits and cots of reclamation	good	high
waterways	canalizing spillways; waterways for terraces	good	very high
terraces areas III, IV with slope > 5º	ladder terraces	below moderate	high
re-vegetation of bush parts	mixture of trees, shrubs and grass	moderate	high
Voi River			
riverbank stabilization	grass planting (and gabions)	above moderate	high
sand harvesting regulation & sand dams	local government support and sand dams	good	high
trenches	digging of trenches as possible with help of locals, start on plots	moderate	high

7 Conclusions and recommendations

7.1 Conclusions

All kinds of erosion induced by water have been seen in the field. Overland flow was present in the whole research area. Rills and gullies were seen also many times (Collective Appendix II). In the Taita Hills was even a big scar of a landslide. So signs of erosion were clearly visible in the field as also stated by drainage density and texture. Erosion was mainly caused by human activities such as deforestation, inappropriate land use techniques, fuel wood collection, settlement, and overgrazing. Because of the climate zone, semi-arid, the area is vulnerable to erosion. Anticipated climate change may enhance erosion even more. Erosion is influencing the activities of people. Gullies are damaging houses, roads, plots and nature as observed in the field and stated by Sirviö et al. (2004). Because of erosion and decreasing vegetation cover, water storage is decreasing too, causing more erosion. Hence, the problem definition is: in the Voi River catchment the capacity of water storage is too low and erosion too high because of decreasing vegetation cover. The objective of this research is to give recommendations on soil conservation measures for a part of the Voi River catchment based on an erosion hazard assessment and data on how soil conservation is rooted in the socio-economic structure of communities, obtained by field measurements, interviews and observations.

The goal of the first research question was to determine the erosion risk of sub-areas. To determine the erosion risk it was necessary to look at the susceptibility to erosion (erosivity) and the erosion intensity of areas. Erosivity has been measured with the parameters slope, difference between recommended and present land use, soil characteristics, and rainfall aggressiveness (Morgan, 1986).
Of chapter 4 it is possible to give some conclusion about these parameters. Slope indicated that the hills and foothills were susceptible to erosion. Difference between recommended and present land use indicated that especially foothills were susceptible to erosion because of human acts. In the Taita Hills and southwest in the research area, near the Voi River, are some areas of very soft soils, so that these areas were susceptible to erosion. Rainfall aggressiveness could only be used as a general parameter for the whole research area, because only weather data of Voi was available. Rainfall aggressiveness was highest in April and was quite high for the area taken into account aridity, low plant cover, and the fact that rainfall intensity is highest at the beginning of the rainy season and plant cover the lowest.
Erosion intensity was measured with drainage texture (number of first order streams per km^2) and drainage density (km gully per km^2). Erosion intensity was highest in big parts of Taita, Sagala, and Mwakingali hill-ranges, because both drainage density and drainage texture were high in these areas, especially in the Taita Hills. For large parts of the plains drainage density and drainage texture are low to below moderate.
In the area have been seen all types of erosion: overland flow, rills, gullies and a scar of a landslide. Important with this is that there have been seen three types of gullies. First type, gullies caused by changing vegetation cover, what was the most common type. Second type, gullies caused by piping on grid 6. Third type, gullies caused by the scar of a landslide, grid 7. These observations are important, because this has several consequences for recommendations to stop gullying.
Erosion risk of an area is combined of the parameters for erosivity and erosion intention. The answer on the first question, what the erosion risk of sub-areas is, has therefore been determined with factorial scoring the parameters slope, difference between present and recommended land use, soil characteristics, drainage texture and drainage density for every 0.33 by 0.33km grid. Erosion risk was highest for the hill areas, especially for the Taita Hills. Also erosion risk south of the Voi River in the hills near Kalambe was quite high. For the rest of the areas erosion risk varied between low to moderate.

For giving recommendations about soil conservation, it was not enough to determine the erosion risk of areas. It was needed to get insight into erosion prevention by local people. The research into erosion prevention by locals has been based on the theory of Poiesz, which tries to explain human behaviour by the factors Opportunity, Motivation and Capacities. Therefore interviews with local farmers have been done to determine these factors of the local people in conservation practices.

In the whole research area erosion was regarded as a big problem by local farmers, so the environment was forcing people to take soil conservation measures. So the Opportunity was their for people to act against erosion. The overall Motivation of people to take conservation measures however was moderate as indicated by experiences of WCT and field observations. Motivation to prevent soil erosion was for the Small Taita Hills quite high compared with the other sub-areas, for Plains it differed from farmer to farmer and near the Voi River motivation was low. The capacities of people to prevent erosion were in the Taita Hills above moderate, of Sisal estate already good enough, and for Plains and Voi River moderate.
On basis of these results the overall conclusion on erosion control practiced by local farmers was for the Taita Hills that it was quite high but most of the times still inadequate, for Sisal estate high and adequate, and for Plains and Voi River moderate to low and inadequate.

Erosion risk and research into soil prevention by local farmers, and observations in the research area have made clear that soil conservation is needed fast, because especially the foothills are deteriorating fast. Conservation recommendations have been made in general and sub-area specific. The soil conservation recommendations exist of agronomic, soil management, and mechanical measures. Agronomic measures are preferred most, but mechanical measures as trenches and terraces are needed. Mechanical measures are needed to make it possible to use the land in present way and to store more water so that vegetation can grow and erosion will be stopped.
Further there have been given some recommendations about how WCT has to implement the soil conservation recommendations. It is very important that WCT gives the people ownership, motivate the people, give the people more capacities and start projects on the plots of people. Also it is important to have a project organisation in Voi, who could manage to project and could keep in touch with the local people.
Based on erosion risk, Opportunity, Motivation and Capacities, it is best to start conservation projects in the Taita Hills. The other areas are also important, especially Voi town and Mwakingali Hills because of the danger that erosion is exposing the people there. But in these other areas it takes more time and efforts to implement soil conservation practises and erosion risk is lower. So this recommendation is only meant for the start of the project. In this way it is hopefully possible to motivate people if they see the benefits of the project so that in the whole area it is possible to bring erosion under control.

7.2 Recommendations

There are several recommendations for further research. The recommendations and their importance are summed up here below. The recommendations have been divided in recommendations for further research and for project performance.

Recommendations for further research

1. For this research no data on soil loss, measured in the field, has been used. However it could be wise to do measurements on soil loss in the field in the rainy seasons, to check if the research area could be matched with scientific studies of semi-arid areas in East Africa and soil loss models as the Universal Soil Loss equation (USLE). Because of the specific local conditions it is not possible to exclude that the area is special in its kind and needs therefore special solutions. If not it is easier to determine effective implementation approaches and conservation measures on the results of other projects. Also this research gives more insight in the severity of erosion in the area.
2. At the moment WCT does not know what the effectiveness is of trenches on reducing soil erosion. However it is very important to know under which specific conditions trenches are most effective and with which other soil conservations measures it could be combined best. Also it could support the use of trenches by WCT and their experience in dealing with erosion and water storage problems in semi-arid lands. In Appendix VII can be found a proposal for research into effectiveness of trenches in reducing soil loss.
3. Good decisions on what kinds of soil conserving measures are needed are depending on characteristics of local weather, especially for making decisions about the kind of terraces

recommended. Also it provides more tools to determine erosivity, such as rainfall aggressiveness and energy of rainfall or rainfall intensity erosivity (Morgan, 1986). Local weather varies very much, because of the great height differences. Because of that weather data of Voi only is not representative for the whole research area. Therefore it is needed to do more research into the characteristics of local weather.

4. More research is needed into the characteristics of the soils in the research area. Because equipment for this research was limited, not much good data on soils could be obtained. However, soil characteristics or erodibility are important for making the right soil conserving recommendations, i.e. it is important to know for example of a soil on a steep slope will flush away easily (is susceptible to land sliding) so that terraces are not possible. This research gives therefore also insight in which kind of terraces are possible, on which still data is needed as described in chapter 6.
5. It would be wise to conduct more research into costs and benefits of different kinds of conservation measures, so that it is possible to choose the most effective measures. It is important to take social costs and benefits and economical costs and benefits into account.

Recommendations for the project

1. It is very important that this study, done for a part of the Voi River catchment, will be done for the whole river system, so that it is possible to make a plan for reducing erosion and increasing water storage catchment wide. A catchment wide approach is the best, because in this way certain areas will not be neglected. Especially changes in water stored upstream can have severe consequences for sub-areas downstream, such as desertification and salinization.
2. The rest of the catchment area lies mainly in the Taita Hills. This area is much more difficult to investigate because of the steep slopes and vegetation cover. So it is important that this area will be investigated by students in two times.
3. It is strongly recommended to implement erosion reducing measures combined with water storage measures. For this study erosion conservation measures have to be combined with the water storage recommendations of Wilco van Bodegraven (2006). This, because erosion can be reduced best when conditions for vegetation growth are good. Water storage influences conditions for vegetation cover as presented in figure 1.8 and needs to be increased, because the area is arid. Water storing measures can make sure that plants have enough water to grow and thereby reducing erosion. Also stopping of erosion result in more storage of water.
4. Before implementing conservation projects it is strongly advised to take into account gender and who will benefit of a project. It is important to let women decide also on which measures are taken. Especially if you take into account that women have the task to provide the family of food, fuel wood, water and they have to raise the children, while men are more doing the commercial agricultural work, livestock keeping and having jobs in towns, as stated in Appendix V. Also women are taking care of most of the agricultural food production and are therefore important to take into account. Also women are taken less into account in most African communities so that their influence is less. Because they are playing such a major role women need to be empowered in the decision stages (Rwelamira, 1999).
   Also the powerless have to be taken into account. In this way they will benefit also and not only the rich people are benefiting of projects. If the powerless are not taken into account, land degradation will continue (Rwelamira, 1999).
5. If WCT wants to do more research into erosion in the future, for this river system or other areas, it is important that WCT use aerial photographs of the area under study. In this way it is easier to see the severity of erosion, it saves time because only some checks have to be done in the field and it is possible to see changes in erosion over the years, so that it is possible to get a feeling of the developments in the area.
6. Before the recommendations made in this report about soil conservation are implemented, it is necessary to collect first more area specific data about soil type, motivation of people and to make blueprints for constructing of trenches and terraces on the slopes etc. So it is needed to make a specific and detailed action plan for implementation of the recommendations.

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Glossary of key terms

•	Active	Producing an intended action or effect. (Answers Corporation, 2006)
•	Agronomic measures	“Measures that utilize the role of vegetation in helping to minimize erosion.” (Morgan, 1986: p. 164)
•	Capacity	What kind of things somebody is capable of, by himself or with tools depending on characteristics, skills, knowledge, resources, and instruments that are necessary for a particular behaviour. (Weenk, 2000)
•	Catchment area	The drainage area of a river. The barriers of the drainage area are determined by the watershed for precipitation created by surrounding hills, mountains and elevations. (Answers Corporation, 2006)
•	Drainage density	The length of streams per unit area. (Morgan, 1986, p.63)
•	Drainage texture	“The number of first-order streams per unit area, which equals often gully density.” (Morgan, 1986, p.63)
•	Erodibility	The resistance of the soil to both detachment and transport by taking into account soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content. (Morgan, 1986)
•	Erosion	A three-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as running water and wind and the sedimentation of those soil particles. (Morgan, 1986)
•	Erosion intensity	Rate for determining how much an area is affected by erosion.
•	Erosion risk assessment/ Erosion hazard assessment	“Identifying those areas of land where the maximum sustained productivity from a given land use is threatened by excessive soil loss.” (Morgan, 1986: p. 63)
•	Erosivity	Rate to determine regional differences in erosion potential for pinpointing areas of high risk. (Morgan, 1986 p.66)
•	Feasible	Practibility: is it possible to implement a measure successful. (Answers Corporation, 2006)
•	Foothill	A hill near the base of a mountain or mountain range. (Answers Corporation, 2006)
•	Gender	“Gender refers not only to women or men *per se*, but to the socially defined roles of each sex, as well as to the relation between them. Gender issues, therefore, form part of the development approach that puts people at the center and ensures their participation in the entire development process.” (Lubwama, 1999)
•	Gully	“Relatively permanent steep-sided water courses which experience ephemeral flows during rainstorms.” (Morgan, 1986: p.29)
•	Gully reclamation	Winning back of land deteriorated by gullies for human needs or for protection of natural diversity.
•	Hill/Mountain	A well-defined natural elevation. (Answers Corporation, 2006)
•	Labour division	The way that different tasks are appointed to different people in a given society. (Dino Felluga, 2002)
•	Maintenance	The work of keeping something in proper condition. (Answers Corporation, 2006)
•	Mechanical measures	“Manipulating the surface topography to control the flow of water and air.” (Morgan, 1986: p.164)

- Motivation — What someone wants to do or what not, what makes someone doing something or not (Weenk, 2000)
- Opportunity — The given circumstances, which a person can not influence by himself only, that are making a particular behaviour possible or not. (Weenk, 2000)
- Plain — An extensive, level area of land. (Answers Corporation, 2006)
- Project — “A series of activities aimed at bringing about clearly specified objectives within a defined time-period and with a defined budget.” (European Commission, 2004: p.143)
- Rainfall aggressiveness — Ratio p^2/P, with p as monthly maximum and P as mean annual precipitation for indicating of rainfall intensity and risk of gully erosion. (Morgan, 1986)
- Re-hydration — To increase the quantity of water available in an area so that people, animals and vegetation can benefit.
- Slope — Numerical measure of a line’s inclination relative to the horizontal, expressed in degree or percentage. (Encyclopaedia Britannica, Inc, 2006)
- Sedimentation — Settling down of soil particles transported by erosive agents such as water and wind.
- Socio-economic — “Refers to environmental, economic, social and institutional patterns, and their linkages that compose the context of development.” (Lubwama, 1999)
- Soil conservation — The protection, preservation, management, and or restoration of soil. (Answers Corporation, 2006)
- Soil management — “Ways of preparing the soil to promote dense vegetation growth and improve its structure so that it is more resistant to erosion.” (Morgan, 1986: p. 164)
- Soil texture — Particle size distribution and structure (Van der Sluijs & Locher, 1990; Morgan, 1986)
- Susceptibility to erosion — Erosion potential of an area. (Morgan, 1986) (see also erosivity)
- Sustainability — “Maintaining environmental assets, or at least not depleting them.” (Rwelamira, 1999)
- Wadi — Seasonal river.

Appendices

I Flow Diagrams and Cause Trees

Of all the important relationships has been made a Flow Diagram. This diagram is standing in figure I.I. The arrows between the variables represent the relationships between the different variables. Is there standing a summation sign (+) besides the arrow, it means that if there is more of the variable from witch the arrow comes, the other variable increases too. For a minus sign (-) it means the opposite, hence that if there is more of the variable of which the arrow comes, there is less of the variable the arrow directs to.

Parameters in the erosion cycle

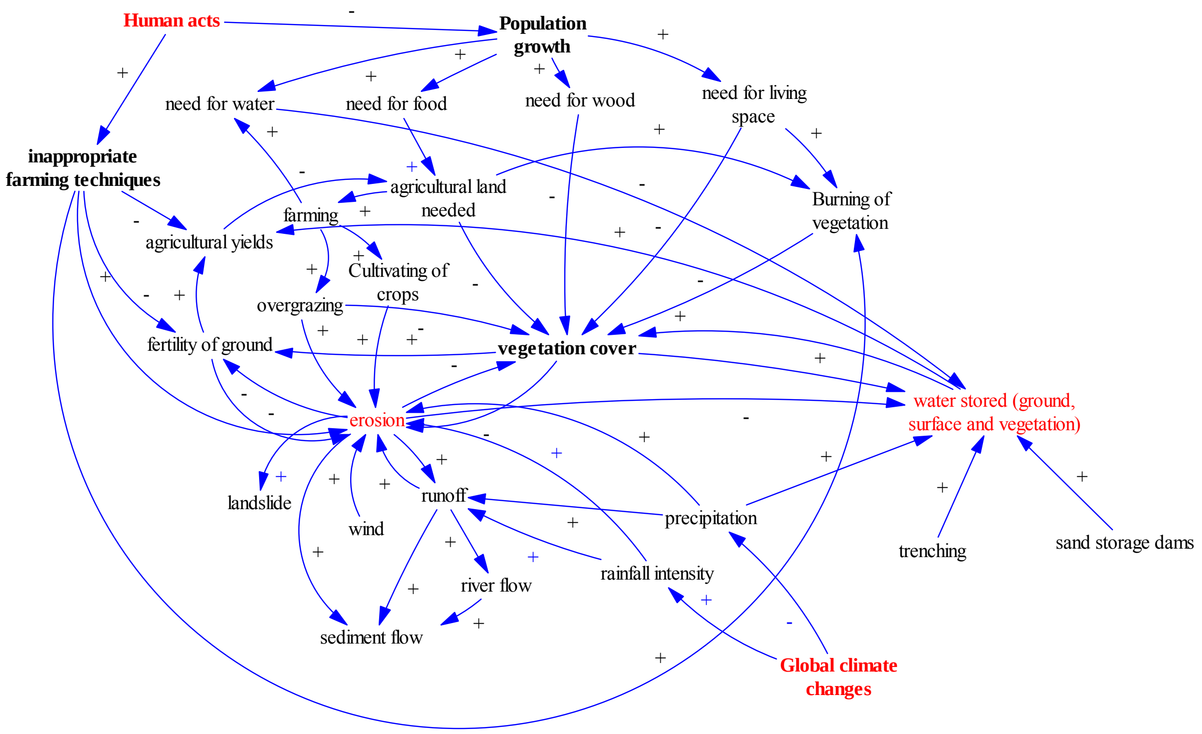


Figure I.I Flow Diagram of the erosion and water storage problem.

Core problem of erosion

Of the total erosion and water storage problem presented in figure I.I has been made a Flow Diagram which presents only the core relationships. This Flow Daigram is presented in figure I.II. There has been made a distinction between variables that are influencing the Voi River system that are possible to influence in the catchment area itself and variables that can not be influenced in the catchment area, i.e. this are climate changes at climatic scale.

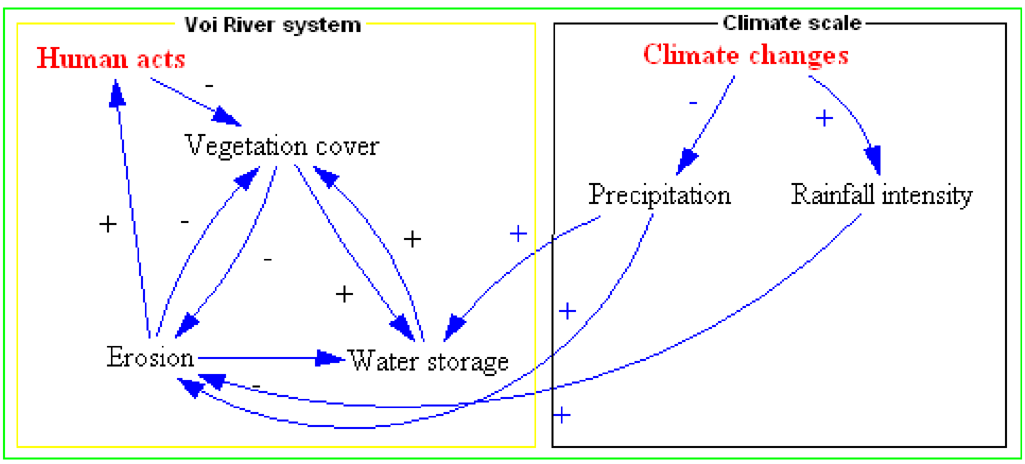


Figure I.II Core parameters influencing erosion and water storage.

In figure I.III and I.IV Cause Trees are presented for the parameters "water stored" and "erosion". These trees identify which variables influence each other and in which sequence. So it helps to determine which actions can be taken to influence a variable.

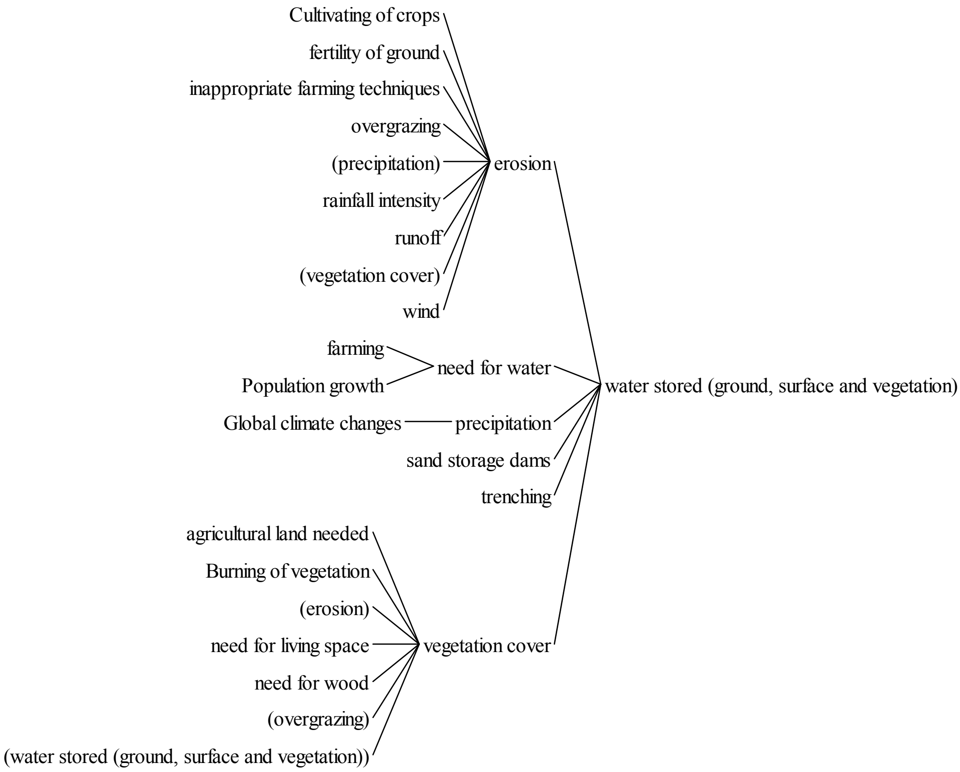


Figure I.III Cause Tree for water storage.

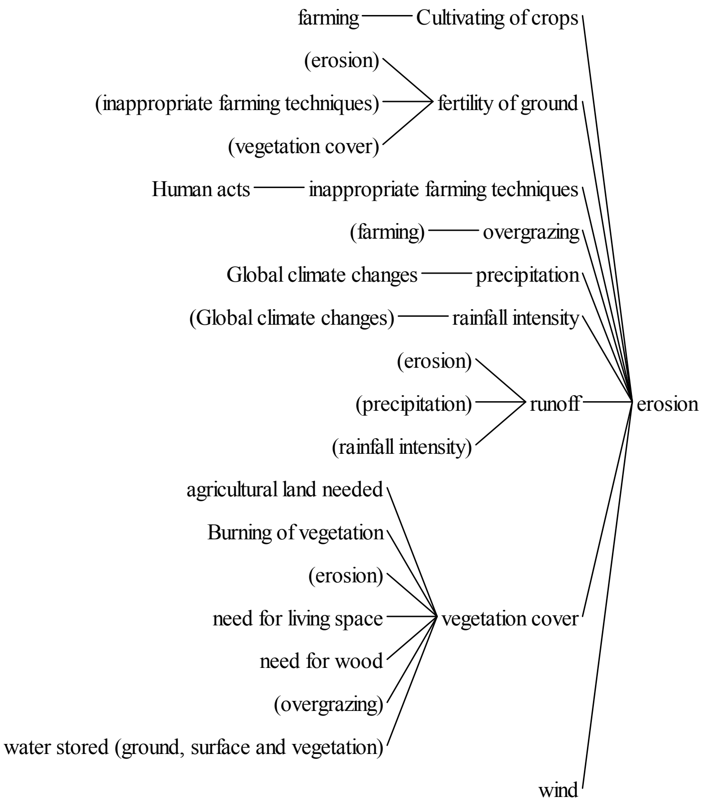


Figure I.IV Cause Tree for erosion.

II Gully development

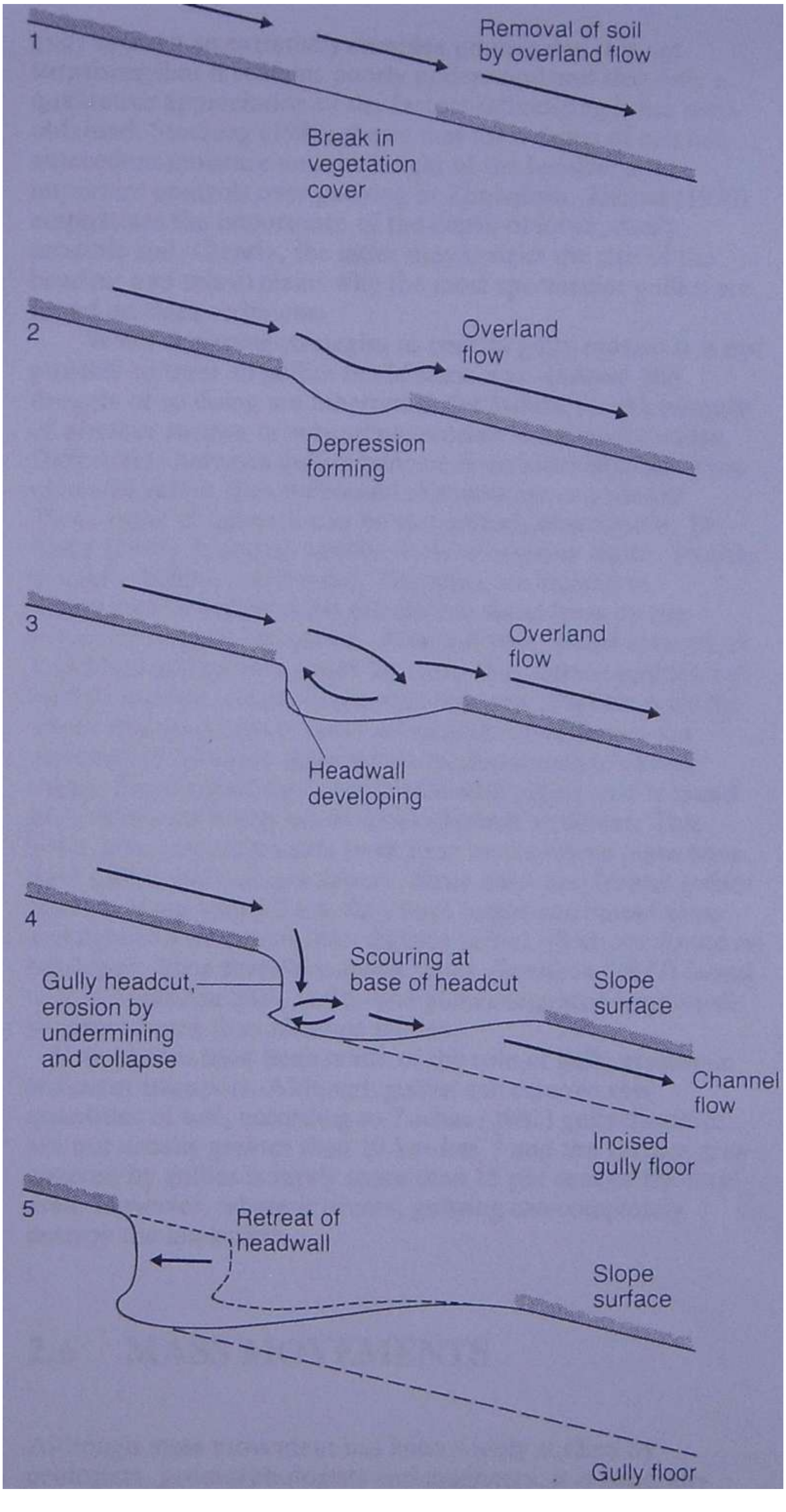


Figure II.I Stages in the surface development of gullies on a hillside. (Morgan, 1986: p. 31)

III Gully data obtained in the field

Table III.I
Drainage texture (number km^{-2})

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	0	0	0	0	3	3	3	1	0	0	0	1
B	3	7	7	3	0	1	0	1	0	2	1	4
C	8	35	11	3	0	1	1	2	1	3	4	10
D	8	16	42	0	8	6	2	1	2	11	9	2
E	**?**	21	11	1	2	1	0	0	1	1	2	3
F	10	21	14	0	0	0	0	0	1	2	5	3
G	2	6	15	0	0	0	0	1	0	1	12	5
H	11	5	9	0	0	0	0	0	0	4	10	2
I					0	0	0	0	0	6	0	0
J					0	0	0	2	1	12	0	0
K					3	5	3	3	3	4	0	0
L					1	3	2	0	0	2	1	0

Table III.II
Drainage density (km km^{-2})

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	0	0	0	0	0.460	0.740	0.160	1.420	0	0	0	0.640
B	1.200	3.560	4.280	1.140	0	0.080	0	2.320	0	0.250	0.300	3.720
C	6.360	16.800	3.660	1.740	0	1.440	1.700	3.280	0.780	0.960	2.840	3.080
D	0.840	3.220	27.500	0	2.060	2.520	1.440	0.520	1.240	4.600	3.800	0.160
E	**?**	5.400	6.080	1.060	1.820	0.580	0	0	0.140	2.760	0.860	1.900
F	2.660	8.000	3.040	0	0	0	0	0	1.300	0.420	2.540	1.200
G	0.820	1.600	3.180	0	0	0	0	0.460	0	0.940	5.820	2.300
H	4.080	0.740	1.340	0	0	0	0	0	0	2.420	4.800	0.160
I					0	0	0	0	0	2.440	0	0
J					0	0	0	0.700	1.040	3.300	0	0
K					1.680	1.680	2.140	1.460	0.880	1.800	0	0
L					0.640	2.240	2.440	0	0	1.420	0.160	0

IV Rainfall and sediment yield data Voi

IV.I Rainfall aggressiveness

In this appendix is standing the rainfall data for Voi. There are two datasets. The first set contains data on the average precipitation per month from 1953 to 1966. So it is covers 13 years of recording. According to this set Voi lies at an altitude of 1837 feet and mean annual precipitation is 590 mm. (Yahoo weather, 2006)

The second dataset covers the period from October 2005 to September 2006. So it covers data of the past year. It is assumed that the data from 1953 to 1966 is more reliable, because it is the average of a longer period. However, because of climate changes it is not possible to say for sure that this is the case, but normally it is. Of both periods the rainfall aggressiveness, p^2/P, has been calculated with p the mean monthly precipitation and P the mean annual precipitation.

For the past year rainfall aggressiveness has been calculated with P both the annual precipitation of that year and the average rainfall over the period 1953-1966. Also the rainfall aggressiveness of the largest showers per month of last year has been calculated with P both 316mm and 590mm. The data and calculated rainfall aggressiveness rates are standing in table IV.I, IV.II, and IV.III. Also of the results have been made figures, i.e. figure IV.I, IV.II and IV.III.

In the first data set it seems that data of April is missing. This is most probably the case, because the last year rain in April was the largest and according to Bindlos et al. (2003) in April rainfall is the most. Without April, May is the month in which rainfall is the second largest. It has an aggressiveness rate of 33.22. Compared with data of tropical areas in Malaysia, 33.22 is not really high. For Malaysia the rates were al in between 50 and 100, but taken into account the aridity and low plant cover of Voi, it is still quite high. (Morgan, 1986)

Figure IV.II and IV.III are showing that rainfall aggressiveness, by using the mean monthly precipitation also gives a good indication of rainfall intensity per month. The rainfall of the largest shower per month is following the rainfall pattern per month. (Morgan, 1986) Also is in figure IV.IV the developing of rainfall and intensity and vegetation cover and erosion presented for areas with a wet and dry season. This gives an indication of the erosion pattern over the year and explains why erosion is so high in the research area, because rainfall and the intensity of rainfall is highest at the start of the rainy season, while vegetation cover is still low. Vegetation starts to grow after rainfall. In the period between erosion is high. Figure IV.IV however is not totally valid for the research area because it only describes areas with one rainy season. The research area has also a rainy season from October to December.

Table IV.I Average rainfall data per month over 13 years from 1953 to 1966. (Yahoo weather, 2006)

Voi

Latitude	03 24 S
Longitude	038 34 E
altitude	1837 feet / 551.1 m

Average precipitation over 13 years, from 1953 till 1966

Month	Average precipitation (mm)	Rainfall aggressiveness
January	40	2,711864407
February	40	2,711864407
March	110	20,50847458
April		0
May	140	33,22033898
June	30	1,525423729
July	20	0,677966102
August	10	0,169491525
September	20	0,677966102
October	40	2,711864407
November	80	10,84745763
December	60	6,101694915
Total	590	81,86440678

Table IV.II Rainfall data from October 2005 until October 2006. (The Weather Underground, Inc., 2006)

Precipitation records Oct 2005- Sept 2006			
Month	**Year**	**Max. precipitation recorded (mm)**	**Total rainfall measured (mm)**
October	2005	7,112	7,112
November	2005	7,874	25,146
December	2005	17,018	24,13
January	2006	11,938	12,7
February	2006	0	0
March	2006	27,94	86,36
April	2006	33,02	106,426
May	2006	10,922	25,654
June	2006	0,508	0,508
July	2006	2,032	2,032
August	2006	0,508	0,51
September	2006	12,954	25,4
Total		131,826	315,976

Table IV.III Rainfall aggressiveness data calculated on basis of rainfall data Oct 2005- Sept 2005 per month and per largest shower per month. (The Weather Underground, Inc., 2006)

Rainfall aggressiveness data (316 mm and 590 mm)					
Month	**Year**	**Rainfall aggressiveness (316 mm)**	**Rainfall aggressiveness (590 mm)**	**Rainfall aggressiveness per shower (316 mm)**	**Rainfall aggressiveness per shower (590 mm)**
October	2005	0,16007717	0,085729736	0,16007717	0,085729736
November	2005	2,00116881	1,071731044	0,196217042	0,105084536
December	2005	1,84272508	0,986876102	0,916564309	0,490868346
January	2006	0,510450161	0,273372881	0,451033762	0,241552278
February	2006	0	0	0	0
March	2006	23,60321543	12,64076203	2,470578778	1,323124746
April	2006	35,84605627	19,19744657	3,450643087	1,848000678
May	2006	2,082840836	1,115470705	0,377528939	0,202186583
June	2006	0,00081672	0,000437397	0,00081672	0,000437397
July	2006	0,013067524	0,006998346	0,013067524	0,006998346
August	2006	0,00081672	0,000437397	0,00081672	0,000437397
September	2006	2,041800643	1,093491525	0,531072347	0,284417146
Total		68,1030	36,4728	8,5684	4,5888

Figure IV.I Rainfall aggressiveness for Voi (based on data from 1953-1966) . (Yahoo weather, 2006)

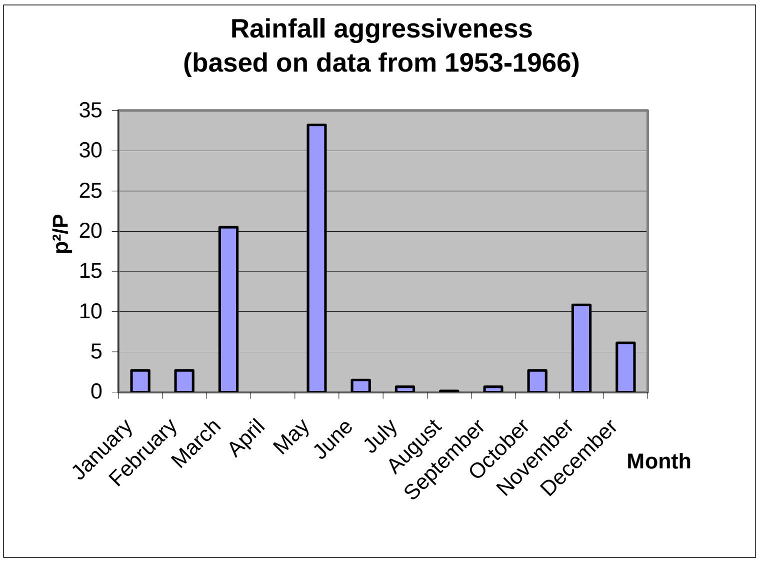


Figure IV.II Rainfall aggressiveness from October 2005 until October 2006 for 316mm and P (590 mm). (The Weather Underground, Inc., 2006)

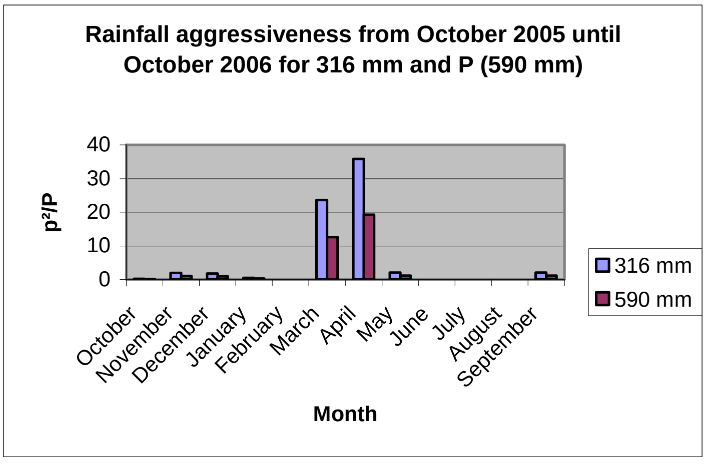
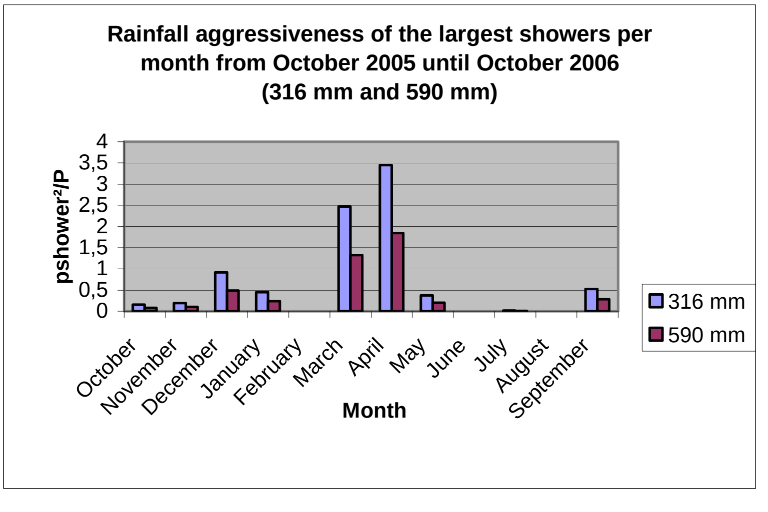


Figure IV.III Rainfall aggressiveness for the largest shower per month from October 2005 until October 2006. (The Weather Underground, Inc., 2006)



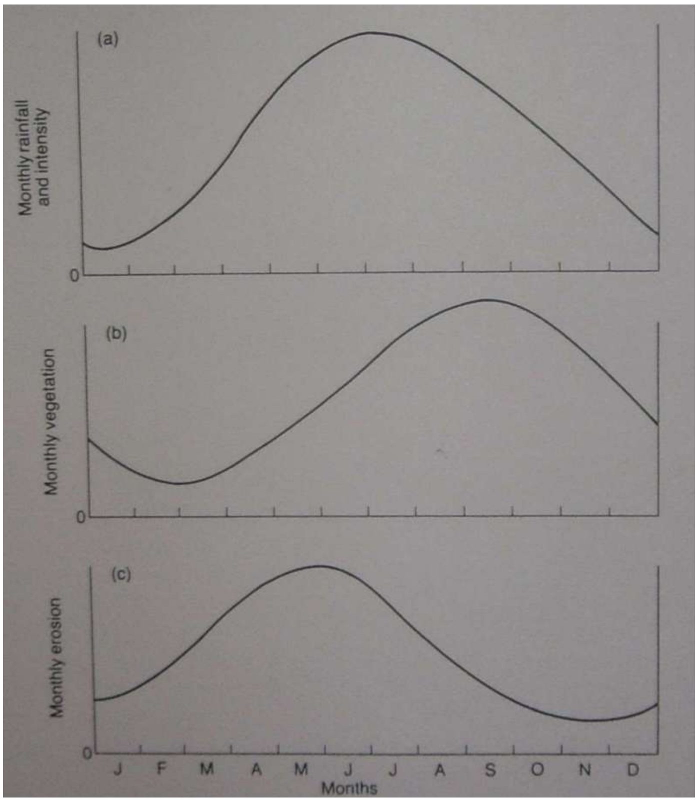


Figure IV.IV The pattern of rainfall (a), vegetation growth (b) and erosion for areas with a dry and wet season (c). The research area experience however also a wet season in October to December, so the principal is also counting for these months. (Morgan, 1986: p. 9)

IV.II Mean annual sediment yield of the research area

For the research area mean annual sediment yield has been calculated with the formula developed by Fournier (Morgan, 1986), i.e.:

$$\log Qs = 2.65 \log\left(\frac{p^2}{P}\right) + 0.46(\log H)(\tan S) - 1.56 \qquad \text{(IV.1)}$$

Qs is the mean annual sediment yield in g m^{-2}, p^2/P rainfall aggressiveness, H mean altitude of the research area, S mean slope of the research area. The rainfall aggressiveness for the area has been calculated in paragraph IV.I. Mean altitude and mean slope of the research area can be calculated using the slope maps of Collective Appendix, Maps, type B and the altitude map, Collective Appendix, Maps . The altitudes and slopes are therefore divided in classes. Of each class is determined how large the area is falling into a certain class. The average of the classes is taken and multiplied by the area belonging to that class. The values have been summed and after that divided by the estimated research area, what gives the mean slope and altitude of the research area (table IV.IV).The mean slope (S) of the research area is 7.01° and the mean altitude (H) 710.23 m. With these values formula IV.1 can be solved:

$$\log Qs = 2.65 \log(33.22) + 0.46(\log 710.23)(\tan 7.01) - 1.56$$
$$\log Qs = 2.634 \qquad \text{(IV.2)}$$
$$Qs = 10^{2.63} = 429.53 g / m^2$$

The sediment yield for the research area according to formula IV.2 is 429.53 g m^{-2} or 429.53 t km^{-2}.

Table IV.IV Calculation of mean annual sediment yield.

Rainfall aggressiveness			Research	area
p²/P	33.22		128	km²

Mean slope of research area

slope classes	average of class (º)	area (km²)	weighted	
0º-10º	5	109,7	548,5	
10º-20º	15	12,5	187,5	
20º-30º	25	4,7	117,5	
>30º	35	1,3	45,5	
Total		128,2	899	
Average (S)			7,01248	º

Mean altitude

altitude classes (m)	average of class (m)	area (km²)	weighted	
<610	550	23,45	12897,5	
610-763	686,5	71,75	49256,38	
763-915	839	25,75	21604,25	
915-1068	991,5	5,62	5572,23	
1068-1220	1144	1,3	1487,2	
Total		127,87	90817,56	
Average (H)			710,2335	m

mean annual sediment yield

Qs	429,53	g/m²
	429,53	t/km²

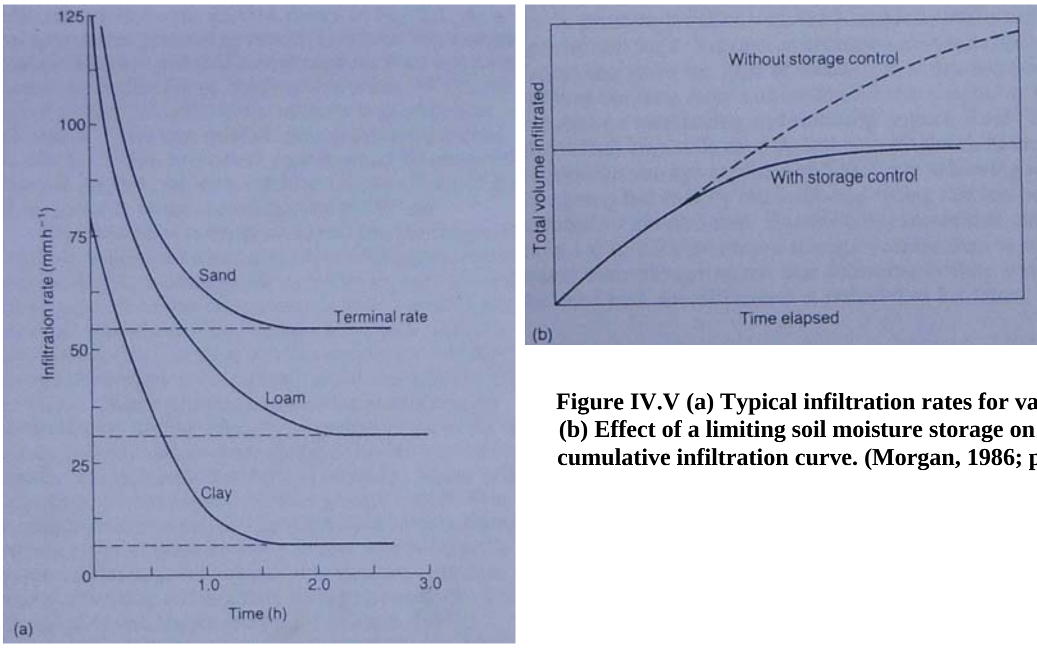


Figure IV.V (a) Typical infiltration rates for various soils (b) Effect of a limiting soil moisture storage on the cumulative infiltration curve. (Morgan, 1986; p.15)

V Research into local erosion prevention

V.I Poiesz Triade-model for explaining human handling

In human behaviour sciences the Triade-model of Poiesz (Weenk, 2000) is used to explain human handling. In this research it is also used as a basis for analysing the motivation and capabilities of people in preventing soil erosion. Poiesz defines human acts according to Weenk (2000), as is stated in chapter 5, on the following relationship: human acts = M*C*O, with M for motivation, C for capacity and O for opportunity.
The Triade-model argues that big differences in factors influencing human handling are reduced automatically, because the factors are influencing each other. This is called the balance effect. This implies several things. The first thing is the primary balance effect. If a person has a goal and has the intention to reach the goal, he will try to get the capacity and the occasion to reach the goal, hence to get it on the same level as his motivation. If he does not succeed, motivation will go down. The second effect is called the cycle effect. A sudden change in one of the Triade-factors cause that the other factors are influenced in the same positive or negative way. Negative influences are more common than positive according to Poiesz. The third effect is the attribution-effect. People tend to believe that success depends on their own motivation and capacities and failure depends on influences of the surroundings. The last effect is the resistance effect. People are expressing contra productive behaviour, because they are influenced too much causing resistance. This effect can be resolved by giving people choices. (Weenk, 2000)

According to Weenk (2000), the Triade-model is used to analyse peoples' behaviour and for explaining it, predicting peoples' behaviour, and for making effective behaviour influencing measures.
Some tools for influencing people are:

- request;
- instruction;
- reward/encouragement;
- to warn/to threat;
- feedback on (potential) behaviour of someone;
- training.

V.II Description of sub-areas

Of the mountain-ranges, land use, erosion measures, water storage, and interviewees have been made photos to give the reader an impression of the people, research area and the sub-areas. These photos are standing in Collective Appendix, Photo gallery.

Voi town & Mwakingali Hills
Voi is a busy, dusty, noisy and dry town situated at the Mombasa-Nairobi highway and railway and the road to Tanzania. In the town are many tribes living side by side. The people are rather kind, but the people in town are not as friendly as the people in the nearby countryside. The streets are dusty and on many places trash is thrown on the street just like that. An important bus and matatu station, lot of shops, hawkers and a big market are in the centre of town.
Important sources of income are tourism, highway related business, sisal, sand harvesting and agriculture. Many people are earning money with cafes and hotels for travellers and truckers. Also a lot of business is conducted on this junction of important roads. Sisal is processed in the town at the sisal estate, and sand harvesting is done in the Voi River. Furthermore almost all people living in the outskirts of Voi have a small plot where they cultivate crops. These crops are sold on the town market. Tourism is important because east from Voi lies Tsavo East National Park. The main gate of this park is in Voi. Because of that lots of tourists visit the town to see wildlife inside the park.
However, Voi is a poor town. The biggest part of the population, just as in the rest of this area, lives below the poverty line. Voi has two some what richer parts, where houses are built of stone. In the centre are some flats. The rest of the town exists mostly of houses and huts made of clay, grass and iron plates.
The city is growing. Everywhere people are building houses. In the centre of the town are a lot of construction sites. (Hurskainen & Pelikka, 2004; Msagha, 2004) There are at least 38,000 people living in Voi (paragraph 1.1.2). Most of them are Christians and the second largest religious group is Muslim.
North of Voi lies the mountain-range called Mwakingali Hills. This mountain-range exists out of some small hills and two somewhat bigger hills. The mountains have a very characteristic shape. The slope increases slowly from the foot towards the foothill of the top. Just before the highest point of the mountains the slope increases extremely. The tops of the hills are steep and rocky. One part of this mountain-range belongs to Tsavo East

National Park. Because the park is nearby, lots of wild animals are living on top of the hills. The hills are for the utmost part dry and barren. Less vegetation is growing on the tops. Trees that are still growing there are illegally cut for firewood. On the mountains lots of cattle is grazed uncontrolled, especially goats. At the northern foothill are some spots where people are digging for building materials and gemstones on small scale. On the southern foothill are the mainly poorer outskirts of Voi. This side of the mountain-range is steep. On this side is a lot of erosion; large gullies are going through the outskirts. The gullies swept away houses and have laid water pipelines bare.

Sisal estate
West from Voi is a big sisal estate called Voi Sisal Estate. The estate covers an area of 2800 ha (7000 acres). Also belongs to the estate an orange estate of 200 acres situated at Voi River. (Interview, farmer 5) On the estates is less erosion, because strip cropping with grass has been practiced. On the sisal estate people herd also a lot of cattle, mainly goats and cows.

Plains
The plains are situated between the big mountain-ranges of Taita, Sagala and Mwakingali Hills. The plains are characterized by three main features, i.e. agriculture, cattle herding, and bush. Besides Voi River is a lot of irrigated agriculture. On the plains further away from the river is varied bush and agriculture depending on rain only. The plains are for a big part covered with bush. The bush exists out of acacia trees, bushes and some grass. In the bush people are herding cattle. The river is the life string of the area. Besides the river is the only strip of evergreen on the plains and it is the only source of surface water.
The people living on the plains are poor. Most of the farmers depending on rain for agriculture only are really poor. The farmers along the river who are able to irrigate are somewhat richer. Almost all the people are living in huts of clay. Once and a while there is a village, but most people have a small hut on there plots where they are living.

Sagala Hills
South from Voi are the Sagala Hills with an average height of approximately 1100 to 1200 m above sea level. These mountains form a massive range of mountains. The hills are very steep, especially at the northern side of the range. This side is bushy and there are a lot of rock-faces. The hills near Voi are not used for agriculture or settlement. The hills are only used for firewood and on the foothill livestock is grazed. On some places they are looking for gemstones on small scale. On the mountain-peaks is living a lot of wildlife. At the foot of the range streams the Voi River. Here are living some farmers. At the side of Sagala the mountains are becoming a little lower. Here lives the Sagala tribe. On the mountain-peaks they are doing agriculture. The steepness of the hills and human acts are causing soil erosion at the foot of the mountains. Gullies are affecting roads, plots and houses.

Small Taita Hills
West from Voi the Taita Hills are situated. In the Taita Hills, part of the Arc Mountains, lives the Taita tribe. This community is doing actively agriculture on the very steep slopes of the hills. This area is much greener and humid than the dry plains. It rains here much often in contrast with the rest of the catchment. This area is a catchment for water. A big reservoir provides the plains, Voi and Mombasa of water. The farmers that are living in these hills are also richer and most people are living in a rather big stone house. The farmers are also doing more to counter erosion. They made terraces and covered gullies with branches of trees. Because of population pressure only a little of the indigenous forests are remaining. The forests have been cut for wood and agricultural land. Erosion by water is a big problem, despite all the efforts of the local people to counter it.

Voi River
The Voi River takes its rise outside the research area in the Taita Hills. The river is totally worn out in the research area. Along the river there is a lot of riverbank erosion, mainly caused by water that with great strength flows from the mountains and the plains in the direction of the Indian Ocean. Erosion of the riverbank is also caused by humans and animals, by descending towards the river along paths that are scooped out and because of uncontrolled sand winning on large scale in the riverbed. (Daily Nation, Fri 11 November 2005)
The river plays an important role in the area. It is a real string of life. It provides people, cattle, wildlife and plants of water for drinking. It gives people also water for washing (clothes and bathing), irrigation and construction purposes. Besides the river is a small strip of evergreen.
In the area around Voi 5 sand storage dams are constructed, 4 by WCT and one for the Nairobi-Mombasa Highway. These dams provide local farmers of more water.

In the rainy season the river floods often causing a lot of damage to houses, trees, crops and plots because it takes the fertile topsoil. Also a lot of sediment settles down on the plots, decreasing the fertility of the ground. At the end of August and September, the river is often dry. Because of this people have no or almost no water available. The people have to dig scoop holes in the riverbed for water.

V.III Results of field observations and interviews

V.III.I Opportunity: erosion is a problem according to local people

For determining if the opportunity is there that people have to act against soil erosion, because it is causing them problems, the indicators "most important problems in farming" and "establishment of erosion by local people" have been used. If farmers regard soil erosion as an important problem and establish also that there is erosion in the area, opportunity is high for them to act and change the situation to a situation that is better for them.

<u>Most important problems in farming</u>

The farmers were asked what the five major problems for them were in farming. After that they had to rank the problems in order of importance. The most important problem for farmers was water shortage and drought. The second important problem was plant diseases caused by insects and pests during growth and storage. At the third place was standing erosion. Poor harvest and bad fertility were also standing in the list of most mentioned problems. Observations in the field made clear that these problems were most of the times related to erosion and bad farming practices. So it is possible to conclude that erosion is even a bigger problem, because these problems related to erosion were also mentioned several times. Research conducted by Sirviö & Rebeiro-Harvgrave (2004) and Sirviö et al. (2004) indicated also that soil fertility in the area decreased because of erosion.

In all the sub-areas erosion is standing in the top six. On the plains erosion is not a very big problem. Observations on erosion intensity are supporting this statement; however it was observed that overland flow influenced the plots still. For the sub-areas Sisal estate, Voi River and Taita Hills erosion was the second or third most important problem. Field observations on erosion intensity were indicating that erosion was a problem as can be seen in Collective Appendix, Maps, type D. In table V.I and V.II the ranking of the problems is presented. Among "other problems" were mentioned availability of water tanks, politics, the closed market of the USA & EU for agricultural products like oranges, severe competition (especially for tomatoes), lack of knowledge of modern farming practices, rent of irrigation pump and tubes. Every time a problem was ranked number 1, it was weighted 6, when it was at the second place, it was weighted 5 and so on. The reason for this is that problems placed on rank 1 are giving a farmer more trouble than the problem on the second place. Because the difference in trouble is not known precisely and differs from farmer to farmer, the weights are taken linear.

Table V.I Most important problems per sub-area.

Sisal Estate		Voi River		Plain		Taita Hills	
Other	13	Water, drought	28	Water, drought	23	Water, drought	36
Erosion	9	Erosion	19	Plant disease	13	Plant disease	22
Water, drought	6	Other	19	Poor harvest	6	Erosion	17
Plant disease	6	Plant disease	10	Wildlife & cattle	4	Wildlife & cattle	12
Theft	6	Price fuel	9	Erosion	2	Animal disease	9
		Poor harvest	8			Other	9
		Good seeds	8			Bad fertility	6
		Wildlife & cattle	8			Good seeds	4
		Animal disease	6				
		Bad fertility	4				
		Theft	1				

Table V.II Ranking of the most important problems.

Problem	Total	Rank
Water, drought	93	1
Plant diseases (insects, pests)	51	2
Erosion	47	3
Other	41	4
Wildlife and cattle	24	5
Animal diseases	15	6
Poor harvest	14	7
Good seeds for sowing	12	8
Bad fertility	10	9
Price of fuel	9	10
Theft	7	11

Establishment of soil erosion by local people

After the farmers had been asked what their most important problems were in farming, they were asked if erosion was a problem for them. The majority of the farmers, men and women, agreed on the fact that they had problems with soil erosion. Of the 18 farmers 12 established soil erosion as a problem and 6 said that they had no problems at all. Only one farmer said that erosion was not in his top five of main problems, while he established erosion on his shamba. Probably, because he was quite active in taking erosion prevention measures by himself. Of the six people who denied that they suffered of erosion, of four of them it was doubtful it they spoke the truth, because field observations into their shambas and the rest of the surroundings made clear that erosion was a problem, at least of overland flow. The other 2 respondents had not many troubles with soil erosion; these were the director of Voi sisal estate and his chef. The owner of the sisal and orange estate practised strip cropping on the sisal estate and earth walls and grass conservation measures on the orange estate to prevent erosion. This ensured that soil erosion was not a big problem for him on the estates, however he also had problems with gully erosion near his sisal factory because a lot of water was coming from the highlands and high way which was concentrated in one gully just passing his factory. Also he had problems with riverbank erosion because of sand harvesting. The answers of the respondents who said that they had problems with erosion matched the field observations. Erosion differed from overland flow, rills, and gullies to riverbank erosion and wind erosion.

Looking at the different sub-areas, erosion awareness was highest in the Small Taita Hills. This can be explained at the hand of observations at erosion intensity. Erosion intensity was highest in the Taita Hills (see paragraph 4.2). Research of the Univeristy of Helsinki, Finland, support this observation, because according to this research erosion intensity was in several parts of this area very high (Sirviö & Rebeiro-Harvgrave, 2004; Sirviö et al., 2004). Along Voi River the establishment of erosion was also quite high, while it for Plains was only fifty-fifty. The reason for the difference in perception between Voi River and Plains is probably that the people on the Plains have most of the times only problems with overland flow, while farmers beside the river have problems with floods and severe riverbank erosion diminishing their plots. It was not possible to define differences between the perception of women and men regarding soil erosion, because the sample group was too small. For more information please see table V.I.

Opportunity

So it is possible to conclude with the results on ranking of most important problems in farming and establishment of erosion by locals that erosion is a big problem in the research area. Hence the *Opportunity* for the people is stimulating them to take actions against soil erosion. Opportunity was high in the sub-areas Voi River, and Small Taita Hills. Opportunity on the Plains was a little lower, probably because the erosion intensity on the Plains is also lower. Opportunity was moderate high for Sisal estate, because the awareness of erosion as a problem was high, but because the owners did a lot to prevent there was almost no problem with erosion anymore. So Opportunity made them acting, but now erosion was not such a problem anymore, opportunity was also decreasing.

V.III.II Motivation of people to prevent soil erosion

As indications of the motivation of the people to prevent erosion has been used the questions 9 and 11 of the questionnaire, Collective Appendix, Interviews. The people were asked if they needed help for taking soil erosion measures and if they owned the plot(s). The only way to know if somebody has the motivation to stop soil erosion is by knowing if he wants to act against it. In this research it is tried to get an indication for motivation by measuring the need for help. It is true that this is measured in narrow sense, but the first weeks,

when testing methods in the field, people, when asked if they wanted to improve their environment, most of the times answered that they had no money to do that, forgetting their own powers. The reason for this was partly that they wanted to get money easy. It was observed that in the research area local people thought that foreigners would give easily a lot of money away. To avoid this bias, what is quite difficult, it seemed better to ask people if they wanted help, because people intended to answer more honestly and most of the times they mentioned also what kind of help. It is true that this indicator is not very accurate for measuring motivation, but it indicates also if there are possibilities for projects by WCT to stop erosion. And this aspect is so important that it was decided to use this indicator as an indicator for motivation.
The other indicator used to measure motivation is land ownership. According to Soini (2005) land ownership played a big role in the destruction of the coffee production in the Taita Hills and according to Rwelamira (1999) communal land tenure, what is still present in big parts of the research area, especially for the bush (observations and interviews with farmer F7, F13 & F18), leads to deterioration of the environment because people do not care about the land because it is not theirs. So therefore it seems a quite good indicator of their motivation to take measures against erosion by themselves. Another good indicator of motivation is the experiences of WCT in the research area.

Did the local people want help for taking erosion prevention measures?
On this question 17 people responded, one remained unsampled. Ten of the 17 farmers wanted help. Surprisingly a big part of the farmers did not want to have help (41%) and another substantial part wanted to have not just any help, but specified the help needed (30%). Only 24% responded that they wanted to have help by not saying which kind of help. Of the people that did not want to have help some farmers had according to themselves no problems with erosion and others took quite some erosion prevention measures by themselves. Of the 30% that specified the help needed, 24% of the interviewees wanted to have knowledge about erosion prevention measures. Farmer 7 asked for specific help for his own project. He tried to make the Voi River stable again by planting vertiver grass and bamboo. In figure V.I the results are presented.
In the sub-area Sisal estate no help was needed. This is also good to explain, because they already took adequate measures as strip cropping, earth walls and grass planting. In the Voi River area and on the Plains farmers would like to have help. In the Taita Hills people especially wanted knowledge about soil erosion countering measures so that they themselves can improve their environment.
At least 30% is motivated to take action by themselves if they have the knowledge and probably this is an underestimation, because some people are doing already something and another 24% would like to get help also.

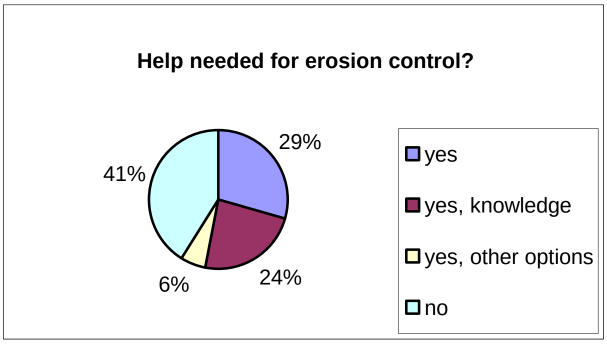


Figure V.I The different responses on the question if farmers needed help for erosion control.

Land ownership
Of the 18 interviewees 15 were land owners and 3 were tenants. Especially for Small Taita Hills, Plains and of course Sisal estate land ownership was high. Besides the Voi River 3 of the 6 interviewees were renting their plots. Two farmers came from the area of the Voi River south of Voi. The land on the riverbank opposite of Voi seemed to be in possession of a landlord. These people were not really motivated to take actions by themselves especially not if the contract was almost ending. In the Taita Hills all farmers were owning land and one rented a plot. Here the people are much more motivated to take erosion countering measures as observed in the field; here were more terraces, trees and grass strips as in the other sub-areas. So land ownership indicates a quite high motivation for farmers to take actions.

Experiences of WCT
According to Mr. Mukusya (Collective Appendix, Interviews), execute director of Excellent Development and companion of WCT, it is difficult to start a project in the Voi River catchment and our research area, because there is not a good community structure. Other problems are, according to him, that the people want money and

in the Taita Hills (Msau area) food before they start to work. So the people are not really motivated according to Mr. Mukusya to do something at the problems. The demand of food by the locals in the Taita Hills can be explained, by the insights given by Mekonnen (n.d.) on soil conservation in Ethiopia. He states that "(…) people in other countries with prolonged FFW (Food For Work) activities (20 years or longer) are unable or unwilling to do anything to better their livelihood without being rewarded in FFW." According to Soini (2005) people in the Taita Hills are already obligated by the Britons to take soil conservation measures a few days per three months voluntary. So it is probably true that the people in the area near Msau, outside the research area, are not really motivated to take soil conservation measures as stated by Mr. Mukusya.
Therefore WCT started a project near Kalambe on the plots of two farmers as a pilot to show the community of Kalambe that trenching works to stop erosion. WCT hopes that the community, if they see that the project works becomes active by themselves and starts trenching. According to Leah Mcharo (Collective Appendix, Interviews) Peter Westerveld told the community that he wanted to help them stop erosion and to make sure that they got more water after WCT had finished the sand storage dam. So WCT just decided to start a project. The risk of this however is that the community does not get the sense of ownership, what already a problem is of projects in general as stated by the EC (European Commission, 2004) and the project could fail. The trenching started in the beginning of 2006 or at the end of 2005 and is still continuing. Therefore the communities had no time to see the trenches working and therefore it is not known of there motivation will increase with time. But motivation to farm and work was not high according to Leah Mcharo, because World Vision gave the people relief food.
Coming year Mr. Mukusya wants to start a local NGO in Voi that will be busy with the re-hydrating project of the Voi River catchment. Maybe this NGO can work on the sense of ownership and motivate the people again.
Observations in the field are supporting the experiences of WCT in the area near Kalambe in the Voi River area and other parts of the Voi River. But observations and experiences in the Small Taita Hills, the part of the Taita Hills in the research area, gave a very different sight. Many people on map 8 were very motivated to stop soil erosion and they were doing their best themselves to counter it. On the plains it is varied and near Voi and on the Sisal estate motivation was not high.

Motivation
In the research area motivation in general is quite moderate as becomes clear of the experiences of WCT and observations in the field. But regional differences were observed. Motivation to prevent erosion was high in the Small Taita Hills on map 8 and on the plains it varied from farmer to farmer. Near the Voi River motivation was low. However analysing the answers of the interviewees indications are better. Most people in the area own land and they say that they want help. So there is a basis of interest in prevention of soil erosion.

V.III.III Capacities of the local people

As indicators of the capacities of the local people to prevent soil erosion have been taken self-initiative of the people to prevent soil erosion, maintenance of conservation measures, organization rate, labour division between man and women, and of course observations on these indicators.

Soil erosion prevention in the research area
The farmers were asked if they did something to prevent soil erosion on their shambas or in their area. The answers were very different. Some people did nothing, because they said to lack the knowledge to do something and others planted grass and made terraces for example. In figure V.II are the results present of what kind of local activities are done by farmers themselves.
As becomes clear of figure V.II most farmers are planting grass in rows in combination with small earth walls. This was also observed in the field. However the earth walls and also the terraces were most of the times not adequate enough. Construction was poor and compared with the slopes on which it was practiced not good enough to reduce erosion substantially.
On the Sisal estate strip cropping with deep cultying was practiced and on the orange estate grass planting and earth walls were used (observation and interview with director of Voi sisal estate). On the Sisal estate was not much erosion observed; only besides the roads were sometimes very small rills. So soil conservation measures here were adequate enough. Along the Voi River was a lot of riverbank erosion. Only one farmer, Paul Mwadime Kombo (F7), was taking erosion prevention measures at the riverbank as observed in the field. He planted vertiver grass and bamboo along the riverbank, what seemed to stabilize the riverbank where it was planted. Furthermore the farmers along the Voi River were doing nothing to protect their plots or they planted grass sometimes combined with small earth walls. On the plains the farmers mostly used small earth walls, grass and branches to stop erosion as observed in the field and also indicated by the interviews. Also some people made terraces and trenches. In the Taita Hills people did the most to prevent soil erosion, maybe because the consequences of erosion were here most severe and therefore the opportunity high. Also motivation was in the

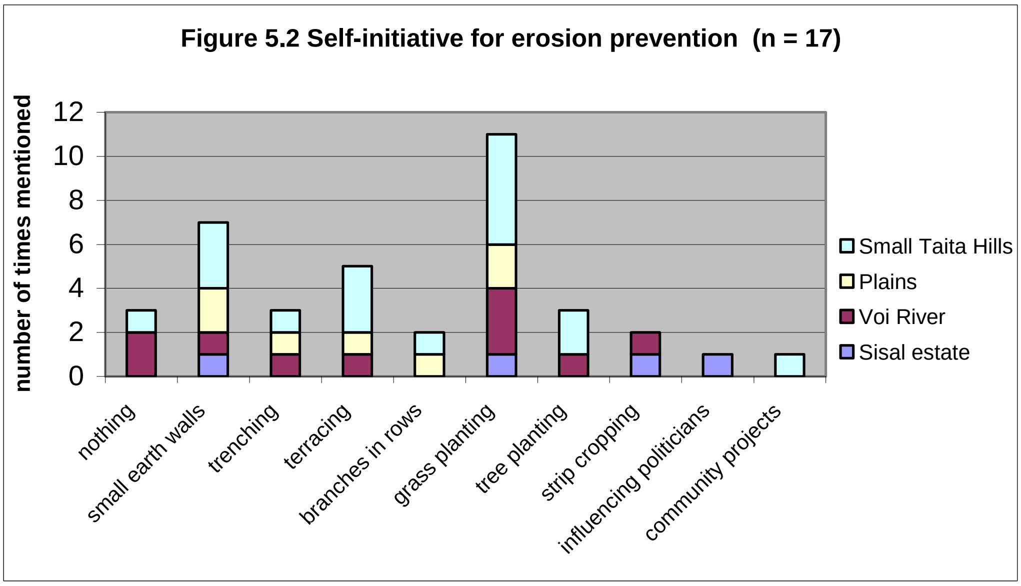


Figure V.II Soil conservation measure taken by farmers.

Small Taita Hills higher than in the rest of the research area as stated in the paragraph 5.4.2. However it differed still from farmer to farmer, most farmers were using a combination of soil conservation measures. Terraces, grass and tree planting, and small earth walls were quite common (interviews & observations). Also some farmers used trenches and there were some farmers who did nothing.
But despite the efforts, in general most farmers had made there conservation measures not good enough in the research area. Many terraces had still a very steep slope or soil conservation measures as small earth walls were taken at steep slopes, which water would sweep away easily. Another problem in the research area was that communities did not take adequate measures against gullies, which were destroying their environment. In the Taita Hills they tried to stop some gullies by putting branches inside it. But most gullies were so big that after every flood water swept the branches away. Another very big problem observed in the field was that people burned parts of the bush for clearing of agricultural land. Because of this vegetation cover decreased fast. Also farmers burned crop residues on their plots, decreasing soil fertility of there plots. Both acts are increasing susceptibility to erosion as already stated by Sirviö & Rebeiro-Hargrave (2004), Sirviö et al. (2004), and Soini (2005). Also many farmers said that they lacked the knowledge to take adequate measures against erosion. This becomes also clear of the help they wanted. Many farmers asked for knowledge about conservation practices.

<u>Maintenance of soil conservation measures</u>
Farmers were asked if there had been any projects in the past for stopping soil erosion and what the results of these projects were. There had been different projects in the research area of different actors, i.e. WCT, World Vision, the Danish government (DANIDA), the FDA of Kenya, and communities themselves. Of these projects only three were still running, that of WCT and the FDA and of some communities themselves. WCT is busy with trenching in the Voi River area. This project is still very young, so that it is not possible to say anything about maintenance by locals. The FDA was giving seminars on soil erosion prevention and water storage in the Small Taita Hills. The effects of these seminars have still to be seen because the FDA was busy starting up terracing committees (F9, F10, F13, F16). But first signals were not that positive. Jotham (F9) said that the people were paid 100 ksh per seminar and that the seminars were given in English, because most people could not speak Swahili. But he said that the most people in that area only could speak Taita, the local language. The FDA had in some parts of the Taita Hills farmers obligated to do also a few days per month soil conserving works (F14). Maintenance and results of this work are not observed. It is unknown if this project has effect, but looking to the state of this area, the practises seemed to have no result. Communities in the Taita Hills were also taking actions against erosion by putting branches inside gullies for slowing down of water, planting of grass in rows, terracing and planting of trees. The maintenance of these works was somewhat better. At least once every year, the people of a community worked together to take measures. However, most measures taken to stop gullies were inadequate. But grass planting seemed to give some results. Grass was maintained well, especially because the farmers used it for roofing and cattle. World Vision provided also seminars on erosion control in the area near Kalambe, Voi River, however they did not work out well. According to Charles Divei (F8) the people still lacked the knowledge to do something and observations were indicating this also. The Danish government has done a lot of projects in the Small Taita Hills to stop gully erosion and to prevent soil erosion on plots by making dams and giving of seminars (interviews F11, F14). This project however failed. The people did not continue with the

project by themselves, according to one farmer because of lack of money (F11). Observations in the field are supporting lack of money, especially for building materials for dams, but probably maintenance and continuation of the project stopped because people had no incentives to continue and because of lack of knowledge and organization. So most likely motivation to continue was dropping.
Observations about maintenance of soil conservation measures in the field indicated that the farmers were very capable of taking measures like planting of grass, making of small earth walls and planting of trees. Many farmers used these techniques and they maintained them every year. Terraces and trenches however were maintained most of the times poorly. The farmers did not scoop the trenches of bench terraces out every year, so that at some spots the measures were gone. It was not clear if this was because of lack of knowledge or manpower, but most probably it was because of lack of manpower. So the people are most capable of maintaining simple techniques.

Organization rate

For determining the potential capacity of a community in an area, it is important to know if a community has organized themselves. If the community is organized they can take bigger conservation measures, because they have more manpower and it is easier to implement projects. Also it is an indicator of motivation of people to take action against a problem. Of the interviewees 7 of the 18 farmers had organized themselves and 11 of the 18 farmers had not organized themselves. The farmers that had organized themselves were all coming from the sub-areas Voi River and Small Taita Hills. Organization rate and therefore capacity in these areas is quite high. People of the Plains and Sisal estate had not organized themselves.

Labour division between men and women

As mentioned before the farmers were asked if there was labour division in farming work between men and women. According to only 4 of the 17 farmers who responded there was some sort of labour division in farming work. According to all the other farmers men and women were doing the same work. Of the women 2 of 5 said there was a difference and of the men 2 of 12 said that there was a difference. Observations however indicate a very different view. However it is true, as stated by most farmers that men and women are doing the same work on the shambas; women were also making terraces, digging the plots, sowing and so on just as men. However women are expected to take care of the children and to make sure that food is ready. Also women had to look for firewood and to fetch water. Men are more taking care of cattle and are working often in the (big) towns, like Voi, Mombasa and Nairobi. Because many men are working these days in the towns, women are obligated to do all the farming work, even cattle keeping but this is not very common as also stated by Rwelamira (1999). According to Rwelamira (1999) the observations done in the field are true for Eastern and Southern Africa. He even says that in many communities in Eastern and Southern African region women have no rights to property. Women have to take care of food and are therefore cropping stable food, while men are more cropping cash crops and taking care of cattle. It was observed in the field that only men and boys were taking care of cattle.
So there is a kind of labour division, however regarding erosion prevention there is almost no difference. The only difference is that women have more tasks besides farming than men. But women can and are taking the same measures as witnessed. They were making even trenches and terraces.

Capacities

The communities are taking already quite some measures, but most of the time they are inadequate or badly constructed. In the Taita Hills the people are using different techniques like grass and tree planting, terracing, trenching, small earth walls, rows of branches, and putting branches in gullies. On the Plains most farmers are using small earth walls, rows of branches, and grass. On the Sisal estate strip cropping and cultying is practiced and on the orange estate planting of grass and earth walls. Besides the Voi River almost nothing was done except for the projects of WCT and one farmer (F7). Maintenance of simple techniques is over the whole research area very well. Of terraces and trenches a little bit less well and communal and projects of NGO’s moderate to bad. The organization rate is only high in the Small Taita Hills and Voi River. On the Plains and Sisal estate organization rate was very low. Men and women have in the whole research area the same capacities for taking soil conserving practices. However men have more time for farming than women, because they don’t have the responsibilities for maturing children, preparing food, and getting water and firewood.
The capacities of the farmers in the Taita Hills are above moderate. Capacities of the owner of the Sisal estate are already good enough. Capacities of people on the Plains and besides the Voi River are moderate.

VI Construction of mechanical soil conservation measures

In this appendix are present some figures and recommendations for designing mechanical soil conservation measures, i.e. trenches, terraces, loose-rock dams and double-fence dams. First recommendations will be given for trenches, than for terraces and at last for gully reclamation tools loose-rock dams and double-fence dams.

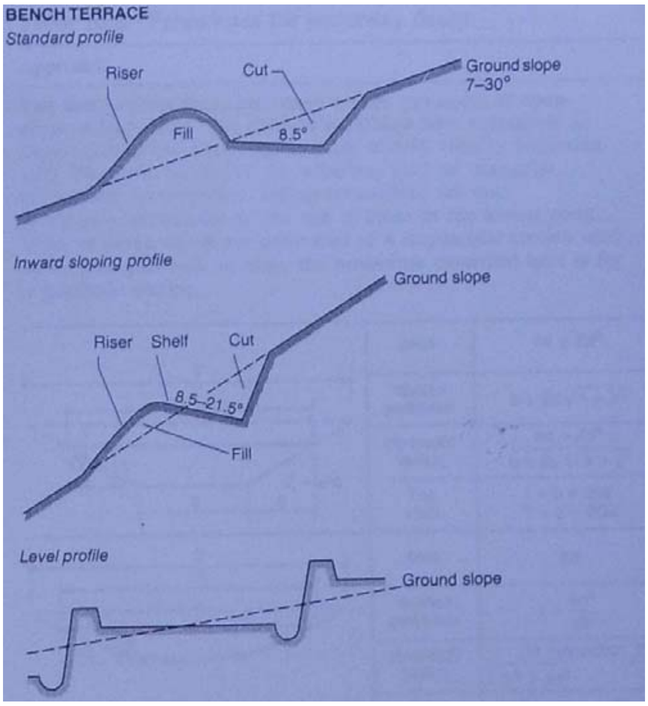
VI.I Trenches

It is important that trenches are constructed in such a way that they will not collapse when the soil is saturated. Therefore it is very important that the soil strength is known. It is important that the shear strength of soils is high enough to avoid landslides as stated by Morgan (1986). In chapter 4 the physical behaviour of soils under wet conditions has been determined. It became clear that some soils in the research area were very soft and were easily flushed away. On such grounds trenches have to be constructed with care if they are necessary. On steep slopes it is even better not to use trenches, while trenches enhance infiltration of water into the ground (Van Westerop, 2006) and make the chance on a landslide of the foothill higher. If the slope of very soft grounds is not so steep, it is possible to use trenches. The banks of trenches have always to be planted with grass, especially when grounds are very soft. Prefered grasses are napier or vetiver grass, to protect the banks of collapsing and to filter ground out of the water that is streaming into a trench.

On hillslopes it is better to decrease sizes of trenches to avert landslides. The standard size now used by Westerveld is 3 m wide at the surface and 2 m at the bottom, with a depth of 1 m (Westerveld & Van Westerop, 2002). This size is way too big for steep slopes with ground layers less than 1 m. It is recommended to do more research at the ideal sizes of trenches for different slope steepness. Also the spacing of trenches has to be fit to the slope of the soil surface. On the moment is taken the fist rule 9 m spacing in between trenches (Westerveld & Van Westerop, 2002) Morgan (1986) states however that spacing of 180 m for 1º, 30 m at 5.5º, and 20 m at 8.5º is effective for reducing soil loss. Morgan (1986) argues also that trenching or contouring on its own is only effective during storms of low rainfall intensity. Therefore he advises to combine contour trenching with vegetation planting, for example strip cropping.

VI.II Terraces

There are different kinds of bench terraces as can be seen in figure VI.I. The best bench terrace for the research area is the fanya juu or ladder terrace, because the risk of landslides in the Taita Hills is probably too high. But if further research at ground strength, characteristics of a rainstorm with a return period once in the ten years and so on indicates that it is possible to let a lot of water infiltrate into the ground without risks, preference is going out to a level bench profile as can be seen in figure VI.I. Because this profile combines water storage, soil conservation and agricultural use the best because of the flat slope of the terraces.



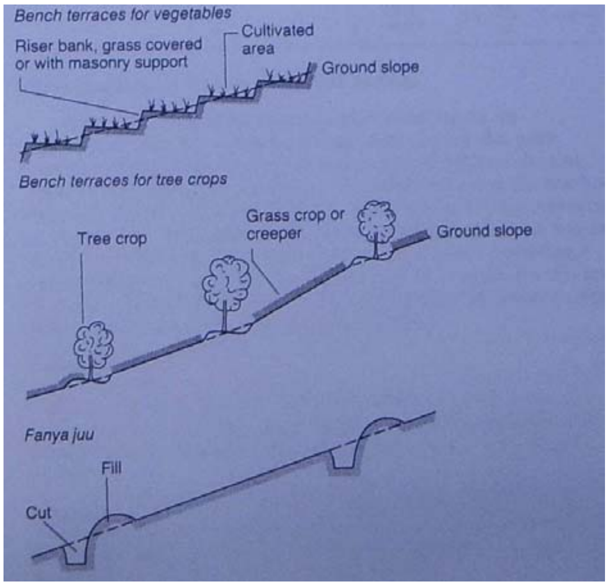


Figure VI.I Types of bench terraces. Fanya juu type is recommended because of risk on landslides. (Morgan, 1986: p. 232)

VI.III Gully reclamation

For gully reclamation two types of dams are recommended, i.e. loose-rock dams and double-fence brush dams. These dams are according to Morgan (1986) strong enough to withstand the great forces of running water. Loose-rock dams are stronger than double-fence brush dams, but it takes also more effort to make them.
For making a loose-rock dam it is necessary to cut back the vertical banks of the gully, as is shown in figure VI.II. The dam has to be made as is described in the figure: a stone trapezoid of 1.5 to 3 m high, with litter at the front side to slowdown the flow and founded at a big rock placed in a trench. According to Morgan (1986) the dam has to be made of a “graded rock structure with 25% of the rocks between 100 mm and 140 mm diameter, 20% between 150 and 190 mm, 25% between 200 mm and 300 mm, and 30% between 310 mm and 450 mm” so that leaking of the dam is avoided (Morgan, 1986: p. 245). It is necessary to make a spillway that is smaller than the width of the gully, because the banks are very vulnerable to erosion and very instable. It was witnessed in the field that sides could collapse very easily. It is important not to forget the apron, because the apron will absorb the turbulent energy of water coming over the spillway. The apron has to withstand great forces. Therefore it is important that heavy rocks are used for the apron and that the end rock of the apron is founded in a trench (Morgan, 1986).

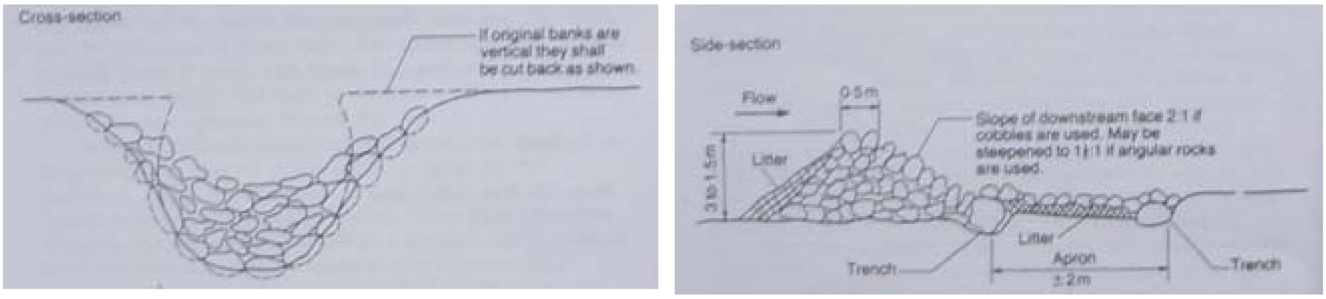
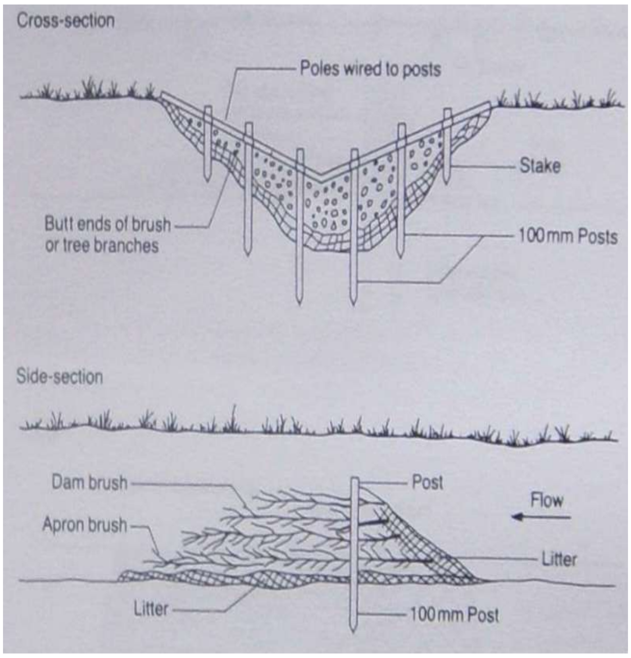


Figure VI.II Design of a loos-rock dam. (Morgan, 1986; p. 244)

In figure VI.III is shown how a double-fence brush dam has to be constructed. First, just as for a loose-rock dam, the sides of the gully have to be cut back. If this has been done two rows of posts have to be placed as shown: 1.2 m into the ground and maximum 1 m above the ground. A 150 mm thick litter layer has to be placed from the beginning of the dam till the end of the apron. With galvanized wire a 30 cm thick brush layer, placed on the apron, is tight at the last row of stouts. Also a row of posts are driven into the ground in the middle of the brush layer. The brushes are tightened at these posts, so that the brush layer forms a thick pack (Morgan, 1986; interview with Mukusya, 2006). The two rows of posts are filled with brushes, placed perpendicular at the stream direction. These brushes have to be compressed very well. The brushes are kept compact with wire. Litter is placed upstream of the dam, to makes sure that water can not leak trough the dam. (Morgan, 1986)



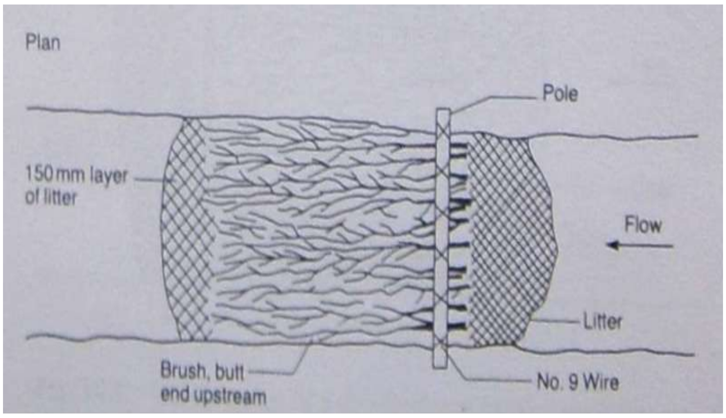


Figure VI.III Design of a double-fence brush dam. Only cheap materials are used. (Morgan, 1986: p. 247)

It is important to plant grass and trees in combination with a dam to reclaim gullies. Vegetation is needed to increase the strength of the gully banks and gully floor and to protect them. Morgan (1986), Mr. Mukusya (interview) and Mekonnen (n.d.) advise to plant napier or vertiver grass on the gully floor for soil conservation, so that soil that is transported by the water can be filtered out. On the gully banks it is important to pant grasses in combination with trees. By taking these measures it is possible to reclaim gullies.

VII Research into effectiveness of trenches in reducing soil loss

In the research proposal of this research was stated that also research should be carried out at the effectiveness of trenches in reducing erosion. However, because of time constraints, lack of rain, and plots not suitable for measuring, this research could not be conducted. In the field has been observed how the trenches were dug and the location of one area that was trenched at that time has been mapped to give future researchers the possibility to get an idea of trenched plots and for using it as an example of how trenching is practiced.

VII.I Research proposal

The motive of research into the effectiveness of trenches on reducing soil erosion is that WCT does not know how effective their trenches actually are in decreasing soil erosion and therefore it is difficult to convince (local) governments, NGOs and other actors of the need of more trenches in semi-arid areas to increase water storage and decrease soil loss. Another reason for this research is that it is not known to what extend trenches on their own are effective enough to reduce soil erosion or that still other measures are needed. Therefore the following research objective, main question and sub-questions are formulated:

Objective
To measure the effectiveness of trenches on reducing soil loss on agricultural plots, by doing field measures at soil loss on a shamba that is trenched and a shamba that not has been trenched.

Main question
What is the effectiveness of trenches in reducing soil loss on agricultural plots compared to plots that are not trenched (on slopes with different steepness)?

Sub-questions

1. What is soil loss?
2. Which parameter(s) are important to measure soil loss with?
3. Which method is used to measure these parameter(s) and why?
4. What is the difference in soil loss between a shamba that is trenched and a shamba that is not (for every slope steepness?

VII.I.I Measuring method

The measuring method is derived of Morgan (1986: p. 150). He describes a method that makes use of a Gerlach trough for measuring soil loss. This device is easy to make taken into account African circumstances. The device works very easy as can be seen in figure VII.I. The Gerlach trough exists of a collecting bottle, hose and trough. In the collecting bottle sediment can deposit, while water can flow away trough an outlet. It works in the same manner as for example troughs in the sewer. With this device and a rain gauge the intensity of a shower and the soil loss during the shower can be measured. With this data soil loss differences can be compared with rain intensity, providing insight in the effectiveness of trenches for different intensities.

VII.I.II Other recommendations for research at effectiveness of trenches

It is important that research on the effectiveness of trenches is conducted during the rainy season so that the chance on rain is greatest and soil loss can be measured at a shamba with trenches and without. Best could be taken the long rainy season from March to the beginning of June, while the chance of rain in this season is greatest and the rain period is the longest (Bindloss et al. 2003).
For measuring soil loss there are different options that could be practiced. It would be possible to test soil loss on a shamba for several years before trenching and after trenching, so that data is obtained that can be compared with eachother, because it is coming of the same shamba ceteris paribus. But taken African circumstances into account (people steel measuring devices, farmers are poor and land can therefore not be taken out of production easily, lack of equipment and resources) and the results that WCT wants to have on the short-term it is probably better to take two shambas, one trenched and the other not trenched. In this way a farmer only can not use his shamba for one or maybe a few years instead of a very long period as with the first option. The latter option provides directly results after one rainy season, but scientific this option have some disadvantages, to know the shambas have maybe not equal rainfall intensities, morphology and slope and so on. It is important that circumstances are taken as equal as possible to make comparison of results possible.

Another thing that is important to measure is the effectiveness of trenches for different slopes. Soil loss increases normally with steeper slopes (Morgan, 1986). So the effectiveness of trenches probably differs with different slope steepness.
It is also important to know effectiveness of trenches combined with other soil conservation measures, so that it is possible to use trenches more effectively under differing conditions.

VII.II Trenches at shamba of Leah Mcharo (F18), grid 4

At the moment of the field study trenches were constructed at the shamba of Leah Mcharo (F18 Interviews), grid 4. Trenching of here shamba was almost complete. As can be seen of the slope measures in figure VII.II, the ground in between trenches was not levelled well. The ground became even steeper than under natural conditions. Furthermore the spacing between gullies is differing much. So, different slope steepness and spacing have to be taken into account with measuring soil loss, because this has consequences for soil loss measured.
Also the depth of trenches differed greatly; it ranged from 0.5 m unto 1.0 m deep. It is possible that this influences soil loss also because infiltration of water and soil moisture content of the ground per trench probably changes, so that runoff also occurs on different times.

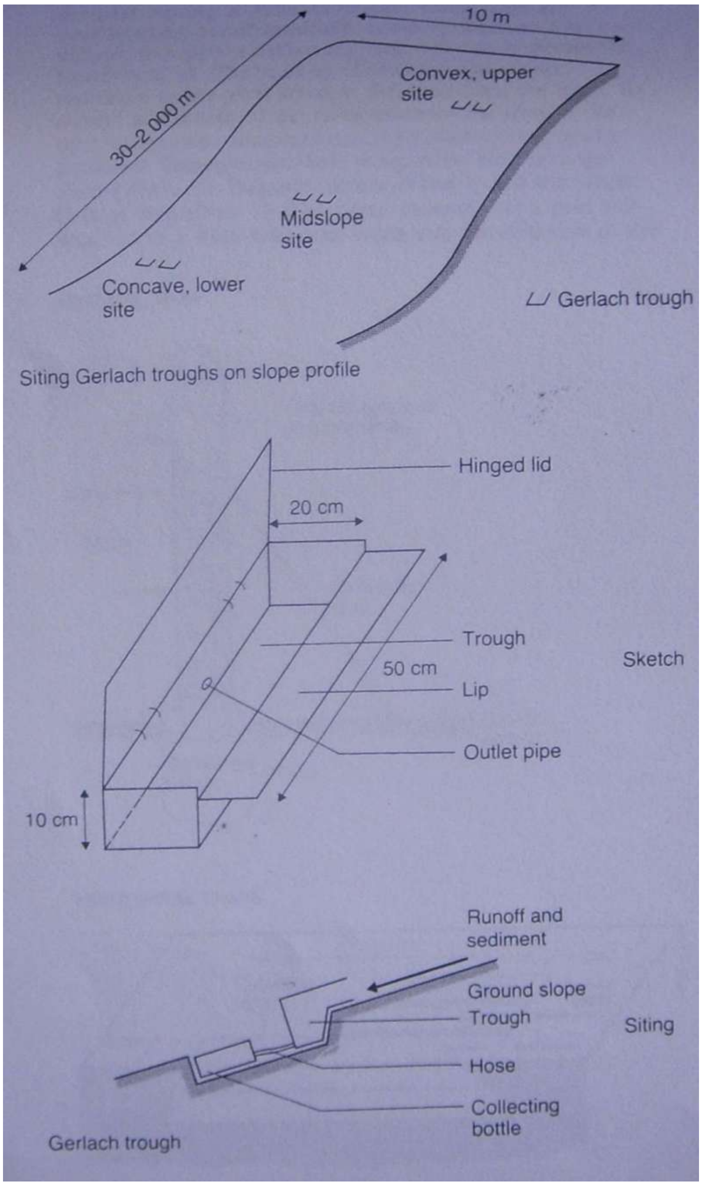


Figure VII.I Gerlach trough for measuring soil loss. (Morgan, 1986:p. 150)

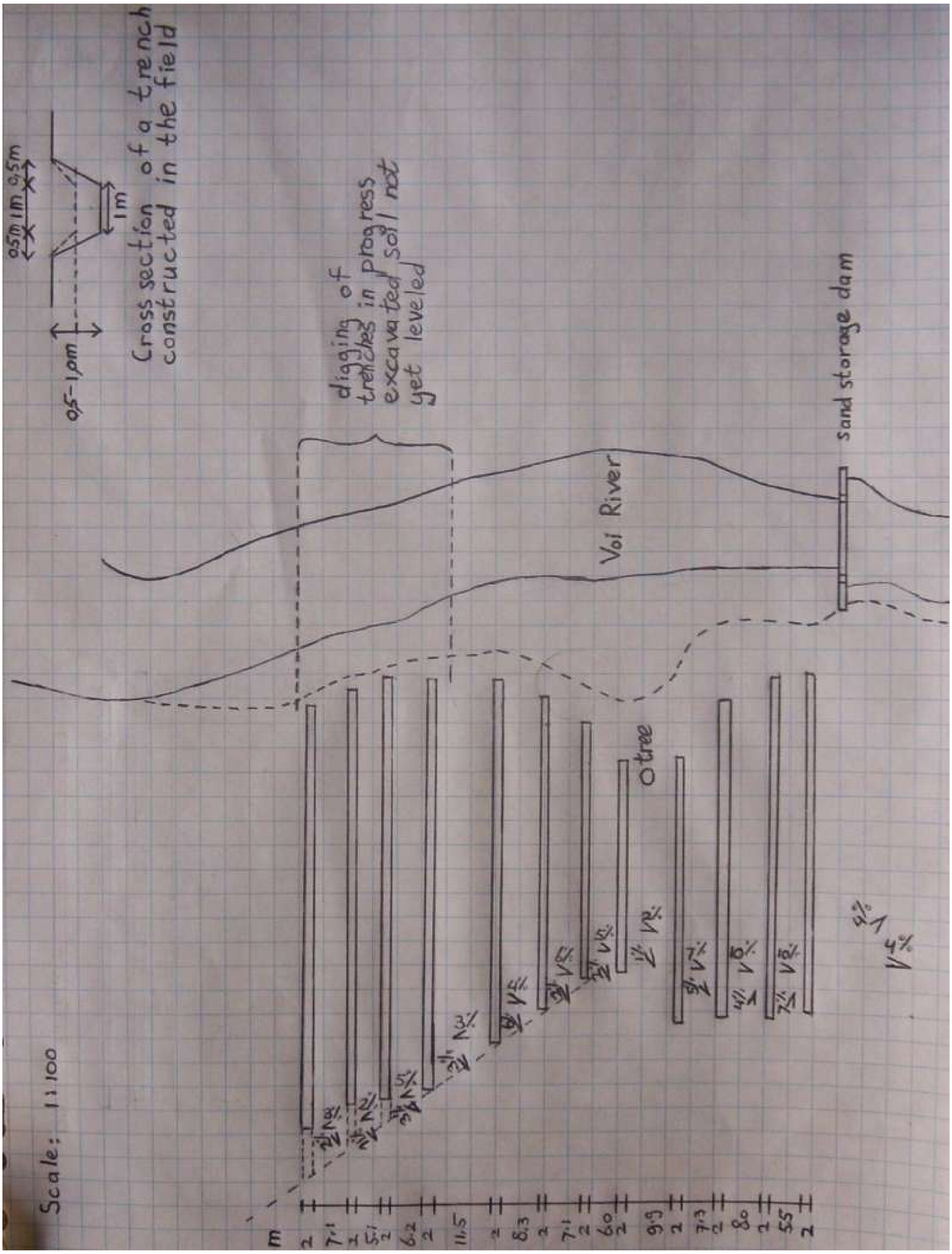


Figure VII.I Map of the shamba with trenches of farmer Leah Mcharo (F18).